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VIA HAND DELIVERY

February 17, 2017

Public Comment
Beneficial Uses and Mercury Objectives
Deadline: 2/17/17 12 noon

The Honorable Felicia Marcus, Chair
and Members of the State Water Resources Control Board
c/o Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814

Re: Comment Letter – Beneficial Uses and Mercury Objectives

Dear Chair Marcus and Members of the Board,

Today, the Association of California Water Agencies (ACWA), the California Water Association (CWA), and the California Municipal Utilities Association (CMUA) and their member agencies are concurrently and timely submitting by email signed versions of the following documents, which are also set forth on the enclosed flash drive:

- A Letter of Comment; and
- A supporting Technical Evaluation Memorandum prepared by Exponent, Inc. (Technical Report).

In addition, ACWA, CWA and CMUA now also timely submit on the enclosed flash drive some of the key technical documents referenced in the Technical Report. The reference documents set forth on the enclosed flash drive were not submitted by email because the file sizes for the documents are too large to email.

The Letter of Comment, Technical Report, and supporting technical reference documents set forth on the enclosed flash drive constitute the complete comment package submitted on ACWA, CWA, CMUA and its member agencies regarding the proposed amendments to Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions, and related Staff Report, including Substitute Environmental Documentation. Thank you and please call or email me if you have any questions regarding this submission.

Sincerely,

Mary Lynn Coffee

Mary Lynn Coffee
of Nossaman LLP

February 17, 2017

The Honorable Felicia Marcus, Chair
and Members of the State Water Resources
Control Board
c/o Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814

Re: Comment Letter - Beneficial Uses and Mercury Objectives

Dear Chair Marcus and Members of the Board:

I. INTRODUCTION.

The Association of California Water Agencies, the California Water Association, and the California Municipal Utilities Association thank you for the opportunity to provide comments on the Draft Staff Report, Including Substitute Environmental Documentation for Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions, issued on January 3, 2017 (referred to hereinafter as the "Staff Report").

The Association of California Water Agencies (ACWA) is the largest statewide coalition of public water agencies in the country. Its 430 public agency members collectively are responsible for 90% of the water delivered to cities, farms and businesses in California. ACWA's mission is to assist its members in promoting the development, management and reasonable beneficial use of good quality water at the lowest practical cost in an environmentally balanced manner. ACWA's public agency members are special districts created to perform specific functions and include irrigation districts, municipal water districts, county water agencies, community service districts, flood control districts and others. ACWA's members carry out highly specialized functions to support their communities and protect public health, ranging from water treatment, and delivery, to wastewater treatment, to recycled water production and distribution, to flood control, to groundwater management and a host of others, ACWA member agencies.

The California Water Association (CWA) is a statewide association that represents the interests of more than 100 investor-owned public water utilities that are regulated by, and subject to the jurisdiction of, the California Public Utilities Commission. CWA's member water companies provide the same types of high-quality water utility services as those provided by the public agency members of ACWA to nearly 6 million people in communities throughout California. CWA provides a forum for sharing best management practices, to optimize utility

operations and customer service, and it promotes sound water policy by representing its members and their customers before the Legislature and regulatory agencies. Further, it creates opportunities for educating the public on the efficient use of water resources.

The California Municipal Utilities Association (CMUA) is a statewide association that represents publicly-owned electric utilities that provide 25 percent of the state's power and 40 public water agency members that deliver water to 70 percent of Californians.

ACWA, CWA, CMUA, and their member agencies and utilities support the designation of beneficial uses that protect human health. Our comments are intended to provide the State Water Board with additional information that it may wish to consider in the adoption of this far-reaching rule-making and incorporate into the Staff Report and the regulatory text of the Provisions to provide guidance to the regional boards, which will be responsible for designating new beneficial uses and adopting WQOs into basin plans and implementing the program to attain objectives to protect beneficial uses.

II. SUMMARY.

Consistent with our missions, ACWA, CWA, and CMUA wish to emphasize that our primary concerns arise with respect to the Mercury Provisions that will apply (1) immediately upon adoption of the proposed mercury program by the State Water Board without further hearings or additional due process or public comment opportunities, and (2) that are not associated with the protection of cultural or socioeconomic driven elevated rates of fish consumption. Specifically, these comments focus primarily on the promulgation and immediate application of the "Non-Tribal/Non-Subsistence Related Provisions" of the mercury program, namely:

- A new Sport Fish mercury objective of 0.2 mg/kg for purposes of protecting human health for those consuming a typical level of fish, which is more stringent than the federal law objective, promulgated to protect COMM, WILD, RARE, WARM, COLD, MAR, EST, and SAL;

- Two new very stringent wildlife water quality objectives (WQO), Prey Fish (0.05 mg/kg) and California least tern (CLT) Prey Fish (0.03 mg/kg), promulgated to protect WILD, RARE, WARM, COLD, MAR, EST, and SAL, rather than beneficial uses directly related to fishable/swimmable goals derived from federal Clean Water Act, 33 U.S.C. § 1251; and

- Three new, exceptionally low effluent limitations (EL) for mercury (ranging from 1 ng/L to 12 ng/L) to be applied upon adoption in all non-stormwater individual NPDES permits, including NPDES permits for effluent discharged from groundwater and surface water supply treatment, wastewater treatment, and water purification/recycled water production, as well as other individual permits such as drinking water system discharges, potable water line dewatering, testing, and industrial discharge NPDES permits.

We have raised concerns regarding the effects that the proposed Tribal beneficial uses (T-SUB and CUL) and Subsistence fishing beneficial use (SUB) could have on minimum

instream flow surface water objectives, and flow-related 401 Water Quality Certification and NPDES permit requirements. However, the Water Board Staff Workshop presentations questions, and testimony at the February 7 Hearing gave us the strong impression that flow and water supply consequences are not intended either by the State Water Board nor by the people that the new beneficial use definitions are being developed to protect. Therefore, we believe that our issues regarding the text of the proposed beneficial uses are relatively limited, and effective text revisions to address those issues should not be difficult to develop to allow their adoption.

The technical evaluation commissioned by the water agencies and attached hereto as **Exhibit A** (Technical Report) and the Staff Report both conclude, however, that the WQOs and the ELs of the Non-Tribal/Non-Subsistence Related Provisions— which were first shared with the regulated community on January 4, 2017 (and were not published as a part of the beneficial use outreach process) — are unattainable even in the extremely long term (multiple decades at a minimum) due primarily to:

- Natural background environmental characteristics of all of the hydrographic units under consideration, including naturally occurring and background levels of mercury in soils and waters. *Cf., Wat. Code* § 13241(b) (requiring consideration of environmental characteristics of hydrographic unit, including water quality).

- The water quality conditions that can be reasonably achieved through controllable water quality factors, given the absence of technologies and methods that enable control of mercury in non-point source discharges of sediment or aerial deposition. *Cf., Wat. Code* § 13241(c) (requiring consideration of water quality conditions that could reasonably be achieved through coordinated control of all factors affecting water quality).

- The absence of measures in the implementation program reasonably designed to achieve the new water quality objectives. *Cf., Wat. Code* § 13242 (a) (requiring implementation program to include a description of the nature of actions necessary to achieve water quality objectives).

- The absence of concurrently adopted compliance protections for dischargers.

III. RECOMMENDATIONS.

1. ACWA, CWA, CMUA, and their member agencies and utilities (the "water agencies") request a time extension pursuant to the United States Environmental Protection Agency (USEPA) Consent Decree in *Our Children's Earth Foundation v. USEPA*, paragraph 35A. The time extension is very much need additional time to work with State Board Staff to integrate all the information and analysis necessary to develop compliance protections and additional implementation program measures to ameliorate the many legal, economic, and environmental issues created by the Non-Tribal/Non-Subsistence Related Provisions.

2. Irrespective of the State Board granting a time extension, the water agencies recommend, among others, the following critical changes to the mercury program established by the Provisions:

a) Assure that the proposed water quality objectives (WQO) and effluent limitations (EL) are properly calculated, and established only after taking into account all factors required by law to be considered and balanced;

b) Properly and comprehensively assess the economic burden on ratepayers likely to be imposed by the Provisions;

c) Amend the Provisions to assure extended compliance schedule authority for NPDES permits to avoid a substantial increase in potential enforcement and third party citizen suit liability;

d) Amend the revised Reasonable Potential Process (RPA) process for mercury currently set forth in the Provisions to require consideration during the RPA analysis of all appropriate factors related to mercury exceedances in receiving waters caused primarily by natural water quality and soils conditions, legacy pollutants and uncontrollable water quality factors;

e) Amend the Provisions to eliminate the disproportionate burden of attaining WQOs placed on dischargers subject to individual non-stormwater permits, MS4 permits and industrial stormwater permits;

f) Amend the Provisions to authorize and clarify permit compliance schedule authority, and to allow compliance schedules of longer duration than currently permitted by the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (SWRCB 2005) (SIP) and Resolution 2008-0025.

g) Adopt authority for, and direction to Regional Water Quality Control Boards (Regional Boards) to implement long-term compliance protections for dischargers, including: completion of Use Attainability Analyses (UAAs) to establish temporary water quality objectives for mercury prior to imposition of ELs; authorization for development of mercury site specific objectives (SSOs) for all beneficial uses (not just SUB); general authorization for development and use of variances for NPDES permits and WDRs; and general authorization for use of mixing zones and/or dilutions credits for NPDES permits and WDRs;

h) Bolster the currently insufficient implementation program by adopting additional implementation measures that will lead to meaningful reductions in mercury in the state's water and fish, some of which may be appropriate to offer as alternative compliance pathways for dischargers;

i) Eliminate vague regulations governing wetlands to assure that the Provisions are consistent with and do not impede: the stated intent of the State Water Board, which is not to prevent new wetland projects because of mercury

concerns; requirements of the State Board's "No Net Loss" policy for wetlands and other similar state and federal law requirements;

j) Tailor beneficial uses to eliminate concerns regarding water supply and instream flow objectives; and

k) Provide guidance to Regional Board with respect to designation of the new water quality objectives, compliance protections, and robust implementation measures that should be considered if newly defined beneficial uses and WQOs are considered for designation and adoption by Regional Boards.

IV. DISCUSSION.

A. Request for Time Extension.

A time extension is requested to assure that the mercury program when adopted can achieve the following goals:

- Directs resources toward achieving real, measurable reductions of mercury in fish and the environment, which are caused, as set forth in the Staff Report, primarily by natural background conditions in soils, aerial deposition, and legacy mercury and gold mines;

- Avoids substantial increases in cost for treatment upgrades and development of new technologies, which must be borne by water and wastewater ratepayers, many of whom are socio-economically disadvantaged, without providing measureable reduction in mercury or improvement in human health outcomes;

- Provides clear and permanent compliance protections necessary to avoid substantial costs to ratepayers, many of whom are socio-economically disadvantaged, to fund enforcement penalties, fines and third party citizen suit attorneys' fees since the Staff Report makes it clear that the very low mercury WQOs ranging from 0.2 to as low as 0.03 mg/kg of fish tissue, may never be attainable in most California receiving waters, or at a minimum should be expected to take decades if not centuries to attain;

- Provides additional implementation program control measures, including alternative compliance mechanisms for dischargers as well as additional state programs, to try to attain real and measurable reductions of mercury in fish and the environment; and

- Avoids direction to Regional Boards to regulate wetlands, including wetlands created for natural treatment, water quality polishing, and/or to enhance beneficial uses or avoid net loss of wetlands, without the provision of meaningful guidance and direction as to what types of regulatory controls might be effective and feasible to implement.

Such an extension of the adoption process for at least the Non-Tribal/Non-Subsistence Related Provisions is feasible and should be granted to allow development of additional information,

collaboration among State Water Board Staff, and the regulated community, and development of additional compliance assurances and implementation program measures because:

- While the adoption of new wildlife protection WQOs must be developed pursuant to a United States Environmental Protection Agency (USEPA) Consent Decree in *Our Children's Earth Foundation v. USEPA*, No. 3:13-cv-2857-JSW (2014), paragraph 35A of that Consent Decree enables USEPA to obtain an extension of the due date for adoption of such objectives.

- While we concur that adoption of an implementation program concurrently with the adoption of new, more stringent wildlife water quality WQOs is appropriate and preferable to federal adoption of objectives and a subsequent state process to adopt an implementation program, the implementation program needs considerable work to provide for attainment of the WQOs and to protect dischargers from enforcement for the time period necessary to reach attainment.

- Although the federal Consent Decree is driving the adoption of new WQOs for protection of wildlife, there are no litigation, environmental justice, or other known concerns regarding the protection of human health driving adoption of a new COMM mercury WQO for those Californians eating a typical diet, rather than an elevated amount of fish as a part of their regular diet.

We therefore urge the State Water Board to grant a substantial extension to allow for the development, in coordination with the regulated community, of additional key scientific and regulatory information regarding, at a minimum, the Non-Tribal/Non-Subsistence Related Provisions and detailed and thorough consideration of their regulatory and economic consequences in light of serious attainment challenges.

B. Establishment of Water Quality Objectives.

1. The Wildlife Mercury Water Quality Objectives Will Become Effective Without Any Further Regulatory Action.

The proposed Provisions would amend the Inland Surface Waters, Enclosed Bays and Estuaries Water Quality Control Plan to include new mercury WQOs for Sport Fish, Prey Fish, California Least Tern (CLT) Prey Fish, Tribal Subsistence (T-SUB) and Subsistence (SUB). Of these, the first three would become effective and would apply statewide upon adoption of the Provisions by the State Water Board and approval by the Office of Administrative Law (OAL) and USEPA. This is contrary to the implication – and the understanding of some – at the Staff Workshop and the State Water Board Hearing that the public would have additional opportunity to comment on the proposed Mercury Provisions when Regional Boards designate specific waterbodies with the proposed new beneficial use definitions of T-SUB, SUB, and Tribal, Tradition, and Culture (CUL). Although this is true with regard to the proposed T-SUB and SUB WQOs and the Sport Fish WQO where CUL is designated, it is important to understand that the WQOs for Prey Fish, CLT Prey Fish, and Sport Fish (for all beneficial uses except CUL) will become effective immediately.

The proposed Sport Fish WQO is proposed as a fish tissue concentration of 0.2 mg/kg to protect human health (COMM and CUL) and wildlife, which is lower than the current USEPA-recommended water quality criterion of 0.3 mg/kg. The Sport Fish WQO would apply to all inland surface waters, bay and estuaries, since all such waters with the beneficial use designations COMM, MAR, SAL, EST, WARM, COLD, WILD, and RARE would trigger the Sport Fish objective upon adoption and approval of the Provisions (*see,* Tab. 2.1). The proposed Prey Fish WQO of 0.05 mg/kg was developed specifically to protect wildlife and would also apply to all surface waters, bays and estuaries, with MAR, SAL, EST, WARM, COLD, WILD, and RARE beneficial uses upon adoption and approval of the Provisions; as would the CLT Prey Fish WQO of 0.03 mg/kg (*id.*).

2. The Proposed Water Quality Objectives Are Unattainable – At Least into the Next Century.

The Staff Report acknowledges that the proposed WQOs, particularly the Prey Fish and CLT Prey Fish WQOs, — which will apply immediately without further action by Regional Boards to designate new tribal, subsistence or cultural beneficial uses — are unattainable even in the extreme long term (multiple decades at a minimum): "The legacy of mercury left by historic gold and mercury mining is not easily controlled and may prevent attaining the Mercury Water Quality Objectives for many fish species for the next century in many waters." Staff Report, p. 267; *see also,* p. 266 (recognizing it may take a "significant period of time" to attain WQOs by implementing the Provisions). The Staff Report also notes that mercury from atmospheric emissions may be a significant source of mercury that will "prevent attainment" of the mercury WQOs (pp. 266-267.)

Sections 1 and 2 of the Technical Report also confirm that the proposed mercury WQOs are likely unattainable due primarily to the following:

- Natural background environmental characteristics of all of the hydrographic units under consideration, including naturally occurring and background levels of mercury in soils and waters. *Cf., Wat. Code* § 13241(b) (requiring consideration of environmental characteristics of hydrographic unit when establishing WQOs).

- Human-caused environmental characteristics of the hydrographic units under consideration, including legacy mercury from historic gold and mercury mines and aerial deposition of mercury. *Cf., id.*

- Water quality conditions that can be reasonably achieved through controllable water quality factors, given the absence of technologies and methods that enable control of mercury in non-point source discharges of sediment or aerial deposition. *Cf., Wat. Code* § 13241(c) (requiring consideration of water quality conditions that could reasonably be achieved through coordinated control of all factors affecting water quality when establishing WQOs).

3. The Mercury Water Quality Objectives Are Not Properly Established under Federal Law.

The federal Clean Water Act's implementing regulations require states to adopt WQOs that protect beneficial uses based on sound scientific rationale. 40 CFR § 131.11(a). For toxic pollutants such as mercury, states must "review water quality data and information on discharges to identify specific water bodies" where a toxic pollutant may be adversely affecting water quality or achievement of a beneficial use. *Id.* However, because the Provisions include a mass adoption of WQOs for inland surface waters, enclosed bays, and estuaries throughout the State without regard to site-specific conditions or the discharges affecting specific water bodies, the WQOs do not meet the requirements of 40 CFR section 131.11(a).

Section 10.1.2 of the Staff Report includes a brief discussion of site-specific water quality information (Environmental Characteristics and Water Quality of the Hydrographic Unit under Consideration). However, that section, comprising less than one-half a page in the Staff Report, refers only to the general conditions in the State as a result of legacy and widespread mercury contamination due to mines and atmospheric deposition, respectively. Nor is the section's cross-reference to Appendix D, a "brief description" of the geographic scope and generalized features of the nine regions governed by the Regional Boards, availing.

For example, the State Water Board Staff has indicated that wildlife-protective WQOs, Sport Fish (except for COMM and (future) CUL), Prey Fish and CLT Prey Fish, would apply even in waters where sensitive wildlife species do not occur. This application demonstrates the importance of examining the water quality conditions of specific waterbodies when adopting WQOs: the wildlife WQOs as applied to waterbodies without wildlife species do not serve the purpose of achieving the stated beneficial use. *See Cal. Sportfishing Protection Alliance v. SWRCB* (2008) 160 Cal.App.4th 1625 (site-specific WQO relaxing basin-wide temperature criteria appropriate where substantial evidence supported finding that creek had no viable population of rainbow trout).

Similarly, the Tribal Subsistence WQO was established based on fish consumption information from the Shilling 2014 report. However, no coastal southern California tribes south of Ventura (Chumash) participated in the study; and it is likely that the fish diet of coastal southern California tribal members would differ from that of their northern California counterparts. This underscores the need to look at the species, trophic level, and size of fish consumed at a regional level, not statewide.

The proposed WQOs – particularly the wildlife WQOs of Sport Fish (except COMM and CUL), Prey Fish, and CLT Prey Fish – are not based on nor do they reflect consideration of water quality data and information on discharges with regard to specific water bodies, contrary to the requirements of the federal regulations.

4. The Mercury Water Quality Objectives Are Not Properly Established under State Law.

Water Code section 13241 factors to be considered in establishing WQOs shall include, but not necessarily be limited to, all of the following: (a) Past, present, and probable future beneficial uses of water. (b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto. (c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water

quality in the area. (d) Economic considerations. (e) The need for developing housing within the region. (f) The need to develop and use recycled water.

The State Water Board is proposing to implement a mass designation of WQOs throughout inland surface waters, estuaries, and enclosed bays for Sport Fish, Prey Fish, and CLT Prey Fish. This fails to take into consideration the environmental characteristics and water quality at the hydrographic unit level. As discussed above, Staff Report section 10.1.2 and Appendix D do not constitute a review of site specific water quality information or environmental characteristics of any hydrographic unit.

The WQOs, particularly the more stringent WQOs established to protect Prey Fish, CLT Prey Fish, and ultimately, potentially, in the future, T-SUB, fail to take into account the water quality conditions that could reasonably be achieved through coordinated control of the factors or conditions affecting water quality insofar as it is acknowledged that it will take decades, if not a century or more, to achieve WQOs under the proposed Mercury Provisions (Staff Report pp. 266-267). The main sources of mercury – natural background conditions, aerial deposition, and legacy mines – are diffuse throughout the environment and not readily controlled through NPDES/WDR permit conditions.

Finally, as documented in section 3 of the Technical Report and Section II.C.3 of this memorandum, contrary to the requirements of section 13241 of the Water Code, the Staff Report fails to fully consider the economic impacts of the new WQOs.

C. Establishment of Mercury Effluent Limitations.

As documented in Sections 5 and 6 of the Technical Report, the proposed effluent limitations for NPDES non-stormwater discharges are problematic for the following reasons:

- They are likely much more conservative than necessary to protect even the most sensitive fish consumers because they are based on overly conservative fish tissue concentrations;
- They are improperly based on national bioaccumulation factors rather than factors that take local conditions into account; and
- They are not based on the best available science.

For these reasons, we urge the State Water Board not to adopt the effluent limitations proposed in the Staff Report until Staff can work with stakeholders to conduct additional review and incorporate the attached Technical Report comments into the analysis.

D. Implementation Program, Compliance and Enforcement Issues and Recommendations.

1. Implementation Program – Legal Framework.

Contrary to law and effective policy the program of implementation is not reasonably designed to address the quality of water as it pertains to mercury, or to attain the proposed

WQOs for mercury. Under State law, Water boards are instructed to consider "water quality conditions that could reasonably be achieved through coordinated control of all factors which affect water quality in the area" (Wat. Code § 13241(c)). Further, the program of implementation for achieving WQOs is required to include the following: (a) A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private; (b) A time schedule for the actions to be taken; and (c) A description of surveillance to be undertaken to determine compliance with objectives (Wat. Code § 13242).

Additionally, under federal guidance published by EPA in April 2016, states and tribes responsible for implementing the Clean Water Act are directed to address implementation as part of the water quality criteria and standards development process, with a focus on addressing implementation issues early that may impede attainability of water quality standards. Priorities for Water Quality Standards and Criteria Programs, FY 2017-2018 (USEPA Apr. 21, 2016).

2. Compliance/Implementation Issues.

a) The program of implementation does not properly consider water quality conditions that could reasonably be achieved through coordinated control of all factors which affect water quality in the area.

Despite the law and guidance requiring that the implementation program must take into account the water quality conditions that could be reasonably achieved through coordinated control of all factors affecting water quality in the area, the Staff Report recognizes that attainment of the new WQOs across the many waters subject to those objectives may take a century and that the legacy of mercury left by historic gold and mercury mining, absence of original mine owners, diffuse distribution of mercury, and mercury emissions to the atmosphere makes coordinated control of contaminants "extremely challenging" (p. 267). The Staff Report further documents that adoption of stringent ELs for mercury for individual NPDES non-stormwater discharges -- and implementation of source controls and advanced treatment to attempt to achieve such ELs – is unlikely to achieve the WQOs:

> Even if all sources of the contaminants are eliminated, the contaminants are likely to remain high for decades, because either they do not degrade or they degrade very slowly. Much of the mercury in fish today is thought to be from historic mining in the late 19th century and early 20th century. Further, current sources may not be directly regulated by the water boards (e.g., atmospheric emissions, naturally occurring in soils, or geothermal sources).

(Staff Report, p. 108.) Nevertheless, the Provisions propose to establish a suite of unattainable WQOs, three of which (Sport Fish, Prey Fish, and CLT Prey Fish) will apply immediately to essentially all inland surface waters, bays, and estuaries, based on the numerous waterbody beneficial uses designations, any one of which triggers application of one or more of the three objectives.

b) The program of implementation does not include a description of the nature of actions which are necessary to achieve the objectives,

including recommendations for appropriate action by any entity, public or private.

The proposed WQOs are not met in the existing condition for most (if not all) of the inland surface waters, bays and estuaries to which they will apply and the implementation program does not identify any means to attain the new objectives because reasonable means to address the naturally occurring, legacy and aerial deposition sources of mercury as necessary to achieve such stringent WQOs do not exist. Consequently, most inland surface waters, enclosed bays and estuaries will have to be listed under Clean Water Act Section 303(d) as impaired for mercury, requiring the time and resource intensive development of TMDLs by the regional boards for all such waters.

c) *The program of implementation does not include a time schedule for the actions to be taken.*

The Staff Report does not include a time schedule for implementation program actions to be taken, other than to declare that the water boards would determine time schedules for compliance with new discharge regulations on a "discharge-by-discharge basis" (Staff Report, p. 268). Substantial reductions of mercury in fish tissue will have to be achieved to meet the proposed WQOs given the baseline levels measured in the State's fish (Technical Report, section 7). According to the Staff Report, achieving the proposed WQOs may take decades, if not a century, due to legacy mercury from mines, widespread aerial deposition and natural background conditions, and the persistent nature of mercury. Such reductions demand implementation program measures that are not focused on individual NPDES permit discharges or industrial or stormwater runoff, but instead are designed to control aerial deposition, and mercury in nonpoint source runoff, particularly within high mercury open space and former mining areas. *See,* Technical Report §§ 3 and 8. Because the Staff Report does not identify sufficient implementation program measures to attain mercury WQOs, it also fails to identify a time schedule for implementation of program measures and actions designed to achieve proposed WQOs.

d) The Effluent Limitations for NPDES Non-stormwater Discharges Will Not Achieve Water Quality Objectives.

Point source dischargers subject to individual non-stormwater NPDES permits represent a minor source of mercury compared to the other sources (Staff Report, pp. 153-54). As such, the implementation program focuses on the wrong mercury discharges and fails to identify actions that would effectively achieve reductions of mercury in fish or the environment to a level that achieves the established WQOs. *See, e.g.,* Staff Report p. 165 (minor reductions that can be achieved through ELs imposed on wastewater and industrial discharges may not translate to noticeable reductions in mercury concentration); *see also*, Technical Report Section 1. As a result, the actual sources contributing the vast majority of mercury to surface waters are not addressed by the proposed implementation program. *See,* Staff Report, p. 108. Instead, the centerpiece of the implementation program is the promulgation of new, very stringent ELs for inclusion in all individual non-stormwater NPDES permits.

Because the proposed ELs (and other implementation measures addressing industrial and urban stormwater runoff) cannot attain the proposed mercury WQOs, and because such

attainment will not, in most circumstances, effectively contribute to mercury reductions, we urge the State Water Board to further amend the revised Reasonable Potential Process (RPA) process for mercury currently set forth in the Provisions to require appropriate consideration during the RPA analysis of appropriate factors related to mercury exceedances in receiving waters caused primarily by natural water quality and soils conditions, legacy pollutants and uncontrollable water quality factors such as aerial deposition, as well as the relatively minor nature of mercury contributed by specific discharges analyzed to determine the *reasonable* potential for such discharges to contribute to mercury pollution, rather than the most conservatively determined potential contribution to mercury pollution theoretically possible as a result of the discharge. The following amendments to the RPA steps set forth in the Provisions are recommended. The operation of these amendments to the RPA process are also graphically set forth in Technical Report § 3, Figures 2 and 3.

Determining Whether a Discharge Requires an Effluent Limitation for Mercury

1. Reasonable Potential Analysis

Step 3: Replace highest *observed* annual average effluent mercury concentration with the ~~highest~~ representative annual average effluent mercury concentration.
This revision allows the RWQCB discretion to consider if any data are inappropriate or insufficient for use in determining the annual average effluent mercury concentration for purposes of determining whether an effluent limitation is required.

Step 6: Replace Step 6 of the SIP with the following: If the B is less than C and mercury was not detected in any of the effluent samples, effluent monitoring is not required. In all other cases, proceed with *Step 7.*
This revision completes the Reasonable Potential Analysis where the observed maximum ambient background concentration is less than the lowest water quality objective for mercury and mercury was not detected in the effluent. This is consistent with the Staff Report, which provides that where the background mercury level is elevated above the lowest EL "it may not be reasonable to require smaller contributors of mercury to reduce their mercury discharge to levels below background." (p. 154)

Step 7: Add to the list of types of information that may be used to aid in determining whether a water quality-based effluent limitation is required the following: existing ambient water quality in the hydrographic unit, background conditions in soil and water, controllable water quality factors, whether the discharge is a significant source of mercury in the waterbody, and whether ELs are an effective means for reducing mercury in fish and the environment.
This information was added to the types of information properly considered in the determination of whether a water quality-based effluent

limitation is required to reflect natural background conditions and legacy mercury in the environment and recognizes the potential limitations inherent in trying to achieve reductions of mercury in fish and the environment. See Technical Report § 3, Figs. 2 and 3.

Step 8: In addition to low volume discharges, the RWQCB may choose to exempt <u>low threat discharges</u> determined to have no significant adverse impact on water quality from this monitoring requirement.
This addition recognizes that certain discharges permitted under an individual NPDES permit pose a low threat to water quality and as such are not expected to contain mercury; therefore these discharges should be exempted from all monitoring requirements provided for in Step 8 for mercury.

e) *The Effluent Limitations for Individual NPDES Permit Non-stormwater Discharges Will be More Difficult to Achieve and More Expensive than Estimated in the Staff Report.*

The Non-Tribal/Non-Subsistence Related Provisions state in Section IV.D.2. that the water quality objectives shall be implemented by the application of very low ELs, ranging from 1 ng/L to 12 ng/L depending on receiving water body flow conditions and beneficial uses for all individual non-stormwater NPDES Permits, 401 water quality certifications, WDRs, and waivers (pp. A-8 – 10).[1] In addition, in the future, other very stringent ELs for other bioaccumulative pollutants must also be developed (e.g., PCBs) to fully protect new wildlife protection and Tribal, Cultural, and Subsistence Fishing beneficial uses if and when designated. See Staff Report, Appendix T).

Although the Staff Report asserts that the proposed 12 ng/L EL "is achievable" with existing secondary treatment technology (with an adjunct mercury source control/minimization program), consistent with the PowerPoint presentation by Thomas Grovhaoug of Larry Walker Associates at the February 7 Hearing, the Technical Report concludes that some NPDES dischargers will not be able to meet this EL without additional upgrades to tertiary treatment. *See,* Technical Report section 2. This means that secondary treatment facilities must be upgraded to tertiary treatment to meet 12 ng/L consistently enough to avoid enforcement of the EL. However, the Staff Report economic analysis fails to consider the costs of the upgrades,

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[1] Although there has been some confusion regarding the NPDES permits that the Provisions will apply to, the Provisions clearly require the implementation of effluent limits in, at a minimum, all individual non-stormwater NPDES Permits and WDRs, which encompass many more permits than just permits those issued to POTWs or municipal wastewater plants and individual industrial dischargers. Appendix N defines "municipal wastewater and industrial NPDES permits" as all individual non-stormwater NPDES Permits and WDRs. In addition, the Staff Report indicates that certain General NPDES permits and WDRs already excluded from the SIP or involving low threat discharges should be excluded from the amended SIP analysis and default effluent limits set forth in the Provisions (pp. 145, N-1). However, the regulatory language of the Provisions does not contain express exceptions or clarify whether other General Permits and WDRs, like the Recycled Water WDRs, would also be excluded from the amended SIP analysis and default effluent limitations.

finding instead that for discharges to flowing water bodies that no facility upgrades are required to meet 12 ng/L for the 308 facilities discharging to meet Sport Fish, Prey Fish, and CALT Prey WQOs (*see,* Staff Report, section 7.2.7 and p. 246).

Furthermore, the attached Technical Report § 2 summarizes persuasive evidence that even with tertiary treatment, some facilities will not be able to achieve the 4 ng/L EL consistently, thus requiring additional treatment upgrades to advanced technologies such as RO (*id*.). This analysis is consistent with information presented in testimony and PowerPoint slides presented by Thomas Grovhaoug of Larry Walker Associates at the Hearing. Thus, many tertiary treatment facilities must implement additional treatment upgrades to meet 4 ng/L consistently enough to avoid enforcement. Again, however, the Staff Report fails to consider these costs in their entirety, finding instead that facilities may need, at most, to upgrade to tertiary treatment to assure that discharges to slow moving waters consistently meet Sport Fish, Prey Fish, and CLT Prey WQO and discharges to flowing water bodies consistently meet T-SUB of 4 ng/L *see,* Staff Report, section 7.2.8).

In addition, pursuant to the Technical Report § 2, and as presented in testimony and PowerPoint by Thomas Grovhaoug of Larry Walker Associates at the Hearing, a new, as yet undeveloped treatment technology is required to consistently meet 1 ng/L. The Staff Report concurs with this conclusion, finding discharges to slow moving waters to meet T-SUB and CLT Prey Fish EL of 1 ng/L may require major, but unspecifiable facility upgrades (Staff Report, section 7.2.9). Nevertheless, as documented in Section 2 of the Technical Report, the Staff Report fails to fully consider the costs associated with development and implementation of new technologies necessary to comply with the proposed ELs. Even by the State Water Board's own estimates, the economic impact of compliance is potentially quite high – source control, BMPs, and treatment controls, e.g., RO – and these costs are understated as outlined above.

Further, no known technologies are available to deploy to treat geographically dispersed discharges in compliance with the ELs, *e.g*., discharges pursuant to individual non-stormwater NPDES permits issued for activities such as dewatering, testing, hydrant flushing, groundwater treatment, and remediation. Nevertheless, the Staff Report fails to fully consider the costs associated with invention, development, and deployment of new, as yet undefined technologies necessary for such discharges to comply with the proposed ELs.

Finally, the proposed ELs are well below currently applicable MLs for mercury of 0.5 µg/L and 0.2 µg/L (500 ng/L and 200 ng/L). At a minimum, new and more expensive monitoring methods and equipment must be implemented by dischargers and significant cost and expense to address detection at levels far below existing MLs. Nevertheless, as documented in Section 2 of the Technical Report, the Staff Report fails to fully consider the costs associated with adoption of new monitoring technologies necessary to assure compliance with the proposed ELs.

We urge the State Water Board to consider the substantial evidence provided in the attached Technical Report indicating that treatment technologies for water treatment and wastewater treatment plants alone would cost ratepayers far more than currently estimated in the Staff Report. Further, increased costs of monitoring and upgrades to tertiary treatment, as well as development of new technologies to consistently meet the proposed ELs are not included in the Staff Report economic analysis, but will be expensive. Unfortunately, despite the

significant economic costs of meeting the ELs, all of which must be borne by water and wastewater ratepayers, only a very small reduction in mercury pollution can be anticipated to result because discharges are such a small source of mercury, and the ELs will not result in attainment of the proposed WQOs. Because all available evidence supports a conclusion that the designated uses do not currently exist in terms of compliance of waters with the WQOs, it is unreasonable to require dischargers, and particularly the ratepayers of such dischargers, to incur substantial economic control costs to protect mercury conditions. *Cal. Ass'n of Sanitation Agencies v. State Water Res. Control Bd.* (2012) 208 Cal.App.4th 1438, 1460. The Staff Report fails to articulate why adoption of the WQOs is necessary in these circumstances to assure the reasonable protection of beneficial uses despite the potential adverse economic consequences. *Memorandum of William R. Attwater, Office of Chief Counsel of the State Water Resources Control Board Re: Guidance on Consideration of Economics in the Adoption of Water Quality Objectives or Waste Discharge Requirements,* pp. 1-2 (Jan 4 1994).

f) *The ELs Create Compliance and Enforcement Risk for NPDES Non-stormwater Dischargers.*

The unavailability and cost of treatment technologies that can consistently meet the lowest ELs proposed for adoption raise serious concerns regarding risk of liability for significant fines, penalties, and attorneys' fees as a result of enforcement action or citizens' suit for permittees discharging under individual non-stormwater NPDES permits and WDRs. This disproportionate regulatory impact and risk of liability is noted in the Staff Report, which discusses inevitable enforcement actions by the water boards or via citizens' suits for permit violations that will occur where ELs cannot be achieved, and notes these costs will be borne by point source dischargers with individual non-stormwater NPDES permits, despite the relatively minor source of mercury in those discharges as compared to other sources. *See,* Staff Report p. 153; *see also,* Technical Report, sections 2 and 3; *also as presented* in testimony and PowerPoint at the Hearing by Thomas Grovhaoug of Larry Walker.

This risk of liability is compounded by limitations on NPDES permit compliance schedules. The Staff Report acknowledges that the mercury WQOs cannot be achieved in the short-term, taking multiple decades, if not a century to attain at minimum. The unattainability of WQOs will, in turn, lead to listing of most waterbodies for mercury impairment, and requirements to develop TMDLs. TMDLs, and particularly the data analyses required to support TMDLs, are extremely time intensive to prepare and approve, often taking at least three years, and many times requiring more than 7 years to fully approve per TMDL.

The Provisions do not clearly exempt individual non-stormwater NPDES permits from the SIP, including its limitations on compliance schedules. The SIP allows only up to five (5) years from the date of issuance, reissuance, or modification of an NPDES permit to complete actions necessary to comply with ELs and no longer than 10 years from the effective date of the SIP (2006) – which is past (2016).[2] Due to the fact that the Provisions immediately require

[2] Even if the USEPA had not disapproved longer timeframes, 15 years, and an additional five years, from the effective date of the SIP to develop and adopt a TMDL, and to comply with WQBELs – which it did – they are similarly not of sufficient duration given the nature of, and the limited measures available to reduce mercury in, the environment. *See,* Letter: California SIP; compliance schedule provisions from USEPA to SWRCB dated Oct. 23, 2006

application of ELs in individual non-stormwater NPDES permits to implement the Non-Tribal/Non-Subsistence-related WQOs, facilities will be required to begin upgrades to treatment processes and/or facilities soon after adoption of the Provisions.[3] *See, e.g.,* Staff Report, pp. 177-180; Technical Report § 2. It is unlikely that dischargers can plan, design, engineer, environmentally review, permit, fund, and construct the necessary upgrades within a five year permit term or the (maximum) five year compliance schedule period available under the SIP. However, the Staff Report does not identify interim actions or compliance schedule authority that individual NPDES non-stormwater dischargers can rely on to assure compliance before TMDLs can be fully adopted. The maximum compliance schedule limitations of the SIP also preclude post-TMDL compliance schedules for individual non-stormwater NPDES permits of sufficient length to provide dischargers compliance assurance, but the Staff Report fails to identify actions to implement to remain in compliance with NPDES permits over the course of the decades it will take to achieve the proposed WQOs.

For these reasons, we recommend the Provisions expressly exempt from the SIP all individual non-stormwater NPDES permits regulated under the Provisions to allow sufficient permit compliance schedules before, during, and after development of mercury TMDLs. Such exemption may be intended since Section 10.2 of the Staff Report appears to indicate that timelines for permit compliance schedules should be established pursuant to the State Water Board's Resolution 2008-0025, *Policy for Compliance Schedules in NPDES Permits.*

However, Resolution 2008-0025 also limits the duration of permit time schedules. Specifically, section 6(b) of Resolution 2008-0025 caps compliance schedules at a maximum of 10 years absent the development of a TMDL. Given the large number of TMDLs that will be required to address the very low WQOs and the typical length of time required to prepare and fully approve a TMDL, it is unlikely that 10 years will be sufficient permit compliance schedule protection during the development of all TMDLs as necessary to protect dischargers and their ratepayers from liability risk associated with enforcement actions and citizen suits.

Federal regulations require that a State must authorize the use of schedules of compliance for water quality based effluent limits in NPDES permits if they plan to allow such schedules. 40 CFR § 131.11(j)(1). Therefore, we urge the State Water Board to modify the Provisions to provide clear permit compliance schedule authority and to allow compliance schedules of longer duration than currently permitted by Resolution 2008-0025.

3. Additional Recommended Compliance Protections for Dischargers.

While compliance schedule authority is critical to protecting dischargers subject to individual non-stormwater NPDES permits from the disproportionate risk of enforcement and third party citizen suit liability that they face under the current Provisions, dischargers also need long-term compliance protections due to the substantial period of time that the Staff Report states will be necessary to achieve meaningful reductions in mercury in receiving waters. Accordingly, it is incumbent on the State Water Board that it include in its order adopting the Provisions an implementation program that offers compliance protections that are real and

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[3] The Staff Report acknowledges that mercury reduction measures without treatment process modifications are unlikely to reduce mercury to the point of compliance with the Provisions' bioaccumulative- based effluent limitation (Staff Report p. 165).

implementable statewide. The Water Agencies propose to work in coordination with the State Board to explore appropriate development of the following long-term compliance protections for dischargers: completion of Use Attainability Analyses (UAAs) to establish temporary water quality objectives for mercury prior to imposition of ELs; authorization for development of mercury site specific objectives (SSO) for all beneficial uses (not just SUB); general authorization for development and use of variances for NPDES permits and WDRs; and general authorization for use of dilutions credits for NPDES permits and WDRs.

a) Use Attainability Analyses.

According to staff in the January 9 Workshop and EPA surveys, UAAs[4] are rarely (if ever) approved in California. However, it is not clear why UAAs are not used in California given that the federal Clean Water Act provides for preparation of a UAA most importantly for this case when a use is not an existing use because the water quality standards necessary to support it are not attained, and attainment of the use and WQO is infeasible. 40 CFR §§ 131.3(e), 131.10(d); 131.10(g). More specifically, federal regulations state that that states may permanently or temporarily remove or relax water quality standards if the state can demonstrate that attaining the designated use is not feasible because:

> (1) Naturally occurring pollutant concentrations prevent the attainment of the use; or
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> ***
>
> (3) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied…; or
>
> ***
>
> (5) Physical conditions related to the natural features of the waterbody…unrelated to water quality, preclude attainment of aquatic life protection uses; or
>
> (6) Controls more stringent than those required by section 301(b) and 306 of the Act would result in substantial and widespread economic and social impact. 40 CFR § 131.10(g).

Further, 40 CFR § 131.10(j) provides that states are actually required to conduct UAAs when designating uses not included in the fishable/swimmable uses specified in CWA

[4] A use attainability analysis demonstrates that attaining the use is not feasible due to the following: naturally occurring pollutant concentrations that prevent the attainment of the use; natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use; human caused conditions or sources of pollution prevent the attainment of the use; dams, diversions or other types of hydrologic modifications preclude the attainment of the use; physical conditions related to the natural features of the water body and unrelated to water quality preclude attainment of aquatic life protection uses; or controls more stringent than those required by Clean Water Act sections 301(b) and 306 would result in substantial and widespread economic and social impact. 40 CFR § 131.10(g).

section 101(a)(2)). Prey Fish and CLT Prey Fish uses are not fishable/swimmable uses, but are instead wildlife protection related uses.

USEPA guidance provides that when waters do not meet water quality standards promulgated under the Clean Water Act, and the problems have been produced over many years and it may take many years and substantial changes in resource management to implement desired water quality standards, UAAs are an appropriate tool, conducted alone or in conjunction with the TMDL process, to allow for use attainability over time. *UAAs and Other Tools for Managing Designated Uses*, Preface p. iv (USEPA March 2006) (UAA Guidance). UAAs are appropriate not only to remove a use that is not an existing use, but perhaps more importantly for this situation, UAAs are appropriate for establishing temporary water quality standards, including WQOs, where the goal of the temporary water quality standards is to ultimately, over time, improve water quality to the point where designated uses are fully supported. UAA Guidance, Montana's Temporary Water Quality Standards, at p. ix. As such, temporary WQOs play a key role in the remediation of damaged water resources. *Id.* The duration of temporary standards is set based on an estimate of the time needed to remediate water resources, and, because clean-up of legacy pollutants takes time, temporary standards can be and are issued for multiple years. *Id.*, p. x. States need only to authorize UAAs to use them to set temporary water quality standards as part of a long program of resource management actions designed to improve water quality. *Id.*, p. ix.

Pursuant to the Staff Report, all of the conditions required by regulation to allow, and even to require, conducting UAAs to establish temporary mercury WQOs are satisfied. Accordingly, we urge the State Board to adopt authorization for water boards to conduct such UAAs, and to include in the Provisions a requirement that regional boards shall conduct such UAAs prior to conducting an RPA for mercury or applying ELs in individual non-stormwater discharge Permits. Adopting authority and directing Regional Boards to develop, consider, and where appropriate, to approve UAAs to establish temporary WQO is particularly important given the "mass designation" approach that the State Water Board is following, and the adoption of very low WQOs for all water bodies without considering the natural background conditions applicable to each waterbody or hydrological unit, and without considering the degree to which water quality factors leading to exceedances of the proposed objectives in that hydrographic unit are, or are not controllable. If those factors are not considered now, when adopting WQOs, the only vehicle for consideration of those factors is via a UAA once it is demonstrated the water body cannot comply for the reasons set forth in federal law. A UAA is also the only vehicle available for long-term relief from WQOs and ELs for the entire duration it may take to attain WQOs.

b) Site-Specific Objectives.

Federal regulations (40 CFR § 131.11), Cal. Wat. Code § 13241, and Section 5.2 of the SIP authorize the development of SSOs based on scientifically defensible methods appropriate to the situation and circumstances found in particular regions and waterbodies. The Provisions and Staff Report currently support and authorize regional boards to develop SSOs for the protection of Subsistence Fishing uses because SSOs will more effectively take into account natural conditions and controllable versus uncontrollable water quality factors in the waterbodies for which they are developed, as well as local and regional fish consumption patterns. In fact, this rationale supports authorization and direction to consider mercury SSOs for the protection

of all beneficial uses, including, COMM, WARM, COLD, WILD, RARE, EST, MAR, and SAL. We therefore urge the State Water Board to consider amending the Provisions to advise Regional Boards that it is appropriate to consider adoption of SSOs to replace all the WQOs in light of all the different beneficial uses they are designed to protect in order to better account for local ambient conditions for mercury in each region, subregion or waterbody.

c) Variances.

On August 21, 2015, the EPA published its water quality standards regulation (80 FR 51020), including water quality standards variances (40 CFR § 131.14). The rule explicitly authorizes the use of water quality standards variances pursuant to Clean Water Act sections 101(a) and 303(c)(2) in the same circumstances as those discussed above for UAAs. The federal regulations specify that variances are appropriate when pollutants are persistent in the environment and lack economically feasible control options (80 FR 51020, p. 25).

Like UAAs establishing temporary WQO, variances allow a state to retain the designated use for a waterbody, but to temporarily relax WQOs or ELs as specified in the variance so long as the variance reflects the highest attainable condition identified at the time of the adoption of the WQS variance. 40 CFR § 131.14(b)(ii) and (iii). The relaxed WQOs may then be used for purposes of establishing interim uses and interim WQOs, as well as for purposes of developing NPDES permit limits and requirements, as well as 401 Water Quality Certification requirements. 40 CFR § 131.14(a). Unlike UAAs establishing temporary WQOs, variances with a term greater than five (5) years must be re-evaluated no less than every 5 years, providing less assurance of long-time compliance protection for dischargers. Nevertheless, if any waterbodies may be close to meeting the proposed WQOs, variances may be an appropriate mechanism to use to allow compliance protection for dischargers until new treatment technologies, and particularly those that have yet to be developed, can be identified, planned, designed, environmentally reviewed, permitted, funded and implemented.

However, currently, no consistent statewide mechanism for establishing water quality standards and NPDES permit variances exists; only the Central Valley RWQCB has adopted a variance for salinity (*see, Public Scoping Meeting for the Proposed Statewide Water Quality Standards Variance Policy* (Jan. 23, 2017); Resolution No. R5-2014-0074). Adoption of a general variance policy consistent with federal regulations the State Water Board would provide necessary State implementation authority, establish a consistent procedure for adopting variances across the Regional Boards, and alleviate the burden associated with each regional board having to conduct a public outreach and hearing process to amend their respective water quality control plans to provide such implementing authority.

d) Mixing Zones and Dilution Credits.

The Staff Report notes in several places that water boards have the discretion to allow mixing zones and dilutions credits where appropriate. *See, e.g.,* Staff Report p. 10. However, Staff comments at the January 9, 2017 workshop indicated that the Provisions are not intended to allow regional boards to permit mixing zones and dilution credits, and this position is confirmed by a number of statements in the Staff Report indicating that dilution credits and mixing zones "would be allowed but would not be recommended in most situations since mercury is a bioaccumulative compound …" (p. 156), and shall be prohibited if the mercury

concentration in fish tissue from fish in the receiving water exceeds the applicable WQOs. Staff Report Appendix A, p. A-11. As a matter of practice, mixing zones and dilution credits are not available statewide; they are never applied, at least in Southern California, despite Precedential Order 2001-006, which provides that mixing zones are allowed even in water bodies listed as impaired. *Cf.*, Staff Report pp. 176, 179, 182, 184 (water boards have the discretion to allow dilution credits in waters that currently meet applicable water quality standards). Pursuant to Order 2001-06, a key consideration in determining to establish a mixing zone and/or dilution credit, even for a listed water body, should be a determination of whether even the elimination of a bioaccumulative pollutant from discharges would have had no effect on pollutant concentrations in the waterbody or in fish.

With respect to mercury, the Staff Report and the Technical Report establish that even if all individual non-stormwater NPDES permit discharges were eliminated, reductions in mercury sufficient to attain waterbody compliance with WQOs would not result. Therefore, we urge the State Board to amend the Provisions to expressly authorize the application of mixing zones and dilution credits in circumstances such as those analyzed in Order 2001-06.

4. Recommended Additional Implementation Program Measures.

We also recommend bolstering the currently insufficient implementation program by considering and adopting additional implementation measures that will lead to meaningful reduction in mercury in the state's waters and fish, and some of which may be appropriate to offer as alternative compliance pathways for dischargers. The additional measures should be specifically focused on measures and the development of information and technologies capable of addressing mercury in the environment. We recommend for additional study and consideration six possible additions to the implementation program that the water organizations and member agencies would like to work with Staff to explore:

1. New or more effective control methods for historic mines and tailings;

2. Regional solutions and programs particularly for nonpoint source implementation measures, and which may involve the engagement of other state agencies;

3. Trading/offset programs to allow funding of measures to address actual sources of mercury;

4. A "water funds" approach to support development of studies and pilot projects for design, testing and evaluation of new technologies and control measures that would better target mercury in the environment, including nonpoint source runoff from open space and areas of elevated mercury, wetlands, and sediment;

5. Coordinated development of state funded control programs among the State Board, local agencies, and CARB to address aerial deposition; and

6. Interventions to protect human health developed in other nations dependent upon subsistence fishing, such as Brazil (Passos *et al*. 2007).

E. Insufficiency of Certain Proposed Implementation Measures.

The Staff Report and Mercury Provisions fail to identify and analyze certain reasonably foreseeable compliance methods/management measures, including those imposed on stormwater and wetlands discharges at the discretion of water boards in areas of elevated mercury.

1. Stormwater Implementation Program Measures.

The Provisions impose new requirements as a part of the implementation program on both MS4 and industrial stormwater discharges. Certain mercury control BMPs are specified for inclusion in MS4 permits, and new, much lower action levels are imposed on industrial stormwater permit discharges. However, the Staff Report fails to evaluate the likelihood that the additional MS4 Permit measures specified may reasonably lead to reductions of mercury in receiving waters. Further, the Staff Report fails to identify any treatment technologies that might be available to implement on a geographically dispersed basis to control urban runoff in a manner that would effectively reduce mercury in receiving waters. Because no treatment technologies are identified or evaluated for assuring that industrial stormwater permits meet the new mercury action levels, the Staff Report's substitute environmental analysis of potential impacts of such technologies is missing contrary to the requirements of CEQA that environmental impacts of all reasonably foreseeable pollution control technologies required by mandate must be analyzed. Cal. Code Regs. tit. 14, § 15126.2.

Further, the new implementation program's regulatory requirements applicable to MS4 and industrial stormwater permits raise serious risk of enforcement and third party citizen suit liability for stormwater permittees. Upon adoption, the new, stringent, and unattainable WQOs will become MS4 permit and industrial stormwater permit "receiving water limitations." As a result, any MS4 or industrial stormwater discharges that "cause or contribute to an exceedance of the mercury WQOs" would create a receiving water limits violation for permittees. The vast majority, if not all inland surface waters, enclosed bays and estuaries will exceed the new WQOs for mercury, creating the risk of liability under industrial and MS4 stormwater permit receiving water limitations, regardless of the significance (or relative insignificance) of mercury contributions associated with those discharges.

To attempt to maintain compliance in light of such receiving water limitations, MS4s and industrial dischargers will be required to expand the reasonable assurance analysis mandated by the permits to attempt to show what the Staff Report could not—that the BMPs deployed to control mercury are reasonably likely to bring receiving waters into compliance with the WQOs. In addition, costs of watershed management plans (WMPs) and industrial stormwater pollution prevention plans (SWPPPs) will increase to attempt to control mercury as required by new mercury "receiving water limitations." As WMPs and SWPPPs are modified, new control measures for mercury in urban and industrial stormwater will have to be implemented, even though there are no effective treatment practices or technologies, thus imposing costs for invention, development and implementation of new mercury stormwater control technologies, despite the fact that stormwater discharges are very small sources of mercury. The Provisions should be modified to clarify that mercury WQOs should be excluded from receiving water limitations in both MS4 permits and the Industrial General Stormwater permit.

2. Wetland Mercury Control Measures.

The draft Provisions address wetlands by providing discretionary control to water boards to use existing law to implement mercury controls in areas with elevated mercury concentrations. The draft Provisions include examples of design features and management measures to reduce the production of methylmercury in the wetland that water boards "should consider requiring." Staff Report § 6.10.3. Yet the Staff Report, including the Wetlands Appendix Q, emphasizes that the science on mercury/methylmercury controls is not advanced enough to provide BMPs that will clearly reduce mercury or methylmercury in most situations. Further, the relative importance of the many factors that can influence mercury chemistry can vary from site to site. *See,* Technical Report section 8. This is why the Staff Report states that the science on mercury/ methylmercury controls is not advanced enough to provide BMPs that will clearly reduce mercury or methylmercury in most situations.

The Staff Report provides, "New wetland projects (creation or restoration of wetlands) should not be prevented because of mercury concerns. However, wetland projects should be done in [a] manner to reduce unintended impacts. If practicable, new wetlands should not be created in areas with high levels of mercury." (p. 136)

As an initial matter, this potentially conflicts with State's no net loss of wetlands policy (E.O. W-59-93). Wetland projects are a cost-effective manner to improve water quality by removing contaminants, including sediments to which mercury binds, before entering receiving waters, and they play an important role in the implementation of TMDLs. Wetlands provide an environmentally sound way to address the pollution caused by urban runoff before the runoff reaches sensitive receiving waters. Wetlands provide a cost effective alternative that can be used to address runoff from existing communities that can't easily be retrofitted.

The challenge for wetlands is that this understanding is not translated into the Provisions regulatory language. The regulatory language, which is what will ultimately survive this rulemaking and drive water boards' future actions, does not reflect the State Water Board's position with regard to the scientific uncertainty of the process of methylation and wetlands. Absent revisions, the text implies (a) the listed measures are necessary and appropriate to incorporate into permit conditions for wetlands development [which they are not]; and (b) the listed measures will achieve mercury reductions from wetlands projects [which they may not] – leaving a cloud of regulatory uncertainty over future wetlands projects.

The Staff Report and regulatory language should be amended to reflect the current knowledge of the effectiveness of control measures as it relates to wetlands and other bodies. We believe the regulatory language should clarify that the listed measures are not BMPs and may or may not be appropriate depending on site specific factors. Alternatively, the listed management measures could be eliminated altogether from the regulatory text at section IV.D.7 [Wetland Projects]. Such amendments would ensure that the Provisions are consistent with the stated intent of the State Water Board, which is not to prevent new wetland projects because of mercury concerns. Otherwise, a cloud of regulation on wetland creation/restoration will have the regulated community looking for alternatives to wetland creation, often to the detriment of water quality and other environmental outcomes.

3. Further Analysis of Stormwater and Wetlands Mercury Control Measures is required under the Water Code and CEQA.

Failure to identify and properly analyze mercury stormwater controls and wetlands implementation measures is a violation of Water Code sections 13241(c) and 13242(a). Delete the limitations or properly identify and analyze such controls consistent with the requirements of the Water Code.

Failure to identify and assess environmental impacts of stormwater controls and wetlands implementation measures is a CEQA violation. Delete the limitations or properly identify and analyze such controls.

F. New Beneficial Uses.

1. The New Beneficial Uses Will Likely Result in Further Water Quality Regulations for Pollutants Other than Mercury.

As recognized in the Workshops and at the Board Hearing, the new beneficial use categories of T-SUB, SUB, and CUL will pave the way for listing, WQOs, ELs, and TMDLs for other constituents. See, Beneficial Use handout, p. 5 (stating that the subsistence beneficial uses may require regulation of other bioaccumulatives). Wastewater and industrial facility upgrades may be needed to comply with multiple future statewide or region wide WQOs for other pollutants regulated in association with new beneficial use categories (facility upgrades likely to involve adding nitrification and denitrification steps or adding additional filtration) (see p. 177).

2. The Staff Report and the Regulatory Text Should Include Direction Regarding the Adoption of Flow and Fish Population Objectives.

It is likely that without specific direction in the Staff Report and the Provisions the new CUL beneficial use will result in flow and fish quantity objectives. See, Workshop Beneficial Use handout, p. 2, (stating that the State Board may develop a flow objective to protect the new CUL beneficial use, although “it is not anticipated.”)

For example, in 2011 the Oregon Department of Environmental Quality adopted the strictest standard for toxic water pollution in the United States to protect tribal members and others who eat large amounts of contaminated fish. The human health water quality criteria have been adopted for 113 pollutants, including mercury, flame retardants, PCBs, dioxins, plasticizers and pesticides. However, the new rule could end up costing millions and improvements in water quality are expected to take years, if not decades; yet it's not clear how much the rules will actually reduce pollution.

Similarly, the State of Washington was thereby restricted from developing and operating infrastructure that would hinder fish passage and thereby diminish the number of fish that would otherwise be available for Tribal harvest. *United States v. Washington*, 20 F. Supp. 3d 986, 1000, 1022 (W.D. Wash. 2013). A Florida tribe challenged the State of Florida’s implementation of new water quality criteria for 39 chemical components not currently regulated by the state and revisions to standards for 43 more were for failing to account for the higher levels of fish

consumption by tribe members who subsist on fish and doesn't include sufficient protections for tribe members who subsist on fish and other seafood. *Seminole Tribe of Florida v. Dep't of Envt'l Protection,* No. 2D16-4305.

3. The Staff Report Does Not Properly Document Consideration of Water Code Section 13241 in the Adoption of the New Beneficial Uses.

Contrary to CWC § 13241 the Staff Report fails to consider the relevant factors in establishing the new B/U categories by failing to consider information about background conditions in specific water bodies or regionally, by failing to identify water quality conditions that can reasonably be achieved through the coordinated control of factors that affect water quality, and by failing to properly consider the full scope of economic impacts associated with treatment plan upgrades and associated mitigation measures.

4. The Staff Report Should Include Policy Guidance and Criteria in the Designation of Beneficial Uses to Avoid Unintended Consequences.

In order to provide consistent application of the Mercury Provisions and the designation of beneficial uses throughout the State and to avoid misapplication of the implementation program, we recommend the State Water Board include guidance for the Regional Boards in the Staff Report as follows:

1. State that with respect to the tribal (T-SUB, CUL) and subsistence (SUB) beneficial uses and WQOs flow and fish quantity criteria/objectives shall not be established.

2. Prohibit the designation of tribal (T-SUB, CUL) and subsistence (SUB) beneficial uses where the use is wholly in the past (*i.e.*, not existing and not probable future use). *See,* Staff Report at Appendix T-4 (stating that regional water boards do no designate waters with beneficial uses that occurred solely in the past).

3. Prohibit the designation of tribal (T-SUB, CUL) and subsistence (SUB) beneficial uses where the water quality does not support the use.

For already designated beneficial uses that will immediately trigger the Mercury Provisions, e.g., COMM and RARE, we strongly recommend conducting a UAA to determine whether the use is attainable. *See, Cal. Ass'n of Sanitation Agencies v. State Water Res. Control Bd.* (2012) 208 Cal.App.4th 1438, 1460 (finding that where a water board has evidence that a designated use does not exist and likely cannot be feasibly attained it is unreasonable to require dischargers to incur control costs to protect that use). Alternatively, regional boards could conduct a UAA prior to imposing ELs in NPDES permits.

G. Adoption of the Mercury Provisions is an Unfunded Mandate.

Section 6 of Article XIII B of the California Constitution provides, in relevant part: "Whenever the Legislature or any state agency mandates a new program or higher level of service on any local government, the State shall provide a subvention of funds to reimburse that

local government for the costs of the program or higher level of service." Where a subvention is not provided, the new program – or in this case, regulation – is an unfunded mandate.

The Mercury Provisions are an unfunded mandate because they mandate a higher level of protection (more stringent WQOs) than required under federal law.

First, the proposed Sport Fish WQO of 0.2 mg/kg, which applies to COMM and is protective of human health, is slightly lower the federal Fish Contaminant Goal of 0.22 mg/kg developed by OEHHA (Klasing and Brodberg 2008). While the federal OEHHA value is not enforceable, it is the contaminant goal for mercury in fish, concentrations above which the federal agency has determined warrant advisories to those consuming the fish. Further, the 0.22 mg/kg value has been used by the State since 2012 for water quality assessment purposes in the state, according to the Staff Report (p. 31).

Second, the proposed Sport Fish WQO of 0.2 mg/kg is also more stringent than the federal EPA national water quality criterion and the USEPA federal regulatory objective for fish tissue of 0.3 mg/kg. The USEPA fish tissue criterion has been used to fulfill the narrative toxicity objective in regards to mercury (*id.*).

Third, the proposed Sport Fish WQO of 0.2 mg/kg is also more stringent than the fish tissue concentration for mercury of 0.37 mg/kg used to derive the currently applicable federal USEPA CTR water criterion for protection of human health (*id.*).

All told, even the least protective human health mercury WQO of 0.2 mg/kg – which would apply immediately upon adoption and approval of the proposed Provisions – provides a higher level of protection as compared to all applicable federal limits, therefore constituting an unfunded State mandate.

In addition, the wildlife beneficial uses (Sport Fish (except COMM, CUL), Prey Fish, CLT Prey Fish) are not supported under federal law if the use is not an existing or probable future use or water quality does not support the use because the federal act authorizes designation of only existing or probable future beneficial uses. Where WQOs are already exceeded, it is highly likely that wildlife uses have not been occurring since 1975 given the legacy nature of mercury pollution. Thus, where a designation is based on a wholly past use, and therefore protected under Porter Cologne, but not the federal act it is an unfunded State mandate.

H. CEQA Comments.

1. Failure to Include the Reservoir Program in the Project Description is Piecemealing.

The Staff Report provides, "Many methods of compliance for the Provisions could be similar to those required for the Reservoir Program, including sediment controls, possible wastewater treatment plant upgrades, and mercury monitoring . . . . Reservoir Management Actions [i.e., methods to manage mercury in reservoirs] are different methods of compliance not required by the Provisions, but some of the impacts could be similar as the impacts of the Provisions." (p. 255) This rulemaking's WQOs will be used to determine which waters are impaired and will therefore drive the Reservoir Program – for water districts with multiple

discharges and operations that will be regulated for mercury, it is important to understand how the Reservoir Program, which is under development, will work in conjunction with the Provisions as a comprehensive statewide mercury program.

2. The Project Objectives are Improperly Narrow and Violate CEQA.

CEQA Guidelines § 15124(b) requires a clearly written statement of objectives, including the underlying purpose of the project, which will help the lead agency to develop a reasonable range of alternatives and aid decision makers in preparing findings or a statement of overriding considerations. The process of selecting the alternatives to be included in the EIR begins with the establishment of project objectives by the lead agency. "A clearly written statement of objectives will help the lead agency develop a reasonable range of alternatives to evaluate in the EIR and will aid the decision makers in preparing findings . . . . The statement of objectives should include the underlying purpose of the project." Cal. Code Regs., tit. 14, § 15124, subd. (b).

However, the Mercury Provisions project objectives are simply listed in the Staff Report and not discussed or explained. CEQA and the State Water Board's implementing regulations require an analysis of reasonable alternatives to the project and mitigation measures to avoid or reduce any significant or potentially significant adverse environmental impacts. Cal. Code Regs., tit. 23, § 3777. Failure to include a meaningful discussion of project objectives undercuts CEQA's requirement to analyze reasonable alternatives.

3. The Staff Report Does Not Evaluate a Reasonable Range of Alternatives.

The SED improperly eliminates alternatives for failing to meet one of a list of five project objectives, where the project objectives are not discussed or explained and no project purpose is identified in the project description (CEQA Guidelines 15126.6(b) [An EIR should not exclude an alternative from detailed consideration merely because it "would impede to some degree the attainment of the project objectives."] Although a lead agency may not give a project's purpose an artificially narrow definition, a lead agency may structure its EIR alternative analysis around a reasonable definition of underlying purpose and need not study alternatives that cannot achieve that basic goal. *In re Bay-Delta etc.,* (2008) 43 Cal. 4th 1143, 1165-66.

However, the Staff Report's project description does not identify a project purpose. For this reason, eliminating alternatives for failing to meet one of five project objectives – particularly where the Staff Report only lists and does not discuss the rationale behind the project objectives – does not comply with the requirement to consider a reasonable range of alternatives.

4. Environmental Impacts Are Not Properly Considered or Analyzed in the Staff Report.

a) *Treatment Facility Upgrades Required to Comply with Effluent Limitations Will Effect Water Supply.*

As a result of planned activities and emergencies, water purveyors have discharges from their drinking water systems, such as line testing. Planned discharges may be scheduled or unscheduled and are due to development and maintenance activities mandated by statutory requirements under the federal Safe Drinking Water Act and the California Safe Drinking Water Act (Health and Saf. Code, division 104, part 12, chapter 4.) Emergency discharges are due to system leaks, facility failures, and catastrophic events.

Drinking water system discharges under the scope of the proposed Mercury Provisions ELs for individual non-stormwater NPDES permits would include both planned and emergency discharges. As discussed above and in Section 2 of the attached Technical Report, added costs to upgrade treatment technologies to meet new ELs as low as 1 ng/L, the lack of treatment technologies to reduce discharges to meet ELs, new listings and associated TMDLs, and the lack of realistic time schedules to comply with the new mercury program pose a significant risk of increased compliance costs, permit violations and penalties, and citizen suit enforcement and attorneys' fees – all of which will increase the cost of water service. While the exemption for small disadvantaged communities will provide some protection, increased cost of service must be passed on to ratepayers or be paid for by eliminating other programs – both of which would adversely affect water purveyors' ability to provide clean, safe and affordable drinking water to their customers.

b) Treatment Facility Upgrades Such as Reverse Osmosis, Necessary to Meet 1 ng/L May Result in Significant Energy Use and Air and GHG Emissions.

As documented in Section 2 of the Technical Report, wastewater treatment facilities with tertiary treatment may need to introduce advanced treatment to meet the proposed 1 ng/L EL for slow-moving waterbodies designated T-SUB. The Staff Report does not offer examples of such treatment options to comply with the 1 ng/L standard; however, the Technical Report indicates that RO could be used. Operation costs for this treatment would require up to twice as much power consumption as tertiary treatment alone. Air quality and climate change effects associated with the concomitant air and greenhouse gas emissions must be evaluated in the Staff Report so that the public and decision makers may understand the scope of potential environmental impacts associated with adoption of the Mercury Provisions.

c) *Sediment Controls to Reduce Mercury May Result in Hydromodification Impacts*

The Provisions recommend water boards impose sediment controls at mine sites and for nonpoint sources in areas of elevated mercury (pp. 171-172). Sediment controls are designed to keep or reduce the amount of sediment from entering into waterbodies. The reduction of sediment in natural stream channels can create "hungry water," resulting in erosion and downcutting of the natural streambed. *See, e.g., Hydromodification Management Plan: County of San Diego* § 6.4.7 (Brown and Caldwell 2011). The Staff Report does not address this potential for hydromodification effects resulting from implementation of sediment control measures as imposed by regional boards.

II. CONCLUSION.

The water agencies appreciate this opportunity to provide comments on the proposed beneficial uses and Mercury Provisions. We support protection of public health, and our comments are focused primarily on concerns with the Non-Tribal/Non-Subsistence provisions. We would very much appreciate the opportunity and time to work with you and your staff to address those concerns.

Sincerely,

Rebecca Franklin
Regulatory Advocate
Association of California Water Agencies

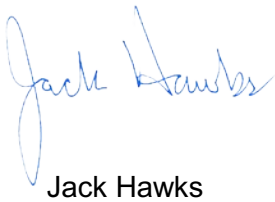

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EXHIBIT A

Exponent®

EXTERNAL MEMORANDUM

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DATE: February 17, 2017

PROJECT: 1608830.000

SUBJECT: Technical comments on proposed California Mercury Provisions

This technical memorandum summarizes Exponent's comments on the State Water Resources Control Board's (SWRCB's) proposed "Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions" (Mercury Provisions), which was released for public review on January 3, 2017.[1] Our comments focus on concerns that the proposal will not produce reductions in mercury concentrations in fish because it fails to address the primary sources of mercury to the State's water bodies and fish. The proposal also contains a number of technical shortcomings that should be addressed before adoption. Our comments fall into seven primary categories, summarized as follows:

1. Point source discharges subject to individual National Pollutant Discharge Elimination System (NPDES) permits (e.g., water treatment plants, wastewater treatment plants, and industrial discharges) are small relative to other mercury sources. Imposing stringent numeric effluent limitations on those sources will have little effect on mercury concentrations in fish and the environment. Stringent numeric effluent limits are inappropriate for most point sources, and alternative implementation mechanisms should be explored and developed by the SWRCB.

[1] SWRCB. 2016. Draft Staff Report, Including Substitute Environmental Documentation, for Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions (Staff Report). State Water Resources Control Board. January 3. Accessed February 6, 2017, at http://www.swrcb.ca.gov/water_issues/programs/mercury/docs/staff_report/hg_staff_report.pdf.

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2. The proposed effluent limitations for non-stormwater individual NPDES dischargers may be unattainable (especially 1 ng/L), and treatment upgrades to meet the proposed limits will be more costly than disclosed by the SWRCB.
3. The implementation program in the State's proposed policy should be modified to focus on actions that will lead to meaningful reductions in mercury in the state's waters and fish.
4. The Staff Report's position on dilution credits and mixing zones for NPDES discharges containing mercury is inconsistent with SWRCB precedential orders. The appropriateness of mixing zones and dilution credits should be evaluated on a site-specific basis.
5. The fish tissue objectives proposed to protect wildlife are likely to be overly conservative and should be revised to address this limitation.
6. The water concentration targets derived from the proposed fish tissue water quality objectives are fundamentally flawed and should not be implemented at this time.
7. The proposed human health objectives may be too conservative.
8. The proposed action to address dredging, wetlands, and nonpoint sources of mercury is vague and does not prescribe or prevent any specific actions.

Details of these comments are included below.

1. Point source discharges subject to individual NPDES permits (e.g., water treatment plants, wastewater treatment plants, and industrial discharges) are small relative to other mercury sources. Imposing stringent numeric effluent limitations on those sources will have little effect on mercury concentrations in fish and the environment. Stringent numeric effluent limits are inappropriate for most point sources, and alternative implementation mechanisms should be explored and developed by the SWRCB.

In Appendix N of the Mercury Provisions, SWRCB presents source analysis data for the 14 existing mercury-related TMDLs in the state; these TMDLs are listed in Table 1.[2] Only three of the mercury TMDLs for these water bodies list wastewater and industrial discharges as sources of mercury.[3] As reproduced in Figure 1, Table N-11 from Appendix N indicates that wastewater and industrial discharges constitute 4% of methylmercury discharged to the Delta and 1.5% of total mercury discharged to San Francisco Bay. (The third TMDL, for Calleguas Creek/Mugu Lagoon, lacks a quantitative source analysis.) Sources related to historical mining (tributaries

[2] Appendix N. Wastewater and Industrial Discharges. pp. N-14 to N-15. Note that Figure 3-1 (p. 33) of the Staff Report shows a map of mercury impaired waters on the 2012 303(d) list, which includes many more water bodies than those for which mercury TMDLs have already been developed.

[3] Appendix N, p. N-14.

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and water body sediments) account for 93% and 82% of mercury in the Delta and San Francisco Bay, respectively, while atmospheric deposition (direct deposition and urban stormwater generated by mercury-laden precipitation) accounts for 15% of mercury in San Francisco Bay. Thus, data from these two TMDLs indicate wastewater and industrial NPDES dischargers contribute little mercury to affected water bodies relative to other sources, suggesting tight limitations on mercury from such dischargers will not result in significant reductions in environmental mercury concentrations.

Table 1. Waterbodies in California subject to a mercury-related TMDL

Water body	Individual NPDES permit dischargers listed as source?
Sacramento-San Joaquin Delta	Yes
San Francisco Bay	Yes
Calleguas Creek/Mugu Lagoon	Yes
Guadalupe River Watershed	No
Walker Creek	No
Clear Creek and Hernandez Reservoir	No
Las Tablas Creek and Lake Nacimiento	No
El Dorado Park Lakes	No
Puddingstone Reservoir	No
Lake Sherwood	No
Consolidated Slip and Fish Harbor, Los Angeles-Long Beach Harbor	No
Cache Creek	No
Clear Lake	No
Rhine Channel, Newport Bay	No

Source: SWRCB. 2016. Draft Staff Report, Including Substitute Environmental Documentation, for Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions. State Water Resources Control Board. January 3. Appendix M. Summary of Mercury TMDLs. Accessed February 7, 2017, at http://www.swrcb.ca.gov/water_issues/programs/mercury/docs/staff_report/hg_apndx_m.pdf.

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Table N-11. Estimated Mercury Loadings from the Sacramento-San Joaquin Delta TMDL (Delta) and the San Francisco Bay TMDL.

Sources	Delta *Methylmercury* (g/day)	San Francisco Bay *Total Mercury* (g/day)	Delta (% total)	San Francisco Bay (% total)
Tributaries (Central Valley)	8.2	1205	57	36
Guadalupe River Watershed (Historic mining, San Francisco Bay only)	-	252	-	8
Sediments in water body (Delta: open water, wetlands. San Francisco Bay: Bed erosion)	5.1	1260	36	38
Atmospheric deposition (San Francisco Bay: direct deposition only. Delta: direct and indirect, so includes atmospheric mercury carried by nonpoint source storm water, but not urban storm water)	0.06	74	0.4	2
Non-urban storm water (San Francisco Bay only: includes mercury enriched sediments and atmospheric mercury. Delta: Atmospheric mercury from non-urban storm water is included in 'atmospheric deposition')	-	68	-	2.0
Urban runoff (Caltrans, MS4s, Construction, Industrial)	0.05	438	0.3	13
Municipal wastewater and **Industrial discharges** (Delta had only municipal wastewater)	0.6	49	4	1.5
Agricultural return flows (Delta only)	0.3	-	2	-
Total	14.31	3348	100	100

Figure 1. Table N-11 from Appendix N of the Mercury Provisions. Source: Appendix N, p. N-15 of "Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions." Accessed February 7, 2017, at http://www.swrcb.ca.gov/water_issues/programs/mercury/docs/staff_report/hg_apndx_n.pdf.

Appendix N states:

> *From the [mercury TMDL source] estimates in Table N-11, atmospheric deposition is not a major source of mercury. In the Sacramento-San Joaquin Delta TMDL, municipal wastewater is more significant than atmospheric deposition. If this information is used to extrapolate relative source contribution to the state as a whole, then for any watershed without historic [sic] gold or mercury mining, wastewater and industrial dischargers can be a significant source of mercury.*[4]

[4] Appendix N, p. N-14.

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However, a finding that atmospheric deposition is small does not lead directly to the conclusion that NPDES discharger contributions "can be a significant source of mercury"—instead, the Staff Report should consider the possibility that *neither* source might be significant. Appendix N also suggests NPDES discharges can be significant in "any watershed without historic [sic] gold or mercury mining,"[5] but this assertion is not supported by data or information in the Staff Report, and no evidence is provided to suggest extrapolating data from the Delta or San Francisco Bay to the entire state is appropriate.

In contrast to the proposal's focus on NPDES discharges, the Staff Report indicates that historical mining, natural soils, and direct deposition are "significant" and "major" sources of mercury.[6] The Staff Report notes that "the median and average mercury concentrations in rain in California were 6 ng/L and 12 ng/L" and "the 99.8th percentile of mercury concentrations in rain in the United States was 174 ng/L."[7,8] Thus, a significant fraction of rain samples in California would have concentrations higher than these values, which, as discussed below, are equivalent to the proposed effluent limitations for point source discharges. The Staff Report also indicates that "[m]ercury deposition from atmospheric emissions is thought to be the major source of mercury in some Southern California lakes and reservoirs (U.S. EPA 2012, Tetra Tech 2008)."[9]

Finally, the Staff Report states, "[m]unicipal wastewater treatment plants are generally a relatively minor source of mercury to the environment compared to other sources. Wastewater

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5 Ibid.

6 The Staff Report notes that "elevated mercury concentrations in present-day mine impacted waters and sediments indicate that hundreds to thousands of pounds of mercury remain at each of the many sites affected by hydraulic mining" (Staff Report at p. 47). The Staff Report also notes, "The Coast Ranges are naturally high in mercury… The soils in these areas that are naturally enriched with mercury erode, contributing to the mercury load in waterways… The mercury from mine waste, naturally enriched soils, and geothermal springs is a major source of mercury in the Coast Ranges, the Sierra Nevada Mountains, and also downstream in the Sacramento/San Joaquin Delta and San Francisco Bay" (Staff Report at p. 49). Finally, the Staff Report finds that "direct deposition of mercury to water bodies (vs. deposition on land upstream) has been found to be very important in determining mercury levels in fish. Harris and colleagues applied isotopically labeled mercury (as $HgNO_3$) to a lake and the surrounding watershed. Essentially all of the increase in methylmercury in fish after 3 years was due to the mercury deposited directly to the lake surface… Furthermore, the results could suggest that controlling emissions that are deposited directly on the water surface may have a rapid effect (few years) on mercury level in fish (Harris et al. 2007)" (Staff Report at p. 50).

7 Staff Report at p. 140.

8 It has been widely demonstrated that precipitation in California has significant concentrations of mercury linked to coal-based Asian industrial emissions. For example, Steding and Flegal conclude that their study "demonstrates the impact of Asian industrial emissions on Hg concentrations in rain in western North America. The analyses substantiate previous reports on the influence of those emissions on Hg deposition in the North Pacific." (Steding, D.J. and A.R. Flegel. 2002. Mercury concentrations in coastal California precipitation: evidence of local and trans-Pacific fluxes of mercury to North America. J. Geophys. Res., 107 (2002):D24, p. 11-6.) They estimate mercury deposition via rainfall at approximately 25–50 nmol/year/m^2, which, if applied over the area of San Francisco Bay (approximated as 2,500 km^2), is roughly the same rate reported in the San Francisco Bay mercury TMDL for atmospheric deposition (74 g/day, from Table N-11).

9 Staff Report at p. 49.

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treatment plants already remove most of the mercury from the effluent."[10] Because mercury sources attributable to NPDES dischargers are small compared to the dominant sources in the state, imposing stringent effluent limitations on NPDES dischargers such as those proposed in the Mercury Provisions will not result in a significant reduction in water body or fish concentrations. The Staff Report acknowledges this, noting that bioaccumulative pollutants, including mercury, are "generally very persistent in the environment," concluding that:

> *Even if all sources of the contaminants are eliminated, the contaminants are likely to remain high for decades, because either they do not degrade or they degrade very slowly. Much of the mercury in fish today is thought to be from historic mining in the late 19th century and early 20th century. Further, current sources may not be directly regulated by the water boards (e.g., atmospheric emissions, naturally occurring in soils, or geothermal sources).*[11]

In summary, the Staff Report establishes clearly that sources other than NPDES discharges are the primary sources of mercury to the state's water bodies and that imposing controls on NPDES discharges will have little or no effect on ambient mercury concentrations. This information should lead the SWRCB to develop a program to address those major sources.

2. The proposed effluent limitations for non-stormwater individual NPDES dischargers may be unattainable (especially 1 ng/L), and treatment upgrades to meet the proposed limits will be more costly than disclosed by the SWRCB.

As discussed in Section 2 of the Staff Report, the proposed water quality objectives for mercury are expressed as fish tissue concentrations. These fish tissue concentrations are "translated" into water column concentrations proposed to be used to evaluate "reasonable potential" (RP) and to derive effluent limitations applicable to point source discharges. The water column concentrations and their proposed applicability to various water quality objectives (WQOs) and kinds of water bodies are summarized in

[10] Staff Report at p. 151.

[11] Staff Report at p. 106.

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Table 2. (Exponent's evaluation of the translation procedures used to derive these water column concentrations is included in Section 6 of these comments.)

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Table 2. Proposed water column mercury concentrations for NPDES discharges and their applicability to various kinds of water bodies

Total Hg water column concentrations	Water quality objectives (WQOs) and water bodies to which water column concentration applies
12 ng/L	Sport Fish and Wildlife WQOs in flowing water bodies
4 ng/L	Sport Fish and Wildlife WQOs in slow-moving water bodies; Tribal Subsistence Fishing (T-SUB) WQOs in flowing water bodies
1 ng/L	Tribal Subsistence Fishing (T-SUB) WQOs in slow-moving water bodies
Case-by-case determination	Subsistence Fishing (SUB) WQOs in any water body; Any WQOs in lakes and reservoirs

Source: SWRCB. 2016. Draft Staff Report, Including Substitute Environmental Documentation, for Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions. State Water Resources Control Board January 3. pp. 173–183. Accessed February 7, 2017, at http://www.swrcb.ca.gov/water_issues/programs/mercury/docs/staff_report/hg_staff_report.pdf.

The Staff Report asserts the proposed 12 ng/L effluent limitation "is achievable" with existing secondary treatment technology and (possibly) a mercury source control/minimization program.[12] However, according to a recent study by HDR, typical mercury concentrations after secondary treatment range from 3.0 to 50 ng/L in Publicly Owned Treatment Works (POTWs) and from 10 to 50 ng/L in industrial discharges.[13] The report does not examine the factors responsible for the variability in mercury concentrations in treated effluent, though it likely depends in part on plant influent mercury concentrations. HDR's data suggest some NPDES dischargers will *not* be able to meet the 12 ng/L effluent limitation with secondary treatment and/or a source control/minimization program.

The Staff Report also asserts the proposed 4 ng/L effluent limitation is achievable with tertiary treatment that includes nitrification/denitrification but not with secondary treatment.[14] Data from the Central Valley Regional Board indicate that tertiary treatment can reduce mercury concentrations to 4 ng/L or below in at least some cases but not in every case. On average, the San Jose/Santa Clara Waste Water Treatment Plant (WWTP) achieves a mercury concentration of 4 ng/L limitation using tertiary treatment,[15] while the Onondaga County WWTP does not.[16] Thus, it is likely some plants already employing tertiary treatment will not be able to meet the 4 ng/L water column concentration.

[12] Staff Report, p. 174.

[13] HDR. 2013. Treatment Technology Review and Assessment. Association of Washington Business, Association of Washington Cities, Washington State Association of Counties. December 4, 2013. p. 7.

[14] Staff Report, p. 177.

[15] Central Valley Water Board. 2010. A review of methylmercury and inorganic mercury discharges from NPDES facilities in California's Central Valley Staff Report Final. March 2010. Rancho Cordova, CA. Table 2, p. 57.

[16] Central Valley Water Board. 2010. Table 5, p. 58.

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In contrast with the 12 ng/L and 4 ng/L effluent limitations, the 1 ng/L effluent limitation proposed for slow-moving water bodies with a Tribal Subsistence Fishing designation is likely unachievable without extraordinary treatment upgrades and expenditures for most NPDES dischargers. The treatment processes that would be needed to meet a concentration limit of 1 ng/L are not disclosed in the Staff Report. The Staff Report indicates the 1 ng/L effluent limitation may be unachievable for NPDES dischargers not already achieving it (i.e., 73% of such dischargers according to Staff Report data).[17] The Staff Report suggests no treatment methods for NPDES dischargers to meet the 1 ng/L effluent limitation. Instead, the Staff Report states, "the Water Boards may use compliance schedules, site-specific objectives (with extended compliance schedules), TMDLs, or variances if the [1 ng/L] effluent limitation is unachievable."[18]

HDR's review of treatment technologies states, "[t]here is limited information available about achieving ultralow effluent mercury concentrations near the 5 ng/L range."[19] The treatment process that appears most likely to meet the proposed 1 ng/L effluent limitation is advanced treatment employing microfiltration and reverse osmosis (MF/RO), and then under optimal conditions where input concentrations are low.[20] Under these circumstances, HDR found dischargers could achieve mercury effluent concentration in the range of 1.2 to 3 ng/L.[21] However, this level of treatment exceeds tertiary treatment and requires substantial additional expenditures (see below), and the Staff Report does not disclose or examine the costs of this level of treatment.

Appendix R of the Staff Report estimates the cost of upgrades from secondary to tertiary treatment that would be required by the policy to be in the range of $9–15 million/year over 20 years. Exponent believes this range significantly underestimates upgrade costs. For example, Sacramento Regional San—a POTW with a design flow rate of 181 million gallons per day (mgd)—is currently upgrading from secondary to tertiary treatment at a capital cost of approximately $2 billion and $50 million/year in operation and maintenance (O&M) thereafter.[22] These estimates for a single plant surpass the Appendix R total estimate for all plant upgrades in the state.

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17 Staff Report at p. 178: "Based on statewide monitoring data for all facilities that may be impacted by the Provisions, it is estimated that eight facilities would not meet the new effluent limits for the [T-SUB] water quality objective in flowing water bodies and will have to undergo a major treatment plant upgrade if they are designated with the T-SUB beneficial use in the future." And from the Staff Report at p. 180: "Recent data from discharger self-monitoring reports indicates [sic] that about 73 percent of all discharges to waters included in the geographic scope of the Provisions exceeded 1 ng/L, based on 2009-2015 data."

18 Staff Report at p. 180.

19 HDR. 2013. p. 12.

20 HDR. 2013. p. 13.

21 HDR. 2013. pp. 13–14.

22 Data accessed February 8, 2017, from http://www.regionalsan.com/echowater-project.

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Given advanced treatment (e.g., MF/RO) will be necessary to achieve the 1 ng/L limitation, costs will be far higher. HDR suggests that the capital cost of upgrading a plant from secondary to advanced treatment (MF/RO) would be about $15–$162 per gallon per day (gpd) of treatment capacity, depending on the size of the plant to be upgraded.[23] This range is 13–142 times higher than the Appendix R estimate of $1.14 per gpd to upgrade to tertiary treatment[24] and would cost $1.5–$16.2 *trillion* for a plant that treats 100 mgd. Clearly, the costs required to upgrade a treatment plant to advanced treatment will exceed the costs to upgrade to tertiary treatment, such that the costs of implementing the SWRCB's proposal will be far greater than disclosed in the Staff Report.

In addition to capital and O&M costs, upgrading POTW treatment to advanced treatment would increase power consumption. For POTW dischargers, HDR estimates advanced treatment would require 50–100% more power than tertiary treatment.[25] Increased power consumption produces increased greenhouse gas emissions. This impact is not considered in the Environmental Document associated with the Mercury Provisions, and no mitigation measures are offered for this potentially permanent, long-term additional source of greenhouse gases.[26]

3. The implementation program in the State's proposed policy should be modified to focus on actions that will lead to meaningful reductions in mercury in the state's waters and fish.

Issue L in the Staff Report addresses the question, "What procedure should be used to determine which municipal wastewater and industrial dischargers would need effluent limitations?"[27] Two options are considered: (1) use a mercury concentration in water; (2) use mercury concentrations in fish tissue. Both options would result in effluent limitations for discharges to most of the state's water bodies, despite the fact that point source discharges are minor contributors to mercury in the state's water bodies; as detailed throughout these comments, such effluent limitations are not likely to result in reductions in ambient mercury concentrations. Although the proposed Mercury Provisions include language stating that the permitting authority is authorized to exempt certain dischargers from some or all of the provisions of the policy if the discharge is found to be "insignificant [de minimis],"[28] it appears that this exemption would be highly limited and unavailable for most dischargers. For this reason, Exponent recommends that the flow charts for both options be modified to consider additional factors and implementation options before concluding that effluent limits are required. Only if the policy is modified to include alternative implementation options will the policy be likely to lead to meaningful reductions in mercury concentrations in the state's waters and fish.

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[23] HDR. 2013. p. ES-2.

[24] Appendix R, Economic Analysis. R-47.

[25] HDR. 2013. p. ES-4.

[26] Staff Report, pp. 220–222.

[27] Staff Report, p. 142.

[28] Staff Report, p. 153.

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As shown in Figure 2 and Figure 3, Exponent recommends the addition of decision points based on the relative importance of point sources to mercury loads in the water body, and the consideration of alternative implementation measures. First, if point source discharges are not significant contributors to mercury in the water body, effluent limitations should not be required. The second query recognizes that effluent limitations on point sources may not be the most effective method for reducing mercury concentrations in receiving waters and fish, and indicates that alternative implementation measures (as discussed below) should be required in lieu of effluent limitations. And finally, when effluent limitations are found to be necessary because point source discharges are an important source of mercury, the policy should require consideration of dilution credits, compliance schedules, and variances, particularly for effluent limitations that are infeasible to achieve, or that will require time and resources to implement.

A second concern relates to the Staff Report's recommendation that water column targets be used to determine reasonable potential and to calculate effluent limitations for point source discharges. As detailed in comment 6, the water column concentration targets calculated using nationwide average BAFs fail to consider the behavior of mercury, which is highly site-specific and complex. As a result, the recommendation to use water column targets calculated using BAFs as the basis for RP and effluent limitations is not scientifically appropriate. Exponent therefore recommends that a modified version of the second option, i.e., the use of mercury concentrations in fish tissue, be used to determine the need for effluent limitations, as shown in Figure 3.

Since, in most cases, the point source implementation measures that are the focus of the proposed Mercury Provisions are unlikely to appreciably reduce environmental mercury concentrations due to the dominance of non-point sources, alternative measures offer the best—and perhaps the only—chance to achieve meaningful reductions in mercury concentrations in the environment. Alternative measures should be investigated and discussed in public workshops prior to adoption of the proposed Provisions. Alternative implementation measures that should be considered include, but are not limited to the following:

- A program for trading or offsets
- A "water funds" approach to regional or watershed-based mercury control measures
- Engaging other state agencies in efforts to control non-point sources (e.g., engaging the Air Resources Board in efforts to control atmospheric sources of mercury)
- Programs to address non-point sources.

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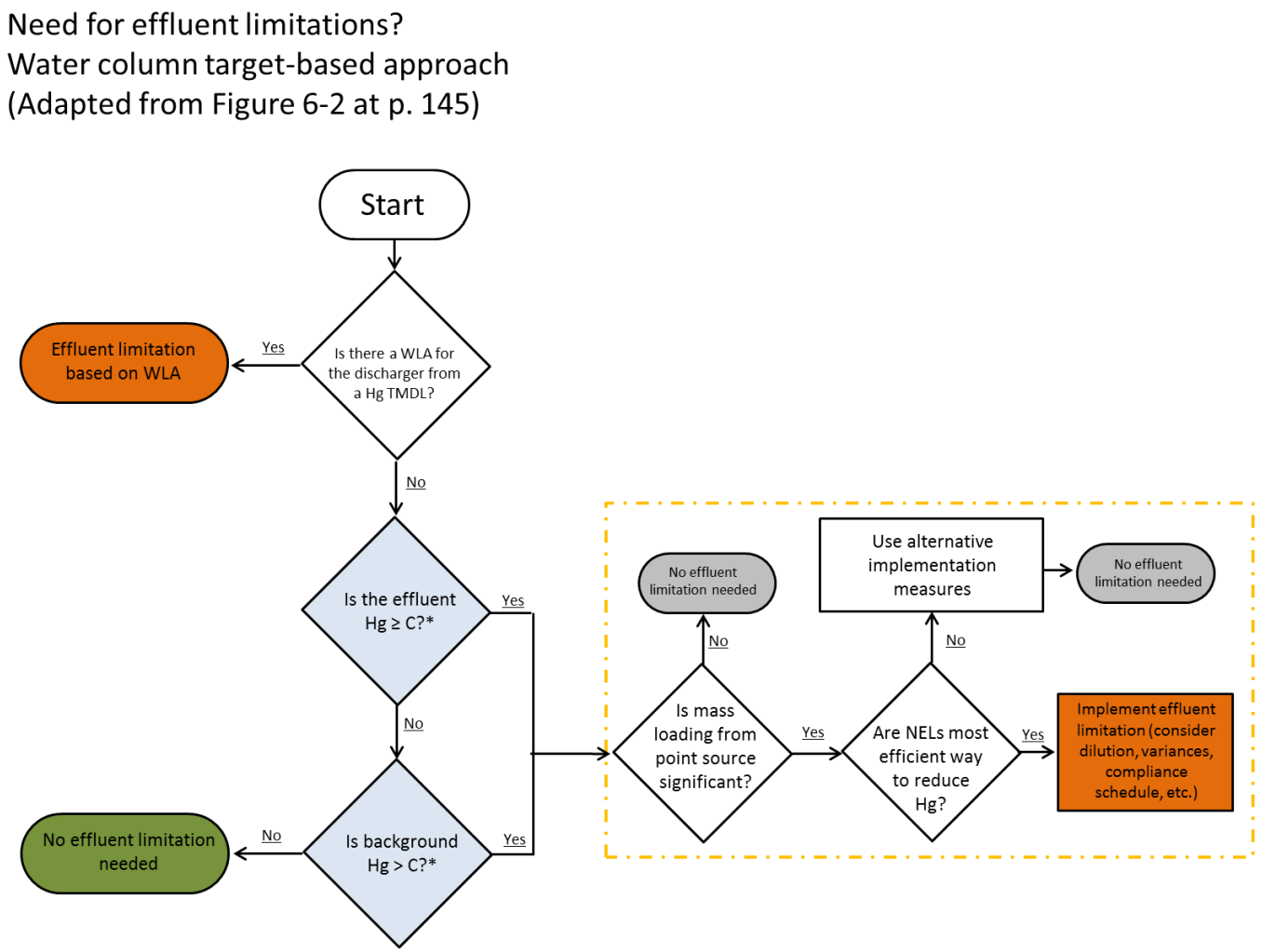

Figure 2. Adapted flow chart for Option 1, a water column concentration-based approach to determining the need for effluent limitations. Only the part of the figure within the dashed orange line has been added. The rest of the figure is identical to Figure 6-2 of the Staff Report (p. 145).

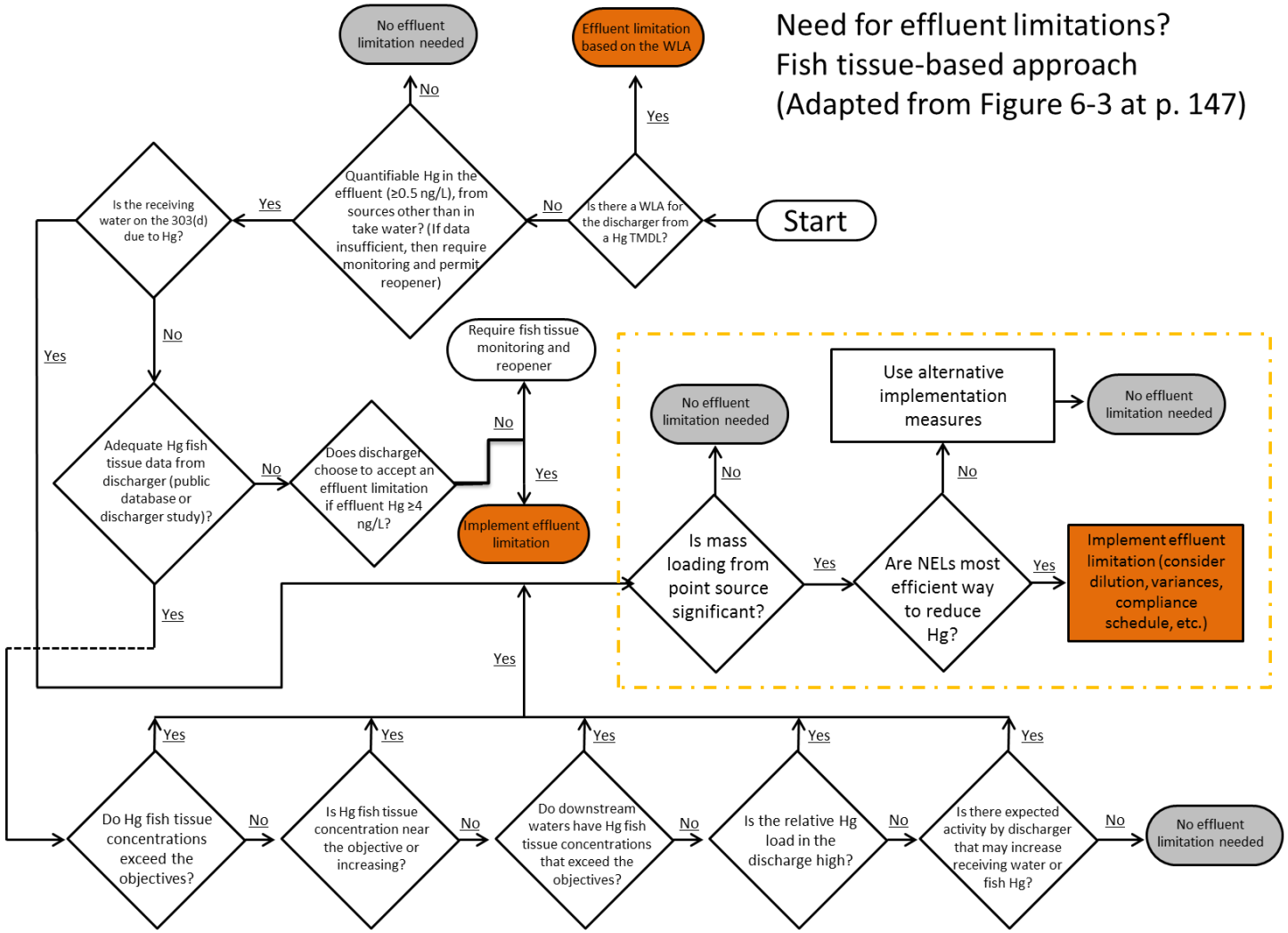

Figure 3. Adapted flow chart for Option 2, a fish tissue-based approach to determining the need for effluent limitations. Only the part of the figure within the dashed orange line has been added. The rest of the figure is identical to Figure 6-3 of the Staff Report (p. 147).

The most effective approaches to mercury control will be those that identify implementation actions for the primary sources of mercury. The implementation measures currently identified in the proposed Mercury Provisions do not effectively target these primary sources. The State's proposed Mercury Provisions should be revised accordingly.

4. The Staff Report's position on dilution credits and mixing zones for NPDES discharges containing mercury is inconsistent with SWRCB precedential orders. The appropriateness of mixing zones and dilution credits should be evaluated on a site-specific basis.

The Staff Report states in several places, "Water Boards have the discretion to allow dilution credits where appropriate."[29] For example, in discussion of the difficulty of meeting the proposed 1 ng/L effluent limitation, the Staff Report states, "if the Water Board exercises its discretion to allow dilution credits, the objective would be much more achievable."[30] The Staff Report also states,

> *Dilution credits would be allowed but would not be recommended in most situations since mercury is a bioaccumulative compound, and the SIP (Section 1.4.2.2.B) and the [U.S. Environmental Protection Agency] recommends limiting dilution for bioaccumulative compounds (U.S. EPA 2010, section 5.3.2). The U.S. EPA explains, "While fish tissue contamination tends to be a far field problem affecting entire water bodies, rather than a narrow scale problem confined to mixing zones, the U.S. EPA's guidance recommends restricting or eliminating mixing zones for bioaccumulative pollutants such as mercury so that they do not encroach on areas often used for fish harvesting (particularly for stationary species such as shellfish). Restriction or elimination might also be used to compensate for uncertainties regarding the ability of aquatic life or the aquatic system to tolerate excursions above the criteria, uncertainties inherent in estimating bioaccumulation, or uncertainties in the assimilative capacity of the water body*."[31]

However, at other points the Staff Report indicates dilution credits would *not* be allowed. For example, the Staff Report indicates the following language would be included in Chapter IV of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries (ISWEBE Plan) (the Implementation Chapter): "Dilution shall be prohibited if the mercury concentration in fish tissue from fish in the receiving water exceeds the applicable MERCURY WATER QUALITY OBJECTIVES."[32] Presumably, this prohibition would apply regardless of whether a water body is on the 303(d) list of impaired waters for mercury. SWRCB Staff also indicated at the January 9, 2017, workshop that dilution credits and mixing zones would not be allowed in NPDES permits for water bodies that are impaired for mercury.

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29 Staff Report, p. 10.

30 Staff Report, p. 180. See also a similar statement on p. 182.

31 Staff Report, p. 154.

32 Appendix A of the Staff Report, p. A-11; capitals in original.

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Disallowing the use of dilution credits would contradict precedential SWRCB orders. For example, the summary for Order 2001-06 states that "A Regional Water Quality Control Board (Regional Water Board) cannot rely solely on a Section 303(d) listing as the basis for concluding that a receiving water lacks assimilative capacity for an impairing pollutant. Rather, the Regional Water Board must base assimilative capacity determinations on the relevant water quality-related data."[33] The facts before the SWRCB in Order 2001-06 included a water body listed as impaired for bioaccumulative pollutants but where the dilution achieved by individual discharges was so great that even the elimination of those discharges would have had no effect on pollutant concentrations in the water body or in fish. Such facts would have to be established on a site-specific basis but appear to be supported for many water bodies given the information provided in the Staff Report for the proposed mercury provisions.

The Staff Report should be amended to clearly indicate, consistent with SWRCB precedential orders, that dilution credits and mixing zones must be considered on a site-specific basis, such that if the proposed effluent limitation (without dilution) would have no discernible impact on mercury concentrations in receiving waters or in fish, dilution must be allowed.

5. The fish tissue objectives proposed to protect wildlife are likely to be overly conservative and should be revised to address this limitation.

The fish tissue objectives proposed for wildlife protection are generally in the range of values commonly used by United States Fish and Wildlife Service (USFWS) and are generally based on peer-reviewed literature. However, in many instances the information for key species is generated using surrogates of mammals or avian species with numerous assumptions. For example, the wildlife value is based on a mallard duck reference dose of 0.021 mg/kg/day, and assumptions regarding the life histories of other avian species, body weight, etc., are used to extrapolate to a wildlife value for all other birds (presented in Appendix K Table K-1).[34] It appears a similar treatment is applied to mammals, using a reference dose of 0.018 mg/kg/day; however, the species used for the determination of this reference dose is not provided (a generic citation of USFWS 2003 appears in the text without any reference to a mammal species). We recommend the mammalian reference dose [p. K-4 and Table K-1] cite the source.

The avian reference dose derived from the mallard duck study by Heinz (1979)[35] appears to be superseded by a later study by the same author.[36] Heinz (1979) identified the lowest dosage of 0.5 mg/kg in diet as the lowest-observed-adverse-effect concentration (LOAEL), whereas a dietary toxicity threshold ranging from approximately 3 mg/kg to 9 mg/kg was found in more

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[33] Summary for Board water quality Order 2001–06, accessed February 9, 2017, at http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/wqo01.shtml.

[34] Staff Report, Appendix K. p. K-4.

[35] Heinz, G.H. 1979. Methyl mercury: Reproductive and behavioral effects on three generations of mallard ducks. J Wildl Manage 43:394–401.

[36] Heinz, G.H., D.J. Hoffman, J.D. Klimstra, and K.R. Stebbins. 2010. Reproduction in mallards exposed to dietary concentrations of methylmercury. Ecotoxicology 19:977–982.

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recent studies (Figure 4).[37] In addition, USFWS applied interspecies and NOAEL-to-LOAEL[38] uncertainty factors to derive the avian reference dose of 0.021 mg/kg/day.[39] A critical review paper by Fuchsman et al. suggests the reference dose of 0.021 mg/kg/day may be too conservative.[40] Based on the current literature, Fuchsman et al. identify/propose ranges of toxicity reference values suitable for risk assessment applications between 0.05 mg/kg/day to 0.5 mg/kg/day on a dose basis, which are a factor of 2–20 higher than the proposed reference dose. This overly conservative approach employing an artificially lower reference dose translates into a lower fish tissue concentration. While we understand this recently published information became available after the Staff Report was released for public review, SWRCB should consider the critical evaluation by Fuchsman et al. (2017) of avian threshold values in their evaluation and revise the reference dose and tissue objectives accordingly.

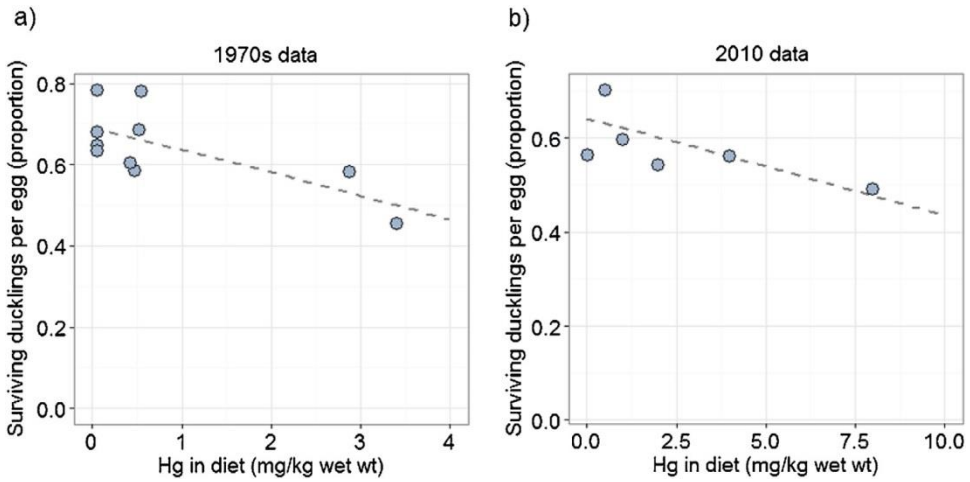

Figure 4. Dose–response relationships for mallards exposed to methylmercury dicyandiamide (1970s) or methylmercury chloride (2010). Dashed lines represent fitted regressions. Response variable calculated as % egg fertility % hatchability % duckling survival. (from Fuchsman et al. 2017)

[37] Fuchsman, P.C., L.E. Brown, M.H. Henning, M.J. Bock, and V.S. Magar. 2017. Toxicity reference values for methylmercury effects on avian reproduction: Critical review and analysis. Environ Toxicol Chem 36(2):294–319.

[38] NOAEL: No observed adverse effect concentration

[39] USFWS. 2003. Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California. October. U.S Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Environmental Contaminants Division, Sacramento, CA.

[40] Fuchsman, P.C., L.E. Brown, M.H. Henning, M.J. Bock, and V.S. Magar. 2017. Toxicity reference values for methylmercury effects on avian reproduction: Critical review and analysis. Environ Toxicol Chem 36(2):294–319.

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Trophic level (TL) values were used in the Staff Report to protect wildlife that consumes prey from more than one trophic level. Clarification on 'statewide' TL values is needed. The 'statewide' values for some species were derived from site-specific data from only one region (i.e., Guadalupe River for Great blue heron and Forster's tern, Clear Lake for common loon; Table K-2, Table K-3, and text on pages K-9 through K-13), and this limitation needs to be consistently documented throughout the Staff Report.[41] Knowing 'statewide' data are derived from a data set that does not truly represent the whole state or given area would allow additional site-specific data to be used preferentially over the default value, when site-specific data become available.

The proposed water quality objective tissue concentrations for protection of wildlife—0.03 mg/kg in TL3 fish less than 50 mm, 0.05 mg/kg in TL3 fish less than 150 mm, and 0.2 mg/kg for TL4 fish 150–500 mm—are similar to or lower than background mercury concentrations in forage (TL3) and predatory fish (TL4). As presented in Figure H-1 of the Staff Report, mercury concentrations in largemouth bass, a common TL4 fish, are 0.4 mg/kg on average, equivalent to 2 times the wildlife value for the same TL, with concentrations that range up to approximately 0.73 mg/kg. For TL3 fish, average concentrations of mercury in rainbow trout and Chinook salmon are approximately 0.1 mg/kg, as shown Figure H-1 of the Staff Report, which are 2–3.3 times the fish concentration target calculated for this TL. A recent review by Fuchsman et al. (2016) indicated average naturally occurring Hg concentrations in forage (TL3) and predatory (TL4) fish are roughly 0.03–0.1 mg/kg and 0.1–0.3 mg/kg, respectively.[42] Given most of the mercury already in the system is from nonpoint sources, it is unlikely the proposed wildlife values of 0.03, 0.05, and 0.2 mg/kg could be attained.

The California least tern prey fish water quality objective should be applied only to water bodies where the species commonly forages. Table K-5 of Appendix K lists 8 counties where this objective is to be applied.[43] However, the map shown in the January 9, 2017 Staff presentation (Slide 20) includes Monterey County, which is not listed in Table K-5, and does not include Alameda or San Mateo County, which are listed in Table K-5. Because there have been very few historical regular breeding colonies between the City of Santa Barbara and Monterey Bay[44] the objective to protect the California least tern should not be applied in Monterey County. Also, as noted in Table K-5, the spatial application of the objective should be limited to areas within a reasonable foraging distance from known breeding colonies. However, slide 20 of the Staff presentation seems to indicate that application of the objective will be applied county-wide, without regard to distance from known breeding colonies. The Staff Report should be

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41 Staff Report, Appendix K. pp. K-9–K-13.

42 Fuchsman, P.C., M.H. Henning, M.T. Sorensen, L.E. Brown, M.J. Bock, C.D. Beals, J.L. Lyndall, and V.S. Magar. 2016. Critical perspective on mercury toxicity reference values for protection on fish. Environ Toxicol Chem, 35:529–549.

43 Staff Report, Appendix K, pp. K-32–K-34.

44 USFWS (U.S Fish and Wildlife Service). 1985. Recovery Plan for the California least tern, *Sterna antillarum browni*. Portland Oregon 112 p. http://ecos.fws.gov/docs/recovery_plan/850927_w%20signature.pdf.

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revised to clarify that objectives to protect the California least tern should be limited to areas within a reasonable foraging distance from known breeding colonies.

6. The water concentration targets derived from the proposed fish tissue water quality objectives are fundamentally flawed and should not be implemented at this time.

The Staff Report derives water column concentrations based on fish tissue bioaccumulation factors (BAF)[45] and translators.[46] Proposed targets of 12 ng/L and 4 ng/L are based on the Sport Fish WQO (0.2 mg/kg in TL4 fish, 150–500 mm; see Table 3). The Staff Report uses an EPA-derived national BAF for rivers and streams to derive a water column target concentration of 12 ng/L total mercury for flowing water bodies, including rivers, creeks, and streams. The target concentration of 4 ng/L total mercury for slow-moving water bodies, such as estuaries and bays, was derived from the combined national BAF for lakes and rivers. Water target concentrations of 4 ng/L and 1 ng/L were derived for flowing waters and slow-moving waters, respectively, based on the Tribal Subsistence mercury objective (0.06 mg/kg in TL4 fish)[47] and the same national BAFs.

Table 3. Water column concentrations based on water body type and beneficial use. From Staff Report. COMM: Commercial and Sport Fishing, T-SUB: Tribal Subsistence Fishing, SUB: Subsistence Fishing by other communities or individuals, CUL Tribal Tradition and Culture, WILD: Wildlife Habitat RARE: Rare, Threatened, or Endangered Species, MAR: Marine Habitat.

Beneficial Use of the Receiving Water	**COMM, CUL, WILD, MAR, RARE**	**COMM, CUL, WILD, MAR, RARE**	**COMM, CUL, WILD, MAR, RARE, T-SUB**	**T-SUB**	**T-SUB**	**SUB**
Water body type	Flowing water bodies (generally, rivers, creeks and streams)	Slow moving water bodies (generally, lagoons and marshes)	Lakes and reservoirs	Flowing water bodies (generally, rivers, creeks and streams)	Slow-moving water bodies (generally, lagoons and marshes)	Any
Value for "C"	12 ng/L total mercury	4 ng/L total mercury	Case-by-case	4 ng/L total mercury	1 ng/L total mercury	Case-by-case

[45] The bioaccumulation factor (BAF) is the ratio between the dissolved methylmercury concentration in water and the concentration of methylmercury in fish tissue.

[46] Staff Report, Appendix I. p. I-1.

[47] The default value is 0.04 mg/kg based on 30% TL4 and 70% TL3 diet, which is equivalent to 0.03 mg/kg in TL3 fish and 0.06 mg/kg TL4 fish (Staff Report, Appendix H, p. H-12). BAF and fish tissue targets in TL4 fish were used to derive water column targets (Staff Report, Appendix I, p. I-1).

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There are several problems with SWRCB's approach to calculating water concentration targets from the proposed fish tissue water quality objectives. First, and most importantly, application of two national BAFs to calculate mercury water concentration targets for every water body in California is inappropriate. National BAFs, California statewide BAFs, and translation factors for mercury are highly variable and uncertain.[48] National BAFs are calculated as the geometric mean of field-measured BAFs obtained from published literature.[49] As illustrated in Figure 5, national BAFs range over two to three orders of magnitude due to variability between the many different regions and water bodies reflected in the 90 percent confidence-interval range (i.e., between the 5th and 95th percentiles). The Staff Report also discusses the potential use of an available California-wide BAF, but because this value is based on a limited dataset, the Staff Report proposes to use the EPA national BAFs instead.[50] However, the use of nation-wide BAFs oversimplifies the very complex process of mercury bioaccumulation and ignores site-specific conditions. A BAF is a site-specific value and is affected by numerous physical, chemical, and biological factors including among others pH, dissolved organic carbon (DOC), salinity, water flow, temperature, redox potential, sulfide and sulfate, suspended solids, nutrient loading, fish size and age, and concentration-dependent demethylation.[51,52,53,54,55,56,57,58] There is potential for mercury methylation and bioaccumulation to vary significantly from location to location and over time (seasonally). Even within California, conditions vary considerably

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[48] Sandborn, J.R., and R.K. Brodberg. 2006: Evaluation of bioaccumulation factors and translators for methylmercury, SDMS DocID 466770.

[49] U.S. EPA. 2010. Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion. EPA 823-R-10-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

[50] Staff Report, Appendix I, p. I-2–I-3.

[51] Brumbaugh, W.G., D.P. Krabbenhoft, D.R. Helsel, J.G. Wiener, and K.R. Echols. 2001. A national pilot study of mercury contamination of aquatic ecosystems along multiple gradients: Bioaccumulation in fish. USGS/BRD/BSR-2001-0009. U.S. Geological Survey, Columbia, Missouri.

[52] Kamman, N.C., P.M. Lorey, C.T. Driscoll, R., Estabrook, A. Major, B. Pientka, and E. Glassford. 2004. Assessment of mercury in waters, sediments, and biota of New Hampshire and Vermont lakes, USA, sampled using a geographically randomized design. Environ. Toxicol. Chem. 23:1172–1186.

[53] Marvin-DiPasquale, M., J. Agee, C. McGowan, R.S. Oremland, M. Thomas, D. Krabbenhoft, and C.C. Gilmour. 2000. Methyl-mercury degradation pathways: A comparison among three mercury-impacted ecosystems. Environ. Sci. Technol. 34(23):4908–4916.

[54] Qian, S.S., W. Warren-Hicks, J. Keating, D.R.J. Moore, and R.S. Teed. 2001. A predictive model of mercury fish tissue concentrations for the southeastern United States. Environ. Sci. Technol. 35(5):941–947.

[55] Ullrich, S.M., T.W. Tanton, and S.A. Abdrashitova. 2001. Mercury in the aquatic environment: a review of factors affecting methylation. Crit. Rev. Environ. Sci. Technol. 31:241–293.

[56] Sonesten, L. 2003. Catchment area composition and water chemistry heavily affects mercury levels in peach (Perca fluviatilis L.) in circumneutral lakes. Water, Air, Soil Pollution 144:117–139.

[57] Rose, J., M.S. Hutcheson, C.R. West, O. Pancorbo, K. Hulme, A. Cooperman, G. DeCesare, R. Isaac, and A. Screpetis. 1999. Fish mercury distribution in Massachusetts, USA Lakes. Environ. Toxicol. Chem. 18(7):1370–1379.

[58] Watras, C.J., R.C. Back, S. Halvorsen, R.J.M. Hudson, K.A. Morrison, and S.P. Wente. 1998. Bioaccumulation of mercury in pelagic freshwater food webs. Sci. Tot. Environ. 219:183–208.

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between regions. As a result, national or statewide default values are likely to be inaccurate on a site-specific basis. As the Staff Report states, the water concentration targets based on national BAFs can be over- or under-protective in different water bodies.[59] Because of this likely possibility, EPA recommends the use of site-specific data over default national values such as those used in developing the mercury water concentration targets.[60,61] The use of site-specific data allows the development of BAFs that are more realistic.

Second, the Staff Report lacks clear guidance on the classification of the receiving water body type as either "flowing" or "slow-moving." The Report refers to "Table 1" for guidance, but there is no Table 1 in the document.[62] The Board expects individual permit writers at the Regional Boards to apply site specific information and "professional judgment" to determine which category fits best for a given water body. However, this approach seems highly subjective and open to arbitrary determinations, despite its importance given the significant difference between the two water concentration targets (12 ng/L versus 4 ng/L) and the potentially significant costs to NPDES dischargers that could result from this choice.

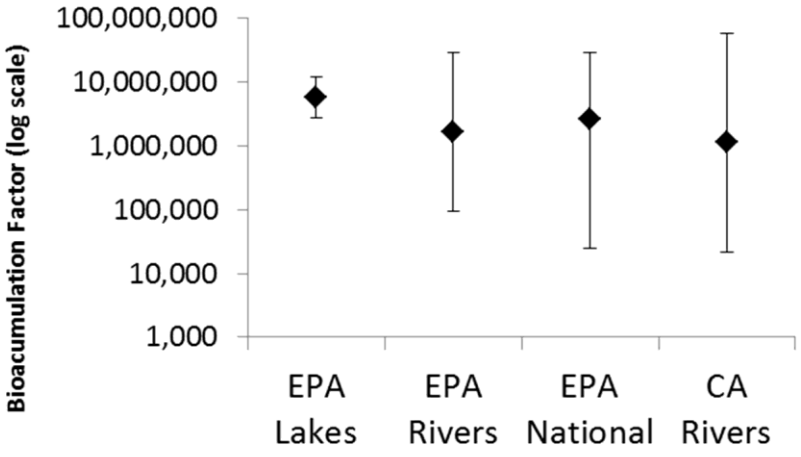

Figure 5. Comparison of National and California Bioaccumulation Factors. Data points (diamond symbols) are geometric means. Vertical bars extend from the 5th to the 95th percentile of the log-normal distribution. (From Staff Report, Appendix I. p. I-2, Figure I-1.)

Third, it is unclear whether estuaries should be understood as "slow-moving" water bodies, and thus whether a BAF applicable to lakes should be applied in calculating water concentration

[59] Staff Report, p. 91.

[60] U.S. EPA. 2010. Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion. EPA 823-R-10-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

[61] U.S. EPA. 2001. Water Quality Criteria for the Protection of Human Health: Methylmercury. EPA-823-R-01-001. January 2002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

[62] Staff Report, pp. 155.

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targets for estuaries. Unlike lakes, most estuaries are actively flowing water bodies containing a wide distribution of many different TL fishes. Our experience indicates that in some estuaries, waters are not "slow-moving"; for example, in Carquinez Strait in San Francisco Bay, water velocities routinely exceed the velocities measured in most rivers, such that it is wholly inappropriate to assume estuaries are "slow-moving."[63] The proposal should be revised to provide clear guidance for distinguishing the two types of water bodies.

Fourth, as noted above, the Staff Report uses a BAF for rivers and streams to derive a water column target concentration of 12 ng/L for flowing water bodies and a BAF for lakes and rivers to derive a water column target concentration of 4 ng/L for slow-moving water bodies, such as estuaries and bays. Thus, the BAFs used to calculate concentration targets for flowing water bodies and slow-flowing water bodies *both* rely on data from rivers. This double use suggests that one or both BAFs may be inappropriate to the flow categories they were used to represent.

Fifth, the method of calculating water concentration targets from BAFs is flawed. A recent study by Dutton and Fisher (2014) shows that methylmercury concentrations in fish are driven by food exposure and not by water column exposure.[64] The BAF approach does not address potentially wide variability in water concentrations and assumes all compartments (water, sediment, and biota) are in equilibrium with each other. In fact, in most cases the water compartment is *not* in equilibrium with the lower portions of the food chain—thus, one of the most basic assumptions behind the use of a BAF is violated.

Sixth, the use of translators adds to the already considerable degree of uncertainty associated with the water concentration targets. Different forms of mercury and methylmercury, such as dissolved/filtered and total/unfiltered, are measured in the water column. Translators are applied to convert dissolved methylmercury concentration (obtained via the BAF method) to total mercury and to total methylmercury concentrations, which are the forms in which mercury water concentration targets are typically expressed. The Staff Report proposes water column target concentrations expressed as total mercury concentrations. Underlying the use of any type of mercury translator is the assumption that mercury levels in fish tissue will respond in a linear manner to reductions in mercury loading. Evidence indicates this relationship between fish tissue levels and loadings is much more complex and influenced by a number of interacting biogeochemical factors that are highly variable in time and space.[65] In addition, relationships used to derive the translation factors are very weak (Figure 6). The translation factor between dissolved and total mercury in a given waterbody can be highly variable, changing spatially and temporally. The Staff Report should be revised to include a detailed discussion of the variability of the translators employed in their methodology.

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[63] During high flow periods of the tidal cycle, flow velocity in Carquinez Strait is routinely higher than three feet per second (fps). See Warner, J., D. Schoellhamer, J. Burau, G. Schladow. 2002. Effects of tidal current phase at the junction of two straits. Continental Shelf Res. 22:1629-1642. Figure 2, p. 1632.

[64] Dutton, J., and N.S. Fisher. 2014. Modeling metal bioaccumulation and tissue distribution in killifish (*Fundulus heterolitus*) in three contaminated estuaries. Environ Toxicol Chem. 33(1):89–101.

[65] See citations provided in prior footnotes.

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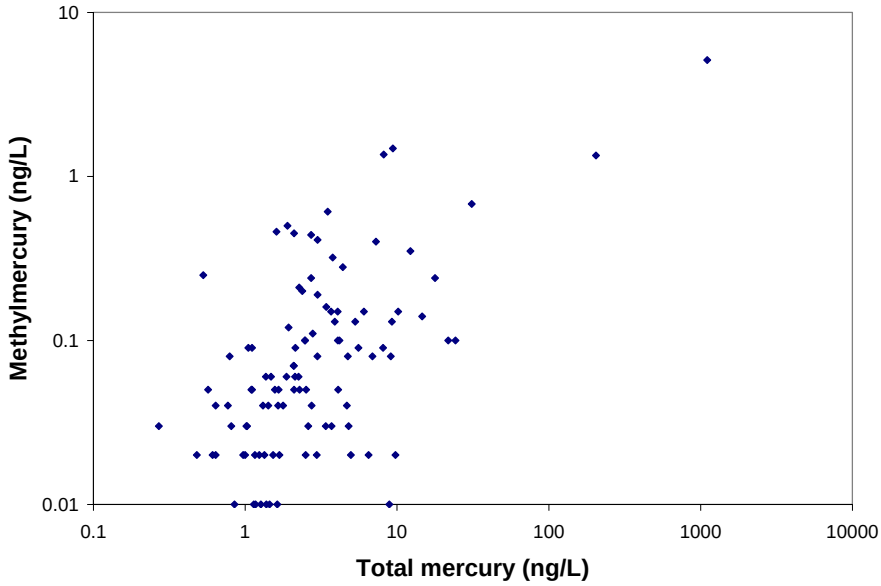

Figure 6. Total Mercury versus methylmercury in stream water samples collected throughout the U.S. as Part of the National Water-Quality Assessment Program (from Krabbenhoft et al. 1999)

In short, there are multiple problems with the Staff Report's approach to calculating water concentration targets in the Mercury Provisions. The use of national BAFs rather than local site-specific BAFs, and the use of mercury translators, introduces enormous uncertainty into the proposed values. In addition, given the lack of clarity about what constitutes "flowing" and "slow-moving waters," it is unclear whether the Staff Report used BAFs for the correct water body categories in calculating the concentration targets. Moreover, the use of BAFs is flawed given the faulty assumptions upon which the methodology is based, such as the assumption of equilibrium between the water, sediment, and biota compartments. Given these problems, and the potentially huge costs that NPDES dischargers would likely incur to comply with the water concentration targets if they are imposed as effluent limitations, SWRCB should revise the proposed targets and should not implement them at this time.

7. The proposed human health objectives may be too conservative.

We share the state's concern about protection of human health but would request that the Staff Report be revised to confirm that specific assumptions are appropriate. The Staff Report describes numerical fish tissue levels for two human health objectives: Commercial and Sport Fishing (COMM) and Tribal Subsistence (T-SUB) (Table 4).[66]

[66] Table 5.1, p. 80 of the Staff Report.

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Table 4. Summary of numerical mercury water quality objectives for human health in the Mercury Provisions

Human Health Objective	Beneficial Uses	Numerical Fish Tissue Level
Commercial and Sport Fishing (COMM)	Commercial and Sport Fishing; Wildlife Habitat[a]; Marine Habitat[a]	0.2 mg methylmercury/kg in Trophic level 4 fish
Tribal Subsistence (T-SUB)	Tribal subsistence fishing	0.04 mg methylmercury/kg in 70% Trophic Level 3 fish and 30% Trophic Level 4 fish

[a] According to the Mercury Provisions, the objectives supporting Wildlife Habitat and Marine Habitat may also be applied to Warm Freshwater Habitat, Cold Freshwater Habitat, Estuarine Habitat, and Inland Saline Water Habitat because each of those includes protection of wildlife habitat.

The proposed fish tissue concentration for COMM is 0.2 mg methylmercury/kg in highest TL fish (TL4, e.g., largemouth bass; fishes in this trophic level contain the highest concentrations of mercury). This value is similar to the Fish Contaminant Goal (FCG) of 0.22 mg methylmercury/kg developed by the Office of Environmental Health Hazard Assessment (OEHHA).[67] The difference between the two fish tissue concentrations (the proposed COMM and OEHHA FCG) arises from the use of a Relative Source Contribution value (see the next comment) in the proposed COMM fish tissue concentration but not in the OEHHA FCG. The OEHHA FCG of 0.22 mg/kg is non-enforceable but has been used since 2012 for water quality assessment purposes in the State, according to the Mercury Provisions.[68] EPA developed a national criterion for fish tissue of 0.3 mg methylmercury/kg in 2001,[69] but the Staff Report did not adopt that value.

Currently, the only enforceable concentration for mercury is for water as established in the California Toxics Rule (CTR) to protect people from consuming mercury from fish caught recreationally; the fish tissue concentration for mercury used to derive the CTR water criterion was 0.37 mg/kg.[70] There is no statewide criterion that addresses subsistence fishers.

The proposed fish tissue concentration for the T-SUB is 0.04 mg methylmercury/kg, assuming a diet comprised of 70% TL3 fish and 30% TL4 fish. This proposed concentration is similar to EPA's national criterion for subsistence fishing of 0.05 mg methylmercury/kg[71] and matches the

[67] Klasing, S., and R. Brodberg. 2008. Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. June 2008. Office of Environmental Health Hazard Assessment. Sacramento, CA. http://oehha.ca.gov/media/downloads/fish/report/atlmhgandothers2008c.pdf. Accessed on February 2, 2017.

[68] Staff Report at p. 31.

[69] U.S. EPA. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Final. EPA-823-R-01-001. January 2001. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington DC.

[70] Table 3-1, p. 31 of the Staff Report.

[71] U.S. EPA. 2001.

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fish concentration of 0.04 mg methylmercury/kg developed for Oregon's Columbia River Tribes.[72] EPA has proposed even lower fish concentrations for subsistence fishing in Washington (0.033 mg methylmercury/kg)[73] and Maine (0.02 mg methylmercury/kg).[74] While EPA has promulgated a fish concentration of 0.03 mg methylmercury/kg for Washington,[75] the state of Maine is contesting EPA's proposal of 0.02 mg methylmercury/kg.

The Staff Report and appendices[76] describe the assumptions and values used in the calculations of the human health objectives (COMM and T-SUB), which are fish tissue concentrations. The equation used to calculate the proposed fish tissue concentrations for COMM and T-SUB is:

$$FTC = \frac{BW * (RfD - RSC)}{FI}$$

FTC = a fish tissue concentration in milligrams (mg) methylmercury per kilogram (kg wet weight) fish. The FTC value is the methylmercury WQO.

BW = average human body weight; a value of 70 kg was used.

RfD = reference dose of 0.0001 mg methylmercury/kg body weight/day was used. This value is EPA's Rfd for oral exposure of methylmercury.

RSC = relative source contribution, estimated at 2.7×10^{-5} mg methylmercury/kg body weight/day. This value is subtracted from the reference dose to account for other sources (e.g., store bought marine fish).

FI = fish intake rate or fish consumption rate (kg fish wet weight/day). A value of 0.032 kg/day (32 g/day) is used for COMM, and a value of 0.142 kg/day (142 g/day) is used for T-SUB.

While the assumptions and values used are EPA default values or specifically based on California data where available, there may be a compounding effect of conservatism, which may result in lower fish tissue concentrations for the objectives than necessary. In other words, the combined impact of the multiple conservative assumptions about exposure and toxicity may lead to the compounding of uncertainty factors only in one direction (i.e., toward worst case) and may result in target fish tissue concentrations that may not be representative of the actual dose and exposure and that may be lower than necessary . For instance,

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72 ODEQ. 2011. Human Health Criteria Issue Paper Toxics Rulemaking. May 24, 2011. Portland, OR. Oregon Department of Environmental Quality.

73 80 FR 55063, September 14, 2015.

74 81 FR 23239, April 20, 2016.

75 81 FR 85417, November 28, 2016.

76 Staff Report, Appendices G and H.

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- The RfD is EPA's maximum acceptable oral dose of a chemical; it is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." While EPA's RfD of 0.0001 mg/kg/day for methylmercury is the standard toxicity value commonly used, EPA applied uncertainty factors to derive the value. While uncertainty factors are intended to provide protection in the face of uncertainty, the compounding of several or many uncertainty estimates can result in overprotective values. In this case, if the RfD is lower than necessary, the fish tissue concentration also will be lower than necessary.

- The RSC is the mean daily exposure estimate of methylmercury from other sources, in this case from store-bought marine fish; EPA developed a default value of 2.7×10^{-5} mg/kg/day in their 2001 water quality criteria for methylmercury.[77] Applying an RSC value of 2.7×10^{-5} mg/kg/day to the RfD drives down the RfD to 0.000073 mg/kg/day, which in turn lowers the calculated fish tissue concentration. While EPA's default RSC value for methylmercury was used by SWRCB to calculate fish tissue levels, other states such as Oregon have decided not to apply that value, acknowledging that their consumption rates already account for the other sources (e.g., store bought marine fish).

- The proposed fish tissue concentrations for COMM and T-SUB were derived using EPA's old default average body weight value (70 kg)[78] rather than the revised default average body weight (80 kg) used in a later document.[79] Using the previously reported lower body weight (70 kg) rather than the revised default weight (80 kg) also results in lower calculated fish tissue concentrations (e.g., the COMM fish tissue concentration would be 0.18 mg/kg instead of 0.16 mg/kg, before rounding). EPA has used the new default body weight (80 kg) to revise human health criteria for several chemicals[80] but not methylmercury.

- The fish consumption rates used in these calculations are 32 g wet weight/day (approximately one and half 5-oz. meals per week) for COMM and 142 g wet weight/day (approximately seven 5-oz. meals per week) for the T-SUB and are based on

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77 U.S. EPA. 2001.

78 U.S. EPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health 2000. EPA-822-B-00-004. October 2000. Office of Water, Office of Science and Technology, U.S. Environmental Protection Agency, Washington DC.

79 U.S. EPA. 2015a. Fact Sheet: Human Health Ambient Water Quality Criteria: 2015 Update. U.S. Environmental Protection Agency, Washington DC. https://www.epa.gov/sites/production/files/2015-10/documents/human-health-2015-update-factsheet.pdf. Accessed February 8, 2017.

80 U.S. EPA. 2015b. Table Comparing EPA's Updated 2015 Final Human Health Criteria to Previous Criteria. U.S. Environmental Protection Agency, Washington DC. https://www.epa.gov/sites/production/files/2015-10/documents/comparison-of-epa-s-2015-final-updated-human-health-awqc-and-previous-awqc-june-2015.pdf. Accessed February 8, 2017.

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> California surveys.[81] EPA's default value for the general population, which was developed under the Clean Water Act, Section 304(a), is 17.5 g wet weight/day (approximately one 5-oz. meal per week).[82] While EPA updated the default fish consumption rate for the general population to 22 g/day (approximately one 6-oz. meal per week),[83] EPA has not updated its methylmercury criteria for human health to reflect this newer rate.

Although applying these assumptions and values may not individually drive down the proposed fish tissue concentrations by a substantial amount, applying them collectively may artificially lower the fish tissue concentrations. Therefore, we recommend the Board review the assumptions and values in the proposed human health objectives for COMM and T-SUB in the Mercury Provisions.

A further concern is that the proposed fish tissue concentrations for human health objectives (COMM and T-SUB) in the Mercury Provisions are likely unattainable. The mercury concentration in fish for T-SUB is 0.04 mg/kg, assuming a diet of 70% TL3 fish and 30% TL4 fish. As shown in Figure H-1 of the Mercury Provisions (reproduced below as Figure 7), mercury concentrations in largemouth bass, a common TL4 fish, are on average 0.4 mg/kg, ten times higher than the proposed objective, with concentrations up to approximately 0.73 mg/kg. Average concentrations of mercury in rainbow trout and Chinook salmon (TL 3 fish) are approximately 0.1 mg/kg (Figure H-1), which are approximately 2.5 times the fish concentration calculated for T-SUB.

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81 San Francisco Estuary Institute. 2000. San Francisco Bay Seafood Consumption Study. Richmond, CA. Shilling, F., A. Negrette, L. Biondini, and S. Cardenas. 2014. California Tribes Fish-Use: Final Report. A Report for the State Water Resources Control Board and the U.S. Environmental Protection Agency. Agreement # 11-146-250. July 2014.

82 U.S. EPA. 2000.

83 U.S. EPA. 2015a.

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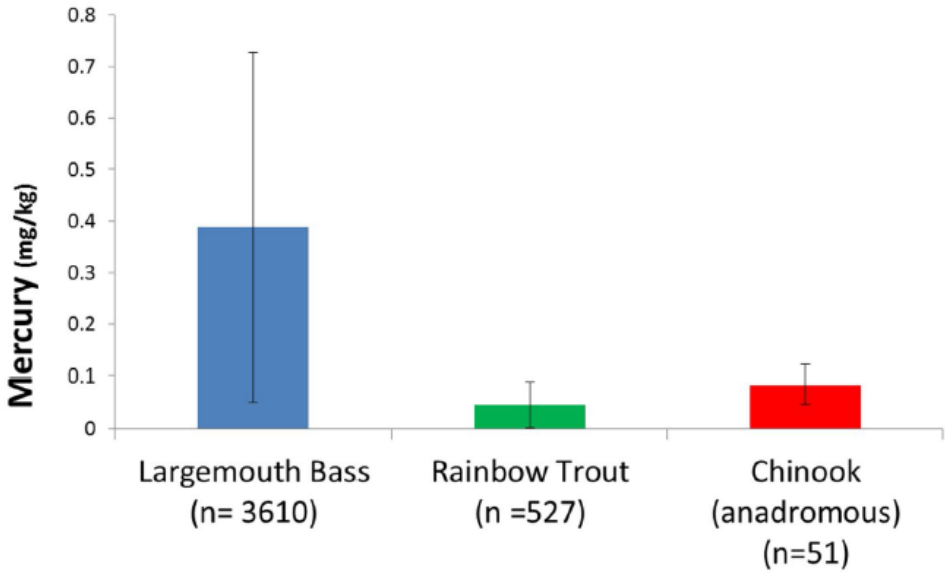

Figure H-1. Mercury concentrations in largemouth bass, rainbow trout, anadromous chinook salmon in California. Largemouth bass and trout were 150-500 mm. Chinook were 500-1000 mm. Data from ceden.org.

Figure 7. Figure H-1 from Appendix H (p. H-6) of the Mercury Provisions. Accessed February 9, 2017, at http://www.swrcb.ca.gov/water_issues/programs/mercury/docs/staff_report/hg_apndx_h.pdf.

Given most of the mercury already in the system is from nonpoint sources, it is unlikely the proposed human health-based values of 0.2 and 0.04 mg/kg for COMM and T-SUB, respectively, could be attained. In addition, salmon largely accumulate mercury during the long time spent in the ocean, not in inland waters and estuaries where the proposed objectives would be applied. In California, freshwater fisheries currently capable of sustaining subsistence fishing tend to be limited to anadromous species such as salmon, which are largely limited to rivers of coastal northern California and tributaries of the Sacramento River. As such, WQOs for other regions of California may be inappropriate.

Finally, alternative implementation measures to protect human health should be considered, particularly since reduction in environmental mercury concentrations is expected to take decades or longer. There are alternatives for lowering mercury exposure in populations of subsistence fishers other than reduction of mercury concentrations in the environment. Extensive experience has been gained in recent decades in balancing public health risks and mercury exposure in indigenous populations in the Canadian Arctic and the Brazilian Amazon that are dependent on fish consumption. This experience has led to several strategies to maintain fish consumption while reducing mercury exposure; these strategies can be implemented where it is impossible to reduce environmental mercury concentrations. These interventions through public health education include:

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- Guidance on mercury status of fish species to encourage consumption of less contaminated species
- Guidance on which waters contain higher mercury levels so that they can be avoided
- Encouraging greater fruit consumption, which may be protective against the bioaccumulation of mercury in human populations exposed via dietary intake of fish.[84]

This section of the Mercury Provisions also contains several significant typographical errors that require correction. On page H-9 of Appendix H (Section H.3.3), the report states "Two example trophic level specific objectives were derived that would protect consumption of one fish meal per week (0.016 mg/kg in fish tissue on average, from Table H-2A)." The value 0.016 mg/kg appears to be a typo. Based on Table H-2A, the value should be 0.16 mg/kg.

8. The proposed action to address dredging, wetlands, and nonpoint sources of mercury is vague and does not prescribe or prevent any specific actions.

The Mercury Provisions present three options to "control mercury discharges from dredging, wetlands and nonpoint source discharges (other than legacy mines… and current NPDES permitted discharges)"[85]:

Option 1. No Action.
Option 2. Emphasize that under existing law the Water Boards have discretion to address nonpoint source discharges of mercury and methylmercury production in wetlands and the Water Boards should consider such implementation measures in areas with elevated mercury concentrations.
Option 3. Establish new requirements for mercury and methylmercury and continue to use existing programs.

Of the three options presented to reduce mercury impact from wetlands, the Staff Report recommends Option 2, which allows for the use of existing law to implement mercury controls where warranted and seeks to emphasize their use in areas of "elevated" mercury. Specifically, the Staff Report identifies areas of "elevated" mercury as locations with mercury of 1 ppm or higher or areas with a history of mercury or gold mining.[86] However, this recommendation is vague and does not prescribe (or prevent) any specific action. It is unclear how this is different from Option 1, "No Action."

It is also unclear how Option 2 is intended to be implemented. In the discussion of wetlands management in Appendix Q, the Staff Report identifies several factors which may be used to minimize mercury transport or methylmercury production, but all of these are areas of active

[84] Passos, C.J.S., D. Mergler, M. Fillion, M. Lemire, F. Mertens, J.R.D. Guimarães, and A. Philibert. 2007. Epidemiologic confirmation that fruit consumption influences mercury exposure in riparian communities in the Brazilian Amazon. Environmental Research 105(2):183–193.

[85] Staff Report, p. 133-35.

[86] Staff Report, p. 133.

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research rather than established management procedures.[87] The science to determine which environmental factors are important in controlling the production of methylmercury in wetlands is still evolving, and the relative importance of the many factors which can influence mercury chemistry can vary from site to site.[88]

There are no established best management practices to reduce the production or transport of methylmercury in wetlands. The Staff Report acknowledges this in Appendix Q but describes wetland studies with "potential" methods to control mercury transport and methylation. Some of the potential management procedures described in Appendix Q are relatively untested, and their possible utility for mercury control on a wide scale is unknown, while others are more applicable and/or straightforward to implement.

For example, settling ponds to reduce sediment load (and potential mercury transport) to other water bodies is a reasonable approach, but care must be taken to minimize potential methylation and/or bioaccumulation in such a system, as the slow-moving conditions required for settling to occur may also be conducive to anoxic conditions that favor mercury methylation. Similarly, wetting/drying cycles, especially in areas with significant organic matter, have been shown to contribute to the production of methylmercury.[89] Managing water flow to minimize wetting/drying cycles caused by water level fluctuation is a reasonable management approach for agricultural or other managed wetlands, but it is not possible at this time to quantify the predicted effect that this would have in any specific system.[90]

In contrast, the recommended use of coagulants for mercury removal in settling ponds is based on a single paper, which used experimental coagulants to attempt to minimize methylmercury bioaccumulation and transport.[91] This study used a single environmental site and a limited time frame (approximately 1 year). The practicality of treating a large wetland or agricultural system using a similar approach is not discussed. There would likely be issues with mercury accumulation in the pond and with the potential to re-methylate mercury in new locations if the coagulated mercury is transported to locations with different chemistry. This is not addressed in either the Staff Report or the cited paper. Additionally, while both experimental treatments reduced the amount of methylmercury produced, only one of the two chemical coagulants

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87 Staff Report, Appendix Q.

88 Bigham, G. N., K. J. Murray, Y. Masue-Slowey, and E. A. Henry. 2016. Biogeochemical controls on methylmercury in soils and sediments: Implications for site management. Integr Environ Assess Manag. doi:10.1002/ieam.1822.

89 Feng, S., Z. Ai, S. Zheng, B. Gu, and Y. Li. 2014. Effects of dryout and inflow water quality on mercury methylation in a constructed wetland. Water, Air, & Soil Pollution, 225(4), p.1929.

90 Larson, J.H., R.P. Maki, B.C. Knights, and B.R. Gray. 2014. Can mercury in fish be reduced by water level management? Evaluating the effects of water level fluctuation on mercury accumulation in yellow perch (Perca flavescens). Ecotoxicology, 23(8), pp.1555–1563.

91 Ackerman, J.T., T.E. Kraus, J.A. Fleck, D.P. Krabbenhoft, W.R. Horwath, S.M. Bachand, M.P. Herzog, C.A. Hartman, and P.A. Bachand. 2015. Experimental dosing of wetlands with coagulants removes mercury from surface water and decreases mercury bioaccumulation in fish. Environ Sci & Technol 49(10):6304–6311.

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reduced the amount of methylmercury accumulated in biota, consistent with other publications reporting that the total mercury concentration is not always the controlling factor in mercury bioaccumulation.[92] The suggested use of coagulants as a management practice in California wetlands is premature.

[92] Driscoll, C.T., H.J. Han, C.Y. Chen, D.C. Evers, K.F. Lambert, T.M. Holsen, N.C. Kamman, and R.K. Munson. 2007. Mercury contamination in forest and freshwater ecosystems in the northeastern United States. BioScience 57(1):17–28.

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REVISED

CALIFORNIA LEAST TERN

RECOVERY PLAN

Original Approval: April 02, 1980

U.S. Fish and Wildlife Service

Portland, Oregon

Revision Approved: DRAFT

Regional Director, Region 1, U.S. Fish and Wildlife Service

9/21/95

Date

THIS IS THE COMPLETED REVISED CALIFORNIA LEAST TERN RECOVERY PLAN. IT HAS BEEN APPROVED BY THE U.S. FISH AND WILDIFE SERVICE. IT DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF COOPERATING AGENCIES AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED KEY ROLES IN PREPARING THIS PLAN. IT HAS BEEN PREPARED BY KATHLEEN E. FRANZREB (U.S. FISH AND WILDLIFE SERVICE, 2800 COTTAGE WAY, ROOM E-1823, SACRAMENTO, CA 95825) AND IS INTENDED TO DELINEATE THE ACTIONS NEEDED TO ACCOMPLISH RECOVERY. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS, CHANGES IN THE SPECIES" STATUS, AND COMPLETION OF THE TASKS DESCRIBED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER BUDGETING CONSTRAINTS.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

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*FORMER RECOVERY TEAM MEMBERS.

CALIFORNIA LEAST TERN RECOVERY PLAN

EXECUTIVE SUMMARY

1. Point or condition when subspecies is considered recovered?

The annual breeding population in California must increase to at least 1200 pairs distributed in at least 20 secure coastal management areas throughout their 1982 breeding range before delisting can be considered. Each of the 20 secure management areas must have a miminum of 20 breeding pairs with a 5-year mean reproductive rate of at least 1.0 young fledged/per breeding pair. Of these 20 secure management areas San Francisco Bay, Mission Bay and San Diego Bay must have a minimum of 4, 6 and 6 secure colonies, respectively. If 1,200 breeding pairs in California occur in 15 secure management areas with a 3-year mean reproduction rate of 1.0, the California least tern may be considered for threatened status. When additional information is available on the extent of nesting in Baja California, the Mexican colonies may be considered in the recovery goal for both threatened status and delisting.

2. What must be done to reach recovery?

Properly managed, suitable habitat of sufficient size must be available for nesting purposes; foraging, roosting, and wintering habitat must be preserved and properly managed. The status of least tern in Baja California, Mexico must be determined and the role of such colonies in the overall recovery must be assessed.

3. What specifically must be done to meet needs of 2?

Various site specific management plans must be developed and implemented; nesting habitat must be preserved and properly managed; colonies must be protected against certain predation pressures and other disturbances; management techniques must be further refined through additional research; a conservation education program should be developed; laws and regulations protecting the tern and its habitat must be enforced. The range, distribution, and population status of California least terns in Baja California, Mexico during the nesting season must be determined; and the range, distribution and status of wintering birds should be adequately identified.

4. What management/maintenance needs have been identified to keep the subspecies recovered?

Implementation of site specific management programs which address future needs of the terns to protect and properly manage tern habitat; periodic review and update of such plans; a continuing effort to inform the public regarding conservation issues to heighten public support.

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PART I

INTRODUCTION

Brief Overview

Once the beaches of southern California teemed with California least terns [Sterna antillarum (=albifrons) browni]. Today, least tern numbers are so depleted that both the U.S. Fish and Wildlife Service (Federal Register 35:16047, October 13, 1970; Federal Register 35:8495, December, June 2, 1970) and California Fish and Game Commission (California Department of Fish and Game 1980) consider the subspecies in danger of extinction and classify it as an endangered species.

The goals of this recovery plan are to prevent extinction and return the California least tern population to a stable, nonendangered status. The plan summarizes available biological information on the terns, identifies their ecologic needs, and proposes orderly and comprehensive actions to restore them to a viable population, and ultimately to delist the species.

Nomenclature

The least tern (Sterna antillarum) of the New World was described by Lesson (1847) as distinct from the cosmopolitan, polytypic species of the Old World (little tern), Sterna albifrons Pallas.

Although known and studied at an early date (Holterhoff 1884, McCormick

1899), the California least tern was not recognized as a separate subspecies until Mearns (1916) published the description. In 1921, Hartert combined antillarum under albifrons, but the common name was kept as least tern (Hartert 1921). The California least tern was then one of 12 recognized subspecies of the least (or little) tern (Brodkorb 1940, Burleigh and Lowery 1942, Peters 1934, Van Rossem and Hachisuka 1937), three of which inhabited the United States (AOU 1957). In 1982, however, the least tern was split from S. albifrons of the Old World and returned to the status of a full species, S. antillarum (AOU 1982, 1983), based upon research by Massey (1976) that documented differences in vocalizations and morphology. The subspecific status of the California least tern has no bearing on its endangered species listing because distinct population segments of a vertebrate species may be listed under the Endangered Species Act of 1973, as amended.

Description

Least terns are the smallest members of the subfamily Sterninae (family Laridae), measuring about nine inches long with a 50.8 cm (20 inch) wingspread. Sexes look alike, being characterized by a black cap, gray wings with black wingtips, orange legs, and black-tipped yellow bill. Immature birds have darker plumage and a dark bill, and their white heads with dark eye stripes are quite distinctive. The California least tern cannot be reliably differentiated from other races of the least tern on the basis of plumage characteristics alone (Burleigh and Lowery 1942).

Distribution

The California least tern is migratory, usually arriving in its breeding area by the last week of April and departing again in August (Davis 1968, Massey 1974, Swickard 1971). However, terns have been recorded in the breeding range as early as 13 March and as late as 31 October (Sibley 1952) and 24 November (San Diego Natural History Museum specimen records).

The historical breeding range of this subspecies has usually been described as extending along the Pacific Coast from Moss Landing, Monterey County, California, to San Jose del Cabo, southern Baja California, Mexico (AOU 1957, Dawson 1924, Grinnell 1928, Grinnell and Miller 1944). However, least terns were nesting several miles north of Moss Landing at the mouth of the Pajaro River, Santa Cruz County, California, at least from 1939 (W.E. Unglish, Western Foundation of Vertebrate Zoology egg collection) to 1954 (Pray 1954). Also, although nesting at San Francisco Bay was not confirmed until 1967 (Chandik and Baldridge 1967), there are numerous spring and summer records for the area, so nesting may have occurred previously (Allen 1934, Chase and Paxton 1965, De Benedictis and Chase 1963, Grinnell and Wythe 1927, Sibley 1952). Since 1970, nesting sites have been recorded from San Francisco Bay to Bahía de San Quintín, Baja California (Figure 1). The nesting range in California has apparently always been widely discontinuous, with the majority of birds nesting in southern California from Santa Barbara County south through San Diego County. Between the

city of Santa Barbara and Monterey Bay, a distance of over 322 km (200 miles), the only known regularly used breeding locations are within 16.1 km (10 miles) of the mouths of the Santa Ynez and Santa Maria rivers in Santa Barbara County. Local sources have also reported least terns once nesting at Morro Bay, San Luis Obispo County, and in 1980 a small nesting colony was present near Oso Flaco Lake, San Luis Obispo County. While San Francisco Bay appears to be the usual northern limit of the least tern's range, there are four records of single birds at Humboldt Bay (Yocom and Harris 1975, P. Springer[1] pers. comm.), two specimens collected at Fort Stevens, Clatsop County, Oregon (Walker 1972), and a single bird observed at Ocean Shores, Washington (Hunn and Mattocks 1979). These extra-limital records probably represent misoriented, migrating individuals.

In Baja California, two nest sites are identified in the literature: Scammons Lagoon (Bancroft 1927, Grinnell 1928), and San Jose del Cabo (Grinnell 1928, Lamb 1927). In 1975, a nesting colony was found near Ensanada (Massey 1977) and in 1976, a small colony was discovered at Bahía de San Quintín (Wilbur [2] pers. comm.). Several other nesting areas in Baja California, including Magdelena Bay, San Felipe, and Bahía del Los Angeles are suspected.

---

1 Dr. Paul Springer, Research Biologist, U.S. Fish and Wildlife Service, Arcata, CA.

2 Mr. Sanford Wilbur, Refuge District Supervisor Oregon/Washington U.S. Fish and Wildlife Service, Portland, OR

KEY TO FIGURE 1

ALAMEDA COUNTY
1. Alameda Naval Air Station
2. Oakland Airport
3. Alvarado Salt Ponds

SAN MATEO COUNTY
4. Bair Island

SAN LUIS OBISPO COUNTY
5. Pismo Beach
6. Oso Flaco Lake

SANTA BARBARA COUNTY
7. Santa Maria River
8. San Antonio Creek
9. Purisima Point (North and South)
10. Santa Ynez River

VENTURA COUNTY
11. Santa Clara River
12. Ormond Beach
13. Mugu Lagoon (Naval Pacific Missle Test Center)

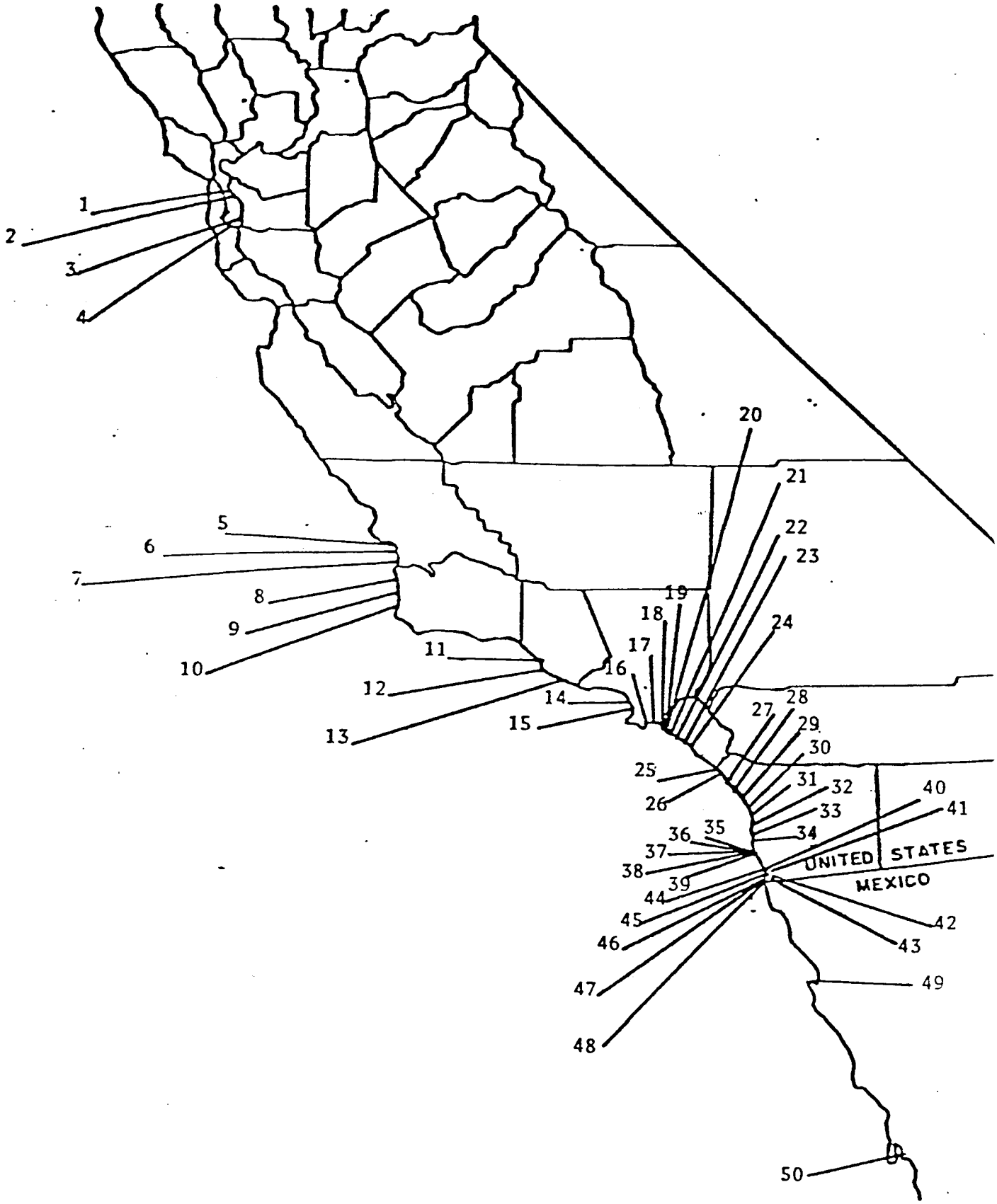
LOS ANGELES COUNTY
14. Venice Beach
15. Playa del Rey
16. Terminal Island
17. Costa Del Sol
18. San Gabriel River
19. Cerritos Wetlands

ORANGE COUNTY
20. Anaheim Bay (Seal Beach Naval Weapons Station)
21. Surfside Beach
22. Bolsa Chica
23. Huntington Beach
24. Upper Newport Bay

SAN DIEGO COUNTY
25. San Mateo Creek
26. Aliso Creek
27. Santa Margarita River
28. Buena Vista Lagoon
29. Agua Hedionda Lagoon
30. Batiquitos Lagoon
31. Whispering Palms
32. San Elijo Lagoon
33. San Dieguito Lagoon
34. Los Penasquitos Lagoon
35. FAA Island
36. North Fiesta Island
37. Stony Point
38. South Sea World Drive
39. Cloverleaf
40. Naval Training Center
41. San Diego International Airport
42. Sweetwater River
43. Chula Vista Wildlife Reserve
44. North Island NAS
45. Delta Beach (Coronado Naval Amphibious Base)
46. Coronado Cays
47. Saltworks
48. Tijuana River Mouth

BAJA CALIFORNIA
49. Estero de Punta Banda
50. Bahía de San Quintín

Figure 1. Distribution of ~~Nesting Sites~~ of California Least Terns. 5



Life History

Night Roosting--Early in the breeding season, California least terns display rather stereotyped night roosting behavior. Prior to incubation terns sleep during the night at varying distances from the actual nesting sites. In natural breeding sites consisting of open sandy beaches, birds generally roost on the beach within 0.4 km (¼ mile) of the locality where eggs are eventually laid. Birds inhabiting colonies in more unnatural areas such as small islands constructed in estuarine areas, land fills, etc. may travel early in the season up to 16.1 km (10) miles from the colonies to nocturnal roosting sites on open sandy beaches.

Once incubation begins, birds roost at night on the actual nesting site. Such nocturnal roosting continues at the colonies through the remainder of the season, except where late season nocturnal predators pressure the family units to return to roosting sites used during the early, pre-incubation period.

The use of roosting sites away from breeding colonies prior to egg laying appears to be related to predator avoidance. By not sleeping on the colony until eggs are laid, the terns delay by 2-3 weeks the time at which the colony might be discovered by nocturnal predators. The usual difference in nesting success between early and late nesting terns, with late-nesters showing decidedly reduced nesting success as the result of predation, suggests that this 2-3 week delay in advertisement by early-nesting birds, may be an important reproductive strategy.

Breeding Biology--Least terns arrive in the vicinity of the nesting areas from mid-April to early May. Some pair bonds may form before arrival in the nesting areas, others begin to form within the group almost immediately, and active courtship may be observed within the first few days after arrival (Davis 1968, Swickard 1971, Massey 1974).

Courtship follows a well-defined pattern, beginning with "fish flights" wherein a male carrying a fish is joined by one or two other terns in high flying aerial display. Aerial glides (pairs flying in unison) follow. Posturing and parading on the ground occur in the late stage of courtship with the male holding a small fish in his beak as he courts the female. During copulation, the female takes the fish from the male and eats it (Wolk 1954, Hardy 1957, Davis 1968, Massey 1974).

Nest Location and Construction--The least tern usually chooses nesting locations in an open expanse of light-colored sand, dirt, or dried mud close to a lagoon or estuary with a dependable food supply (Craig 1971, Swickard 1971, Massey 1974). Formerly, sandy ocean beaches regularly were used, but increased human activity on most beaches has made many of them uninhabitable. As a result, terns have been forced to nest on mud and sand flats back from the ocean, and on man-made "habitats" such as airports and land fills (Longhurst 1969, Craig 1971). Least terns are colonial but do not nest in as dense concentrations as other tern species. Although nests have been found as close together as 0.8 m (2.5 feet) (Davis 1968), usual minimum distances between nests are 3.0m-4.6m (10-15 feet), with averages usually much greater (Wolk 1954, Hardy 1957, Massey 1974). At one site, Swickard (1971) found nest densities

to be 40-45 per ha (16-18 per acre). In other instances, colonies are widely dispersed with over 91 m (300 feet) between nests. In northern Santa Barbara County, where nesting occurs in almost limitless expanses of coastal dune habitat, as few as 15 nesting pairs can be widely scattered in colonies with a 1.6 km (1 mile) perimeter or more. Thus, nesting densities are highly variable and seem to be related to amount of available habitat. In general, nesting colonies are located near coastal lagoons and estuaries.

The nest is a small depression in which the eggs are laid. In sand, it is scooped out by the bird (Davis 1968, Swickard 1971, Massey 1974), but in hard soil, it may be any kind of natural or artificial depression - for example, a dried boot print (Swickard 1971). After the eggs are laid, nests are often lined with shell fragments and small pebbles. Swickard found a nest depression completely lined with small twigs.

Eggs and Duration of Nesting Season--Least tern eggs measure approximately 31 x 24 mm (1.2 x 0.9 in.), and are buffy with various brownish and purplish streaks and speckles (Bent 1921, Davis 1968, Hardy 1957, Massey 1974). One to four eggs are laid, with two to three-egg clutches being reported most often (Anderson 1970, Massey 1974). Egg laying usually occurs in the morning, with the eggs laid on consecutive days (Davis 1968, Massey 1974).

The nesting season extends from approximately 15 May into early August, with the majority of nests completed by mid-June (Bent 1921, Grinnell 1898, Swickard 1971). A second wave of nesting occurs from mid-June

to early August. These are mainly renests after initial failures and second year birds nesting for the first time (Massey and Atwood 1981a). Most authorities agree that least terns are capable of successfully raising only one brood per pair in a season.

Incubation--Incubation, which begins with the laying of the first egg, is irregular at first but becomes steady after the clutch is completed (Davis 1968, Massey 1974, Swickard 1971).

Both parents participate, but the female initially takes a much greater part than the male (Davis 1968, Hagar 1937, Hardy 1957, Massey 1974, Swickard 1971). Extremes of from 17 to 28 days have been documented. The usual incubation period is 20-25 days (Massey 1972), with an approximate mean of 21 days (Massey[1], Pers. comm.)

Nest Success and Survival of Young--Most California least tern colonies suffer some losses of eggs and young to predators or unfavorable weather conditions during the course of a normal nesting season. Despite this, hatching success is usually high (especially compared to fledging success--see below). Eighty to 90 percent hatching success of eggs was reported by both Massey (1974) and Swickard (1971) during the 1970-72 period. Infertility appears to be a minor cause of least tern egg failure. For example, Massey found only six infertile or addled eggs out of 157 laid in her study area. Predators have been implicated in

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[1] Ms. Barbara Massey, Research Associate, California State University, Long Beach, CA.

a number of egg losses and colony failures, with coyote (Canis latrans), Norway rat (Rattus norvegicus), striped skunk (Mephitis mephitis), long-tailed weasel (Mustela frenata), common raven (Corvus corax) and American crow (Corvus brachyrhynchos) often named as the known or suspected predators. Dogs (Canis familiaris), gulls and other less commonly implicated species also destroy eggs.

Fledging rates vary greatly from colony to colony and from year to year (Swickard 1971, Massey 1974). The maximum overall success rate (percent of eggs laid resulting in flying young) yet observed in a major colony is about 70 percent (Massey and Atwood 1979). Since 1978, fledging rate (number of young fledged per number of breeding pairs) has varied from an estimated low of 0.46 in 1982 to an estimated high of 0.86 in 1981 (Table 1). Because of its large number of nesting colonies, San Diego County usually contributes the highest percentage of fledglings produced (among counties) in the state. Statewide data from specific nesting colony sites are given in Table 2.

Post-hatching Period Including Predation--Eggs usually hatch on consecutive days, and the chicks, although precocial, are initially weak and helpless. The adults brood continuously during the first day (Davis 1968), but by the second day, the chicks are stronger and make short walking trips from the nest. From the third day on, they are increasingly mobile and active (Davis 1968, Massey 1974). Flightless young have been seen as late as the first week of September (Tijuana

Table 1. Total California Least Tern Breeding Population[1], Minimum Number of Fledglings, and Estimated Fledging Rate in California.

Year	No. of Pairs[1]	Min. Est. No. Fledglings	Fledging Rate[3]
1973	624	N.D.[2]	N.D.
1974	582	N.D.	N.D.
1975	600	N.D.	N.D.
1976	664	N.D.	N.D.
1977	775	N.D.	N.D.
1978	776*	418	0.54
1979	845*	650	0.77
1980	890*	745	0.84
1981	963*	826	0.86
1982	1015*	469	0.46
1983	1180*	857	0.73

[1] Number observed per colony during an entire season of monitoring (movements caused by disruption of individual colonies were taken into consideration to reduce the possibility of double-counting).

[2] N.D. = Not Determined

[3] Fledging rate estimated from minimum number of fledglings divided by the minimum number of breeding pairs.

* Minimum numbers of pairs

Table 2. California Least Tern Reproductive Data (Number of Fledglings) by Colony Site.

Management Area [1]	County and Site	Minimum No. of Fledglings 1978	1979	1980	1981	1982	1983
	ALAMEDA						
a.	Alameda Naval Air Station	13	+	5	103	0	1
a	Alvarado Salt Ponds	1	2	5	0	0	1
a	Oakland Airport					11	6-9
	SAN MATEO						
a	Bair Island	0	0	14	28	23-93	0
	SAN LUIS OBISPO						
b	Pismo Beach					5	?
b	Oso Flaco Lake	0	0	0-6	0	0	0
	SANTA BARBARA						
c	Santa Maria River	15	10	15	5-10	3	3
d	San Antonio Creek	6	4	0	4	2	10
d	Purisima Point (North)	7	0	0	0	0	9
d	Purisma Point (South)	0	25	18-22	12	1	
d	Santa Ynez						4
	VENTURA						
e	Santa Clara River	12	25	11-16	25	16	2
f	Ormond Beach	0	3	0	0	0	2
	Mugu Lagoon	0	0	1	0	0	15
	LOS ANGELES						
g	Venice Beach	75	140	240	195	60	140
g	Playa del Rey	30	25	0	0	0	0
h	Terminal Island	0	0	0	7	15	77-1
*	San Gabriel River	70	60	0	0	0	0
i	Cerritos Lagoon	0	0	6	0	0	0
*	Costa del Sol	0	0	0	12	2	14
	ORANGE						
j	Anaheim Bay	0	0	24	20	2	2
j	Surfside Beach	0	0	3	0	0	0
k	Bolsa Chica (North)	0	3	15	20	70	35
k	Bolsa Chica (South)	0	3	0	0	5	10
l	Huntington Beach	100	90	85	168	50	60
m	Upper Newport Bay	0	0	0	0	0	2

Table 2. (cont.)

Management Area[1]	County and Site	Minimum No. of Fledglings 1978	1979	1980	1981	1982	198
	SAN DIEGO						
n	San Mateo Creek				0	0	0
n	Aliso Creek		5-10	22	10	0	9
n	S. Margarita River (N.)	8	18-25	1-4	25	50	160
n	S. Margarita River (S.)		0	1	25	0	21
o	Buena Vista Lagoon	0	0	2	0-2	0	0
p	Agua Hedionda Lagoon	4	8-10	4	0	0	0
q	Batiquitos Lagoon	0	25-40	16-18	25-27	6	2
r	San Elijo Lagoon	0	5-8	8	8+	12	20-
s	San Dieguito Lagoon	0	0	0-1	0	0	0
*	Whispering Palms Encinitas	0	0	0	4-6	0	0
t	Los Penasquitos Lagoon	10	0	0	0	0	0
u	FAA Island	5	45-50	180-200	80	0	90
u	North Fiesta Island	8	4	3-4	0-2	75	0
u	Stony Point					1-3	0
u	South Sea World Drive					2-4	0
u	Cloverleaf					0	0
v	Naval Training Center	5	0	0	0	0	0
v	San Diego Int. Airport	10	40-65	0	0	2-3	14+
v	Chula Vista Wildl. Reserve	0	0	31	35	12-16	8-
v	Sweetwater River	15	15-20	0	0	2	0
v	North Island NAS	0	60-80	6-12	5	25-30	90
v	Delta Beach	4	2-3	0	0	0	
v	Coronado Cays	10	7	0	0	0	
v	Saltworks	2	8-10	4	0	0	0
w	Tijuana River Mouth	8	18-20	25	15	17	50+
	TOTALS	418	650-742	745-793	826-839	469-553	857-

[1] The prime objective specifies that a minimum of 20 distinctive management areas (MA) are necessary for the tern to qualify for delisting. See objectives for other details. San Francisco Bay, (MA a), Mission Bay (MA u), and San Diego Bay (MA v) must have a minimum of 4, 6, and 6 secure colonies, respectively, before each can qualify toward the goal of 20 secure, distinct management areas. Colonies with the same letter indicate that they are considered representative of a management area.

* Not included as site counted toward 20 secure management locations.

River mouth, R. G. McCaskie[1] and J. M. Sheppard[2], pers. comm.).

Flight stage is reached at approximately 20 days of age, but the young birds do not become fully proficient fishers until after they migrate from the breeding grounds. Consequently, parents continue to feed their young even after they are strong fliers (Massey 1974, Swickard 1971, Tompkins 1959).

Loss of tern chicks has been attributed to American kestrels (Falco sparverius) (Craig 1971), loggerhead shrikes (Lanius ludovicianus) and American crows (Atwood et al. 1977, Bender[3] pers. comm.), house cats (Felis cattus) (Edwards 1919) and dogs (Pentis 1972); to cold, wet weather (Pentis 1972) and to extreme heat spells (CDFG 1981); and to dehydration and starvation (Massey 1972). Burrowing owls (Athene cunicularia) have been known to feed on nesting adult least terns and young (Jorgensen[4] and Collins[5], pers. comm.). Common ravens and red foxes (Vulpes vulpes) are also reported predators. Human disturbance is a perennial problem at some colonies (i.e., Tijuana River Mouth, Delta Beach, and Santa Maria River).

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1 Mr. Guy McCaskie, San Diego, CA.
2 Mr. Jay Sheperd, Office of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C.
3 Ms. Kristen Bender, past California Least Tern Recovery Team member.
4 Mr. Paul Jorgensen, Biologist, California Department of Parks and Recreation, San Diego, CA.
5 Dr. Charles Collins, Department of Biology, California State University, Long Beach, CA.

In the past, high tides washed away many California least tern eggs (Sechrist 1915, Shepardson 1909); however, most California least terns nest in situations where flooding is not a normal factor. Summer rains sometimes cause losses where nests occur on soils less permeable than beach sands (Swickard 1971).

Post-breeding Dispersal--Fledglings accompanied by adults are often observed at various shallow-water, freshwater, and estuarine marshes prior to migrating south. Post-breeding dispersal to such areas probably affords juveniles the opportunity to develop foraging skills prior to the demands of migration. Most known post-breeding, foraging and roosting areas appear to be characterized by (1) suitable food resources, (2) proximity to active breeding colonies, and (3) relatively protected loafing and nesting sites. The known post-breeding dispersal sites include: Oso Flaco and Dunes Lakes, Santa Ynez River mouth, Mugu Lagoon, Harbor Lake, Guajome Lake, Lake Val Sereno, Whelan Lake, various stretches of the Santa Margarita and San Luis Rey Rivers and O'Neill Lake, Buena Vista, Batiquitos and San Dieguito Lagoons, San Diego River Flood Control Channel, Delta Beach, and the Dairy Mart Ponds.

Migration and Wintering Grounds--Least terns usually arrive along the California coast in mid-April to early May and head south by September. Little is known about where the remaining 8 months of each year are spent.

Up to 78 least terns have been observed during the winter as far north as

Colima, Mexico (A. Craig[1] unpubl. rpt.) but subspecfic identify could not be determined. There are only a few reports from the Pacific Coast in Honduras and Guatemala. Small numbers of birds (2-3 individuals) have been reported from the Pacific Coast of Panama, but other investigators have checked suitable locations in Panama and not found wintering least terns. The winter range is still in great need of documentation.

Nothing is known about actual migration routes, but the terns presumably move along the west coast of Baja California, to the west coast of Mexico and further south.

Longevity and Breeding Age--Banded least terns (including all three North American subspecies) have been recovered at up to 21 years of age, and 31 of 61 banded individuals were 5 years old or older (Massey and Atwood 1978). A 15 year old bird has been documented to breed in San Diego (B. Massey and E. Copper[2] pers. comm.). This suggests a relatively long life for individuals of this species.

Banding studies have demonstrated that the usual age of first breeding is 3 years, but that least terns occasionally do breed at age two (Massey and Atwood 1981a,b). One-year old birds occur rarely in breeding areas during the nesting season; they do not participate in breeding activities nor are they in breeding plumage (Massey and Atwood 1978).

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1 Mr. Allan Craig, Biologist, California Department of Fish and Game.
2 Ms. Elizabeth Copper, Tern Biologist, San Diego, CA

Food and Feeding Habits--The California least tern obtains most of its food from shallow estuaries and lagoons, and nearshore ocean waters. Feeding activity at the few sites that have been studied occurs mostly within 3.2 km (2 miles) of breeding colonies, and at many sites foraging is primarily in nearshore ocean waters less than 18.3 m (60 feet) deep. Colonies located near productive estuarine habitats appear to utilize such areas heavily but data regarding the relative value of estuaries to feeding least terns are scarce. The increased use of freshwater marsh systems, lakes, lagoons, and estuarine areas during post-breeding dispersal suggests the special importance of such habitats during the breeding cycle when juveniles are learning to fish for themselves.

The California least tern has not been observed eating anything but fish (Massey 1974). Most fish taken are apparently younger than 1 year old. General size characteristics of the fish eaten are a maximum body depth of less than 1.2 cm and a maximum body length of about 8 cm. The main food items are variable from colony to colony, but usually include northern anchovy (Engraulis mordax) and topsmelt (Atherinops affinis). In San Diego County, deepbody and slough anchovies (Anchoa spp.) are relatively important. Other locally or temporally important species include shiner surfperch (Cymatogaster aggregata), several gobies [notably the yellowfin goby (Acanthogobius flavimanus)], the longjaw mudsucker (Gillichthys mirabilis), California killifish (Fundulus parvipinnis), jacksmelt (Atherinopsis californiensis), and mosquitofish (Gambusia affinis) plus other species (Atwood, Minsky, and Massey, pers. comm). At least 50 species of forage fish have been identified from fish dropped at colony sites (Massey and Atwood 1981b).

Past Conservation Efforts

Past efforts to conserve the California least tern have involved monitoring breeding colonies to determine distribution and location of colonies, pairs, number of fledglings, reproductive rate, and predation problems. Fencing of colonies has been effective in some cases in minimizing human disturbance. Predator control through judicious use and placement of electric fences and other barriers as well as by trapping efforts have reduced losses of adults, eggs, and/or young.

The number of nesting pairs has increased throughout recent years largely because of the result of the above conservation efforts. Unfortunately preliminary data for 1984 indicate a 25-30% reduction of nesting adults (Massey, pers. comm.). As yet, causes for this unexpected decline have not been determined.

A non-inclusive list of actions that have been undertaken on behalf of the least tern include the installation of an electric fence on NASA Island (Seal Beach National Wildlife Refuge) in addition to marsh restoration efforts to increase tidal action. The U.S. Marines-Camp Pendleton and the California Department of Parks and Recreation routinely maintain a fence around nesting colonies and post admonitory signs to minimize human disturbance. This is especially important because Venice Beach and Huntington Beach are two of the largest colonies in the state. Local concerns, other agencies, and the Fish and Wildlife Service cooperate in an effort to manage the Santa Margarita colonies, another essential site.

The U.S. Navy at Point Mugu instituted a research project to evaluate the impacts of predation on terns by the introduced red fox. As indicated by the above, the scope and complexity of recovery actions for least terns has been varied and has involved a host of various agencies.

California Department of Fish and Game (CDFG) has created nesting islands in Bolsa Chica, one of which now supports a large breeding tern colony. CDFG has also attempted to abate the sedimentation problem in Upper Newport Bay in addition to creating nesting sites and protecting existing birds.

The U.S. Navy has fenced Delta Beach to prevent disturbance to the site. Site preparation to enhance the suitability of the area for terns has been undertaken.

Reasons for Decline

No reliable estimates are available on historical numbers of California least terns, but they once were abundant and well-distributed along the southern California coast. Shepardson (1909) describes a colony of about 600 pairs along a 4.8 km (three-mile) stretch of beach in San Diego County. "Good-sized" colonies were located in Los Angeles County (Grinnell 1898).

Reduction in numbers was gradual. This subspecies appears to have escaped the slaughter inflicted on the East Coast populations by the millinery trade of the late 1800's (Bent 1921, Hagar 1937), although there were some early local losses to shooting (Holterhoff 1884) and egg collecting (McCormick 1899). It is doubtful these activities were widespread enough

to adversely influence the population. Although certain least tern colonies were still thriving in the early 1900's, others were already beginning to feel the pressure of human influence.

The Pacific Coast Highway was constructed early this century along previously undisturbed beach, and summer cottages and beach homes were built in many areas. Soon children, dogs and cats were being blamed for disrupting tern nesting (Chambers 1908, Edwards 1919, Massey 1974). The buildup of human use of the beaches displaced more and more colonies at the same time their bay feeding areas were being developed, filled in, and polluted. By the 1940's, most terns were gone from the beaches of Orange and Los Angeles counties (Cogswell 1947), and they were considered sparse everywhere (Grinnell and Miller 1944). Continuing loss of both nesting and feeding habitat and high levels of human disturbance at remaining colonies have been responsible for the continued decline to the present time (Craig 1971).

Current Status

The least tern breeding population in California was approximately 890-1215, 963-1171, 1015-1245, and 1180-1299 pairs in 1980, 1981, 1982, and 1983, respectively (Table 3).

Earlier apparent increases were partly attributable to more thorough surveys of colony locations resulting from experience gained in previous years. Subsequent increases have resulted from colony management and protection efforts. The number of terns nesting in Baja California is

Table 3. California Least Tern Breeding Colonies and Numbers of Nesting Pairs.

Management Area 1	County and Site	Minimum No. of Breeding Pairs 1978	1979	1980	1981	1982	198
	ALAMEDA						
a	Alameda Naval Air Station	80	40	60	74	70-75	3
a	Alvarado Salt Ponds	2	3	12**	0	0	5-
a	Oakland Airport					16-17	56-
	SAN MATEO						
a	Bair Island	0	4	38**	23**	50-55	22
	SAN LUIS OBISPO						
b	Pismo Beach						?
b	Oso Flaco Lake	0	6-8	6-8	0	3	1(
	SANTA BARBARA						
c	Santa Maria River	17-20	18-23	15-18	25	12	7
d	San Antonio Creek	8-10	4	2	4	6	14
d	Purisima Point (North)	5	0	0	0	0	14
d	Purisma Point (South)	0	24-30	25-30	30	15-20	8
d	Santa Ynez						
	VENTURA						
e	Santa Clara River	10-15	15-20	13	20-25	17-20	3
f	Ormond Beach	0	6-8	0	0	7	4
f	Mugu Lagoon	10-12	+	12	0	12-14	22
	LOS ANGELES						
g	Venice Beach	60-75	80-95	150-165	140-160	150-189	140-
g	Playa del Rey	25-30	18-25	+	16	0	0
h	Terminal Island	0	0	0	30-45	60-69	80-
*	San Gabriel River	60-65	50-55	+	16	0	0
i	Cerritos Lagoon	0	0	12-15	3	0	0
*	Costa del Sol	0	0	0	15-21	18-24	20-
	ORANGE						
j	Anaheim Bay	0	6	38-43	40-45	17-20	4
j	Surfside Beach	-	-	2-5	0	0	0
k	Bolsa Chica (North)	0	15-20	20-26	31-54	70-92	110-
k	Bosa Chica (South)	0	19-23	+	19-21	8-10	25-
l	Huntington Beach	75-90	80-95	70-90	105-120	85-111	
m	Upper Newport Bay	8-10	6-7	2-5	0	0	9

Table 3 (cont.)

Management area [1]	County and Site	Minimum No. of Breeding Pairs 1978	1979	1980	1981	1982	198
	SAN DIEGO						
n	San Mateo Creek				1	0	(
n	Aliso Creek	-	15	65-75	23	1	10-
n	S. Margarita River (N.)	30-40	32-40	12-20	25-75	100-115	134-
n	S. Margarita River (S.)	#	0	35-45	25-35	15-30	93-
o	Buena Vista Lagoon	0	0	1	2-3	0	0
p	Agua Hedionda Lagoon	11-15	23-28	11-12	2-6	0	0
q	Batiquitos Lagoon	22-27	38-40	25-30	39	19-31	1
r	San Elijo Lagoon	9	12	15-18	12	24-30	25-
s	San Dieguito Lagoon	0	1	4-5	0	0	0
*	Whispering Palms Encinitas	0	1	0	8	0	2-
t	Los Penasquitos Lagoon	18-25	16	14-16	0	0	0
u	FAA Island	135-155	96	150	75+	0	80
u	North Fiesta Island	8-9	15	6-10	8	55	65-
u	Stony Point	-	-	-	-	4-22	0
u	South Sea World Drive	-	-	-	-	4	0
u	Cloverleaf	-	-	-	-	25	0
v	Naval Training Center	8-12	0	0	0	0	0
v	San Diego Int. Airport	43	108	71	0	4-12	27
v	Chula Vista Wildl. Reserve	0	0	55-60	95-100	73+	75+
v	Sweetwater River	47	24-28	12-15	0	1	1
v	North Island NAS	36	75-80	100	60	61-70	60-
v	Delta Beach	4	10-12	0	0	0	0
v	Coronado Cays	8-10	38-40	0	0	0	0
v	Saltworks	29	28-30	16-25	1	0	0
w	Tijuana River Mouth	8-12	25-30	35-40	12	21-30	60-
	Totals	776-887	845-1049	890-1215	963-1171	1015-1245	1180-1299

* Not included as site counted toward 20 secure management areas.

** Number of nests. 1980 statewide total includes estimated 70-90 pairs in San Francisco Bay Area.

\# Numbers nesting here in 1978 were included in Santa Margarita River (North) site total.

0 No terns present.

\+ Number of fledglings undetermined.

\- No data.

[1] Refer to footnote on Table 2.

unknown. Additional information is needed to assess the importance of least terns nesting in Baja California to the overall recovery effort. Security and management of Mexican colonies must be evaluated to assess the impact of these colonies on recovery goals. Those factors that have contributed to the decline of the California least tern - loss of nesting and feeding habitat, and continued disturbance of nesting colonies - continue to operate, and the bird's status continues to be precarious. There is potential, however, for creating or restoring nesting and feeding habitat in the vicinity of most existing colonies, and in areas that have not been used in the recent past.

PART II

RECOVERY

Objectives

The primary objective of this recovery plan is to restore and subsequently maintain the breeding population of California least terns at a secure level so that delisting can be considered. To achieve this level, the annual breeding population in California must increase to at least 1,200 pairs distributed among secure colonies in at least 20 secure coastal management areas throughout their breeding range. Concurrently, efforts should be directed toward protecting the existing breeding population in Baja California, Mexico. Data from California least tern populations in Baja California are insufficient to incorporate population numbers and necessary fledging rates into the prime objective for reclassification. When these data become available the prime objective will be modified accordingly. Because of current Mexican land use practices, remoteness of areas, and minimal monitoring of land uses, it appears unlikely that the Mexican colonies will contribute substantially to the recovery effort. However, this situation requires clearer definition.

If the 1,200 pair population level is achieved, delisting of the species can be considered, with these provisions: 1) sufficient habitat to support at least one viable tern colony (defined as consisting of a minimum of 20 breeding pairs with a 5-year mean reproductive rate of at least 1.0 young fledged per year per breeding pair) at each of the 20 coastal

management areas (see Table 2) (including San Francisco Bay, Mission Bay and San Diego Bay, which should have 4, 6 and 6 secure colonies, respectively), that are managed to conserve least terns; and 2) land ownership and management objectives are such that future habitat management for the benefit of least terns at those locations can be assured. The security and status of Baja California colonies must be assessed; if any such colonies are estimated to be secure and will be managed in perpetuity to benefit least terns, such colonies will also be incorporated into the quantified prime objective.

Interim reclassification to threatened status can be considered when: 1) the 1,200 pair population level is achieved; 2) 15 coastal management areas (including San Francisco Bay, Mission Bay and San Diego Bay, which should have 3, 5 and 4 secure colonies, respectively) support viable least tern colonies and are managed to conserve least terns; and 3) a 3-year mean reproductive rate of at least 1.0 young/breeding pair is achieved. Once additional information on the Baja California colonies is available, possibly one or two secure sites of the above 15 may be located in Baja. Because of possible non-security of Baja California habitats, it appears unlikely that the Mexican populations will contribute significantly to tern recovery. However, this must be more thoroughly investigated. As additional data become available, the prime objective may be modified to reflect current information.

The chief limiting factor influencing the number of least tern breeding pairs is the availability of undisturbed suitable habitat on the breeding grounds. Therefore, many tasks outlined in this plan include preservation

and management of existing nesting, foraging and roosting habitat, restoration of former nesting habitat and degraded coastal wetlands, creation of nesting islands, and protection of nesting and roosting areas from excessive human disturbance and predation. Research is needed to refine and direct a number of these management actions. Recovery will depend upon a continuing cooperative effort by the U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Parks and Recreation, U.S. Army Corps of Engineers, U.S. Navy, U.S. Marine Corps, U.S. Air Force, Federal Aviation Administration, numerous city, county and other local government agencies, private conservation organizations, and the governments of Mexico and other countries within the range of this subspecies.

Step-down Outline

Primary Objective: In order to consider delisting, increase the least tern breeding population in California to a secure level of at least 1,200 pairs distributed in viable colonies in at least 20 coastal management areas distributed throughout its current breeding range with at least a 1.0 reproductive rate as a 5-year average for the total population within the 20 management areas while encouraging the preservation of the existing breeding population in Baja California. Reclassification to threatened status may be considered when there are 1,200 breeding pairs in 15 secure coastal management areas, with an overall-mean productive rate of 1.0 for a consecutive 3-year period.

1. Preserve and manage nesting habitat.

    11. Preserve and manage nesting areas of existing colonies.

111. Develop and implement least tern management plans/programs for secure[1] nesting habitat in Alameda, San Mateo, Santa Barbara, Ventura, and Los Angeles counties.

1111. Alameda Naval Air Station.

1112. Bair Island.

1113. San Antonio Creek.

1114. Purisima Point.

1115. Santa Clara River Mouth.

1116. Mugu Lagoon.

1117. Venice Beach.

112. Develop and implement least tern management plans/programs for secure nesting habitat in Orange County.

1121. Anaheim Bay (Seal Beach National Wildlife Refuge, Naval Weapons Center-Seal Beach).

1122. Huntington State Beach Least Tern Natural Area.

1123. Bolsa Chica Ecological Reserve.

1124. Upper Newport Bay Ecological Reserve.

113. Develop and implement least tern management plans/programs for secure nesting habitat in San Diego County.

1131. San Mateo Creek.

1132. Aliso Creek.

1133. Santa Margarita River Mouth.

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[1] Secure land is defined as being in public ownership or control and is actively managed for its resource values emphasizing endangered species.

1134. Buena Vista Lagoon.

1135. San Elijo Lagoon.

1136. Delta Beach.

1137. San Diego Bay salt pond dikes.

1138. Tijuana River Estuary.

114. Preserve and manage nesting areas for currently insecure colonies.

1141. Protect/secure nesting habitat now in private ownership (San Diego County unless otherwise stated).

11411. Agua Hedionda Lagoon (eastern part).

11412. Los Penasquitos Lagoon.

11413. Playa del Rey (Los Angeles County).

11414. Bayfront end of "D" Street Fill", Sweetwater Marsh.

11415. Oakland Airport (Alameda County).

1142. Manage when, and if, secured.

11421. Agua Hedionda Lagoon (eastern part).

11422. Los Penasquitos Lagoon.

11423. Playa del Rey.

1143. Develop and implement management plans to establish secure nesting areas for colonies on public lands (San Diego County unless otherwise stated).

11431. North Island Naval Air Station.

11432. Chula Vista Wildlife Reserve.

11433. Oso Flaco Lake (San Luis Obispo County).

115. Secure and manage a minimum of six least tern nesting sites in Mission Bay (San Diego County).

1151. Establish an interagency coordinating team to annually maintain least tern colonies.

1152. Annually maintain Crown Point Sanctuary.

1153. Annually maintain FAA Island site.

1154. Annually maintain and protect North Fiesta Island breeding area.

1155. Annually maintain and protect Stoney Point nesting site.

1156. Establish and manage at least two additional breeding sites at the Cloverleaf and South Sea World Drive, or at other potential sites.

116. Develop management plans/programs that identify special site protection problems of certain insecure colonies and implement corrective action as needed in Ventura, Los Angeles, and Alameda counties.

1161. Coyote Hills (Alameda County).

1162. Ormond Beach (Ventura County).

1163. Santa Clara River Mouth (Ventura County).

1164. Cerritos Lagoon (Los Angeles County).

1165. Playa del Ray (Los Angeles County).

1166. Terminal Island--Reeves Field and the land-fill site (Los Angeles County).

117. Develop management plans/programs that identify special site protection problems of certain insecure colonies and implement corrective action as needed in San Diego County.

1171. San Diego International Airport.

1172. Grand Caribe Island, Coronado Cays.

1173. D Street Fill.

12. Provide adequate nesting habitat in former, potential, or newly identified breeding areas.

121. Develop and implement management plans to construct and manage new nesting sites in protected areas.

1211. Anaheim Bay (Seal Beach National Wildlife Refuge, Naval Weapons Station Seal Beach)

1212. Sunset Aquatic Park.

1213. Bolsa Chica Ecological Reserve.

1214. Upper Newport Bay Ecological Reserve.

1215. Silver Strand, south end of San Diego Bay

1216. Naval Training Center, San Diego.

1217. Marine Corps Recruiting Depot-San Diego

122. Manage newly identified sites.

123. Develop and implement least tern management plans/programs for currently non-secure habitats with emphasis on construction of adequate breeding sites.

1231. Protect and manage San Dieguito Lagoon.

1232. Protect and manage mouth of Santa Ana River (southeast area).

2. Protect and manage non-nesting habitat.

21. Maintain adequate feeding habitat for colonies.

211. Protect existing coastal feeding grounds of colonies.

2111. Mugu Lagoon.

2112. Bolsa Chica Bay.

2113. Terminal Island.

2114. Anaheim Bay.

2115. Los Penasquitos Lagoon.

2116. Tijuana River Estuary.

212. Investigate and implement actions needed to increase populations of fish eaten by terns in degraded or potential tern feeding areas.

2121. Mouth of Santa Ana River, southeast area.

2122. San Elijo Lagoon.

2123. Batiquitos Lagoon.

2124. Other areas as needed.

213. Identify major feeding areas.

22. Protect important[1] non-nesting, feeding, and roosting habitats from detrimental land or water use changes in San Luis Obispo, Santa Barbara and Los Angeles Counties.

221. Oso Flaco and Dune Lakes (San Luis Obispo County).

222. Santa Ynez River Mouth (Santa Barbara County).

223. Harbor Lake (Los Angeles County).

224. Belmont Shores (Los Angeles County).

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[1] "Important" = used more than on merely a casual basis.

225. Identify and protect other habitats as needed.

23. Protect important non-nesting, feeding, and roosting habitats from detrimental land or water use changes in San Diego County.

231. Guajome Lake.

232. Lake Val Sereno.

233. Whelan Lake.

234. Santa Margarita River-O'Neil Lake.

235. San Luis Rey River.

236. Dairy Mart Ponds.

237. San Dieguito Lagoon.

238. Buena Vista Lagoon.

239. San Diego River Flood Control Channel.

3. Monitor least tern population to determine status, distribution and progress of management during the breeding season.

31. Determine breeding success.[1]

311. Determine colony locations.

312. Estimate breeding population size.

313. Conduct annual breeding colony surveys.

32. Investigate population dynamics, life history, and movement of terns by banding and marking.

4. Conduct research on California least tern to provide additional necessary information for tern management.

41. Determine effects of environmental pollutants on least terns.

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[1] "Breeding success" = number of young that fledge per number of least tern pairs.

42. Determine factors affecting the choice of location for roosting, loafing, and feeding areas used during the breeding and post-breeding seasons.

43. Determine amount of habitat that is necessary to maintain the current population and the prime recovery objective.

44. Identify potentially suitable nesting sites, including beach, landfill, salt pond, and estuarine areas.

45. Identify factors causing colony disruption and nest site abandonment.

46. Develop or refine management techniques for providing adequate nesting sites and implement techniques where needed.

461. Investigate nest site requirements of colonies.

462. Investigate methods of enhancing nesting sites of existing colonies.

463. Investigate methods of constructing adequate nesting sites in potential breeding habitat.

5. Encourage the protection of population outside the United States.

51. Protect least tern population and habitats in Baja California.

511. Determine colony locations and population size.

512. Identify least tern population and habitat protection problems.

513. Develop cooperative programs between the United States and Mexican governments for least tern protection and habitat preservation.

52. Identify and protect key migration and winter habitats outside the United States.

6. Utilize existing laws and regulations protecting California least tern and its habitat.

   61. Evaluate success of law enforcement.

   62. Propose appropriate new regulations or revisions.

7. Develop and implement a conservation education program.

Narrative

1. Preserve and manage nesting habitat.

California least tern conservation and recovery depends upon the adequate protection and management of habitat for nesting, feeding, roosting, post-breeding dispersal and wintering. It is particularly important that nesting habitat be properly managed to maximize tern productivity. Human disturbance must be minimized. This may entail posting admonitory signs, erecting fences, providing adequate patrols and law enforcement, and undertaking an energetic conservation education program.

Predation of adult terns, eggs, or young and prevention of colony abandonment may be attempted by judiciously monitoring colonies to detect potential or actual predation problems. Control of problem predators by trapping, shooting, use of electric fences, and other means is required and has been successful at increasing tern nesting and reproductive success. Emergency procedures may need to be implemented to maximize tern survival and reproduction.

11. Preserve and manage nesting areas of existing colonies.

In California, least terns have nested in about 20 coastal ecosystems since 1969. The numbers of colonies and their nest site locations in many of these areas have varied from year to year. At least two more nesting areas exist in Baja California, Mexico. If

colonies are to continue in these areas, their nesting and feeding habitats must be preserved.

At some breeding sites, habitat management actions are needed annually to provide suitable nesting substrates. Growth of vegetation, wind, rain, tidal action, vehicle or human foot traffic, and other factors contribute to the deterioration of the quality of nesting substrates. Generally, site preparation actions are needed between February 1 to April 15 (no later than the start of the nesting season). Pre-breeding season management actions may include site inspections to evaluate management needs, removal of vegetation, deposition of sand or other substrate material, disking and leveling of substrates, prevention of rain or tidal water flooding, and placement of clay, concrete or other artificial shelters in or near nesting sites to provide shade for chicks and use of decoys to attract adults. Schedules for annual nest site enhancement actions on State or Federal management areas must be incorporated in management plans for those areas.

Where potential nesting sites are created and adequately prepared, annual nest site enhancement actions and experimentation should continue for at least five years to entice breeding pairs to establish new colonies. If, after this 5 year period, a colony has not become established, the site should be re-evaluated as a potential nesting area.

In some areas, recommended management actions include the

construction of alternate nesting sites where currently used sites are highly vulnerable to disturbance or are jeopardized by habitat loss. In some instances where land development plans would cause the destruction of a nesting site, construction of an alternate nest site may be the only feasible alternative to avoid detrimental impacts.

In areas where nesting sites and/or feeding areas are protected under public ownership or jurisdiction, this plan recommends that responsible agencies develop and implement least tern management plans. Coordination of plans is the responsibility of the California Department of Fish and Game and the U.S. Fish and Wildlife Service.

111. Develop and implement least tern management plans/programs in Alameda, San Mateo, Santa Barbara, Ventura, and Los Angeles Counties.

For most existing colonies, the nesting area is the habitat element most in need of preservation. In California, not all currently used colony nesting sites are protected under State, Federal or other public ownership or jurisdiction. Protected sites are reasonably secure from adverse habitat alteration or are located where human access can be controlled. The remaining active colony nesting sites are located in areas where human disturbance is a recurrent problem, where needed management programs are now difficult or nearly impossible to implement,

or where land use changes threaten the suitability of the site for breeding. For a few of these sites, construction and protection of nearby alternate nesting areas, where possible, would be preferable to the protection of those currently used, but always vulnerable nesting sites. For the remaining areas, however, efforts are now needed to preserve essential nesting habitat through acquisition, zoning or other actions.

1111. Alameda Naval Air Station.

The most effective means of tern conservation in this area is through development and implementation of a least tern management plan. The Navy is currently formulating such a plan; it has constructed and maintains a protective fence around the nesting colony. Monitoring of the colony and predator control is routinely undertaken.

1112. Bair Island.

The most effective means of tern conservation in this area is through development and implementation of a least tern management plan. CDFG is currently working on such a plan.

1113. San Antonio Creek.

The most effective means of tern conservation in this area is through development and implementation of a least tern

management plan.

1114. Purisima Point.

See item 1113.

1115. Santa Clara River Mouth.

See item 113.

1116. Mugu Lagoon.

See item 1113.

1117. Venice Beach

See item 1113.

112. Develop and implement least tern management plans/programs for secure nesting habitat in Orange County.

For most existing colonies, the nesting area is the habitat element most in need of preservation. In California, not all currently used colony nesting sites are now protected under State, Federal or other public ownership or jurisdiction. These protected sites are reasonably secure from adverse habitat alteration or are located where human access can be

controlled. The remaining active colony nesting sites are located in areas where human disturbance is a recurrent problem, where needed management programs are now difficult or nearly impossible to implement, or where land use changes threaten the suitability of the site for breeding. For a few of these sites, construction and protection of nearby alternate nesting areas, where possible, would be preferable to the protection of those currently used, but always vulnerable nesting sites. For the remaining areas, however, efforts are now needed to preserve essential nesting habitat through acquisition, zoning or other actions.

1121. Anaheim Bay (Seal Beach National Wildlife Refuge, Naval Weapons Center-Seal Beach).

The most effective means of tern conservation in this area is through development and implementation of a least tern management plan. Construction of an alternate nesting site is planned. Site enhancement, monitoring, and predator control is ongoing.

1122. Huntington State Beach Least Tern Natural Area.

Effective tern recovery depends upon the development and implementation of a suitable mamagement plan. Monitoring and control of predators is an ongoing process.

1123. Bolsa Chica Ecological Reserve.

See item 1122.

1124. Upper Newport Bay Ecological Reserve.

See item 1122.

113. Develop and implement least tern management plans/programs for secure nesting habitat in San Diego County.

For most existing colonies, the nesting area is the habitat element most in need of preservation. In California, not all currently used colony nesting sites are now protected under State, Federal or other public ownership or jurisdiction. Protected sites are reasonably secure from adverse habitat alteration or are located where human access can be controlled. The remaining active colony nesting sites are located in areas where human disturbance is a recurrent problem, where needed management programs are now difficult or nearly impossible to implement, or where land use changes threaten the suitability of the site for breeding. For a few of these sites, construction and protection of nearby alternate nesting areas, where possible, would be preferable to the protection of those currently used, but always vulnerable nesting sites. For the remaining areas, however, efforts are now needed to preserve essential nesting habitat through acquisition, zoning or other actions.

1131. San Mateo Creek.

See item 1122.

1132. Aliso Creek.

See item 1122.

1133. Santa Margarita River Mouth.

See item 1122.

1134. Buena Vista Lagoon.

See item 1122.

1135. San Elijo Lagoon.

See item 1122.

1136. Delta Beach.

This beach was recently fenced to prevent human disturbance. Vegetation was removed to enhance the site's suitability for tern use. It has been used as a roosting site by large numbers of post-breeding terns. It is anticipated that terns will increase their use of the area and may nest there. The beach

is managed by the Naval Amphibious Base-Coronado.

1137. San Diego Bay Salt Pond Dikes.

See item 1122.

1138. Tijuana River Estuary.

Presently this site does not provide suitable conditions to support a secure least tern colony. A management plan is needed to control human disturbance (primarily horseback riding), minimize the effects of flooding and high tides (may require moving nesting areas to higher ground), and to limit vegetation encroachment. A management plan, once implemented, would be an effective tool to enhance tern reproduction in this location.

114. Preserve and manage nesting areas for currently insecure colonies.

Numerous least tern nesting colonies are located on land that is not managed to benefit least tern. The status of terns is such that their recovery necessitates adequately protecting currently insecure nesting colonies.

1141. Protect/secure nesting habitat now in private ownership (San Diego County unless otherwise stated).

Certain colony sites have the potential to provide good nesting and/or feeding habitat if properly managed. Securing such sites either by acquisition, conservation easements, memoranda of understanding, or other means is necessary to insure their protection; otherwise future habitat modification may make the areas unsuitable for terns. Any habitat that Fish and Wildlife Service may be involved directly in securing will require the preparation of a Land Protection Plan. Such a plan delineates the possible methods of securing a given site.

11411. Agua Hedionda Lagoon (eastern part).

This site is now in private ownership. Proper management to conserve and recover least terns is essential. Considering the pressures to develop the area, acquisition may be the best method to insure the continued use by least tern.

11412. Los Penasquitos Lagoon.

See item 11411.

11413. Playa del Rey (Los Angeles County).

See item 11411.

11414. Bayfront end of "D Street Fill", Sweetwater Marsh.

See item 11411.

11415. Oakland Airport (Alameda County).

See item 11411.

1142. Manage when, and if, secured.

Once areas are secured, active management will be necessary to provide the best habitat conditions for least tern.

11421. Agua Hedionda Lagoon (eastern part).

After this area has been secured, intensive management to conserve and enhance California least terns will be required to maximize the reproductive potential of terns using the site.

11422. Los Penasquitos Lagoon.

After this area has been secured, intensive management to conserve and enhance California least terns will be required to maximize the reproductive potential of terns using the site.

11423. Playa del Rey.

See item 11422.

1143. Develop and implement management plans to establish secure nesting areas for colonies on public lands (San Diego County unless otherwise stated).

Several areas in public ownership provide nesting sites for terns but need additional efforts to improve tern nesting success. Specific management plans should be developed for each area. Enhancing these sites will increase productivity and state-wide population levels.

11431. North Island Naval Air Station.

An existing management plan is being revised in response to development planned on the nesting site. Intensive management of the remaining nesting area and alternate nesting sites is necessary to enhance reproduction.

11432. Chula Vista Wildlife Reserve.

Presently this site does not provide suitable conditions to support a secure least tern colony. A management plan, once implemented, would be an effective tool to enhance tern reproduction in this location.

11433. Oso Flaco Lake (San Luis Obispo County).

See item 11432.

115. Secure and manage a minimum of six least tern nesting sites in Mission Bay (San Diego County).

Twelve different sites around Mission Bay have supported tern nesting colonies since 1960. As recently as 1975, eight of these sites were in use, and in 1982 five areas were used. At least six sites that have been used in the past still possess the potential, if managed, to support viable tern colonies. Controlling vegetation, human disturbance and predation is the key to fostering successful tern colonies around Mission Bay.

1151. Establish an interagency coordinating team to annually maintain least tern colonies.

Several agencies are involved in managing Mission Bay. A coordinated, focused effort is needed to ensure that breeding areas are maintained and properly protected.

1152. Annually maintain Crown Point Sanctuary.

This area could support far more terns than it now does. Annual maintenance (e.g., vegetation removal) is required to maintain habitat quality. Other forms of maintenance may also be required to maximize the reproductive potential of this site.

1153. Annually maintain FAA Island Site.

For its size, this area has supported more nesting terns than any other colony in California. Annual maintenance (e.g., vegetation removal) is required to maintain habitat quality. Effective predator control is required to maximize the reproductive potential of this site.

1154. Annually maintain and protect North Fiesta Island breeding area.

This area could support far more terns than it now does. Annual maintenance (e.g., vegetation removal) is required to maintain habitat quality. Predator control is also required to maximize the reproductive potential of this site.

1155. Annually maintain and protect Stoney Point colony site.

This area could support far more terns that it now does. Annual maintenance (e.g., vegetation removal) is required to maintain habitat quality. Predator control is also required to maximize the reproductive potential of this site.

1156. Establish and manage two additional breeding sites at the Cloverleaf and South Sea World Drive.

These two colony sites in Mission Bay plus the above four sites, if adequately managed (including predator control and fencing),

could substantially increase the reproductive output of least terns in San Diego County.

116. Develop management plans/programs that identify special site protection problems of certain insecure colonies and implement corrective action as needed in Ventura, Los Angeles, and Alameda counties.

Success of insecure (and also secure) colonies may be enhanced by first determining what site specific problems exist. Needed actions may involve signing, fencing, and/or patrolling to control unwarranted human intrusion. Site enhancement (i.e., vegetation removal or thinning) and predator control also may be necessary.

1161. Coyote Hills (Alameda County).

Management actions which deal directly with site specific problems affecting tern survival and reproductive success at this colony site are required. The exact problems of the colony must first be ascertained so that protective strategies can be developed and implemented.

1162. Ormond Beach (Ventura County).

Management actions which deal directly with site specific problems affecting tern survival and reproductive success are required. Disturbance from heavy ORV use appeared to be a major problem at this site but has been prohibited since 1982.

1163. Santa Clara River Mouth (Ventura County).

The major problem at this site is flooding of the nesting area caused by closure of the river mouth by drifting sand in the summer. Opening the mouth is required several times during an average nesting season. Encroaching vegetation and disturbance from ORV's are the other problems that need attention.

1164. Cerritos Lagoon (Los Angeles County).

Management actions which deal directly with site specific problems affecting tern survival and reproductive success are required. There are major people-trespass and predator problems that should be examined in greater detail and alleviated. Problems within the colony must be evaluated so that protective strategies can be developed and implemented.

1165. Playa del Rey (Los Angeles County).

Management actions which deal directly with site specific problems affecting tern survival and reproductive success are required. The exact problems of the colony such as human disturbance and predation must first be identified in greater detail so that protective strategies can be developed and implemented.

1166. Terminal Island--Reeves Field and the land-fill site (Los Angeles County).

Management actions which deal directly with site specific problems affecting tern survival and reproductive success are required. The exact problems of the colony must first be ascertained so that protective strategies can be developed and implemented to secure a permanent nesting location.

117. Develop management plans/programs that identify special site protection problems of certain insecurecolonies and implement corrective action as needed in San Diego County.

Success of insecure colonies may be enhanced by first determining what site specific problems exist. Needed actions may involve signing and/or fencing the important nesting areas or patrolling to control unwarranted human intrusion. Site enhancement (i.e., vegetation removal or thinning) and predator control may be necessary.

1171. San Diego International Airport.

Management actions which deal directly with site specific problems affecting tern survival and reproductive success are required. Problems with airport operations need resolution.

1172. Grand Caribe Island, Coronado Cays.

Because colony site characteristics have been destroyed, a management plan should be developed and implemented that will provide a replacement site.

1173. D Street Fill.

Management actions which deal directly with site specific problems affecting tern survival and reproductive success at this colony site are required. The exact problems of the colony such as human intrusion and predation must first be evaluated so that protective strategies can be developed and implemented. The time required for colony reestablishment needs to be determined once human disturbance has been curtailed. Continued monitoring of human disturbance and predator-related problems will be necessary so that appropriate actions can be taken to alleviate them.

12. Provide adequate nesting habitat in former, potential, or newly identified breeding areas.

A number of areas if properly managed could support nesting colonies of least terns. One important management tool is the creation of additional or alternative nesting habitat. We have achieved some success in determining how sites should be prepared to be attractive to terns. Prevention of unnecessary human

intrusion and an active predator control program may be part of managing these areas.

Least terns readily accept artificial bare ground areas as nesting sites. This is evidenced by the fact that from 1969 to 1977, terns have chosen nest sites on at least 23 human-made land fills or other earthen structures in coastal wetland areas. In 1975 and 1976, 60 percent of known breeding pairs nested on man-made substrates. Experience at the Camp Pendleton (Swickard 1971) and Bair Island colony sites demonstrates that specially constructed nest sites can be acceptable to breeding least terns. Further research and experimentation are needed to refine this management technique. Construction of new nesting sites, restoration of abandoned nesting areas and restoration of feeding areas are recommended actions at many coastal wetlands. These actions are necessary to encourage new colonies to form in potential breeding habitats and to enhance conditions that will allow existing colonies to increase in size.

121. Develop and implement management programs/plans to construct and manage new nesting sites in protected areas.

If new colony sites can be prepared and adequately managed, terns may recolonize certain areas. This could result in an increase in overall number of nesting pairs and reproductive success. It is particularly advantageous to encourage additional nesting in secure habitat since the birds usually have a greater probability of success.

1211. Anaheim Bay (Seal Beach National Wildlife Refuge, Naval Weapons Station-Seal Beach)

Anaheim Bay lies within the Seal Beach National Wildlife Refuge which occupies land owned by the Naval Weapons Station, Seal Beach. The entire colony site at NASA Island may have to be fenced to alleviate predation problems. Because of these predation problems, additional nesting sites may be needed to improve reproductive success. Nesting sites should be created in areas where predators and other disturbance can be effectively controlled.

1212. Sunset Aquatic Park.

In this area, additional nesting sites (preferably adjacent to the National Wildlife Refuge), including an appropriate available nearby food supply, are needed to help augment the numbers of nesting least terns. Nesting sites should be created in the best potential habitat such as areas that are relatively predator-free or could be managed to minimize loss because of predation; areas that are not prone to human intrusion or where access could be properly controlled, and sites near the necessary food supplies.

1213. Bolsa Chica Ecological Reserve.

Additional nesting sites may be desirable to augment the two

created nesting islands. Nesting sites should be created in the best potential habitat such as areas that are relatively predator-free or could be managed to minimize loss because of predation; areas that are not prone to human intrusion or where access could be properly controlled, and sites near adequate food supplies.

1214. Upper Newport Bay Ecological Reserve.

In this area additional nesting sites are needed to help augment the numbers of nesting least terns. Nesting sites should be created in the best potential habitat such as areas that are relatively predator-free or could be managed to minimize loss because of predation; areas that are not prone to human intrusion or where access could be properly controlled, and sites near the necessary food supplies. It appears to be necessary to increase the elevation of the newly created nesting island at the upper end of the bay, and possibly provide additional nesting habitat at an alternate site.

1215. Silver Strand, south end of San Diego Bay (Naval Radio Receiving Facility

The feasibility of establishing a nesting site, such as at the Naval Radio Station, should be investigated. Nesting sites should be created in the best potential habitat such as areas that are relatively predator-free or could be managed to minimize

loss because of predation; areas that are not prone to human intrusion or where access could be properly controlled, and sites near adequate food supplies. In November 1983, the down-coast end of the Silver Strand State Beach was designated as a Natural Preserve. The California Department of Parks and Recreation plans on reestablishing native plants and a least tern nesting colony.

1216. Naval Training Center, San Diego.

Since terns last nested at the site here in 1978, the area has become over-grown with vegetation. Intensive site enhancement is necessary if terns are to nest here again. A management plan, developed and implemented by the Navy, is needed to recreate a colony site.

1217. Marine Corps Recruiting Depot-San Diego

The site should be examined to assess its potential as a future tern nesting colony.

122. Manage newly Identified Sites.

Ten or 12 pairs of California least terns nested in the Santa Ynez River Mouth last year. Fledglings were observed, however no census was undertaken (Farley[1], pers. comm.). The possibility

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1 Commander Earl Farley, Vandenberg Air Force Base

of enhancing tern nesting in the area should be investigated.

123. Develop and implement tern management plans with emphasis on construction of adequate breeding sites in non-secure habitats.

Least tern breeding habitat has been drastically reduced from historical levels. Additional habitat needs to be restored or developed to increase overall nesting numbers. Potential habitat should thus be secured through acquisition, easements, or other means, if necessary, and restored as per a management plan designed specifically for each potential site.

1231. Protect and manage San Dieguito Lagoon.

Part of San Diequito Lagoon is in private ownership. To adequately protect this area, acquisition may be necessary although this is only one possible alternative to secure the site. A management plan should be prepared that stresses preparation of nesting habitat and protection from predators and human beings on the private acreage. The San Dieguito Lagoon Resource Enhancement Program has been approved and is currently being implemented by the City of Del Mar. This includes the construction of a tern nesting island of over 15 ha (6 acres). The California Department of Fish and Game is in the process of designating San Dieguito Lagoon as a state ecological reserve.

1232. Mouth of Santa Ana River, southeast area.

To adequately protect this area, acquisition, conservation easement or other alternatives, may be necessary. A management plan should be prepared that stresses preparation of breeding habitat.

2. Protect and manage non-nesting habitat.

Non-nesting habitat such as that used for roosting, loafing, or feeding must also be protected to enhance tern survivability and the recovery effort.

21. Maintain adequate feeding habitat for colonies.

An ideal nesting substrate will not attract and support least tern breeding pairs if suitable feeding conditions do not exist within a reasonable distance. With few exceptions, colonies form adjacent to estuaries, lagoons, bays or channels where food supplies are readily available. If efforts to preserve colonies are to be successful, the associated feeding areas also must be preserved. Yearlong habitat preservation efforts are needed in major least tern foraging areas. Especially important are feeding areas where least tern adults and fledglings roost after the nesting season ends and before migration south begins.

Least tern colonies need dependable supplies of small fish to sustain the adults and young throughout the breeding season. Several southern California coastal wetlands are now in a degraded condition (e.g., Mudie et al. 1974, 1976). This plan recommends that responsible management agencies investigate and implement actions that are needed to improve feeding conditions for least terns in wetland ecosystems which lack adequate fish populations. In some wetlands restoring tidal circulation is essential to restoring estuarine fish populations. Sedimentation and pollution are other factors that affect forage supplies.

211. Protect existing coastal feeding grounds of colonies.

Existing coastal foraging habitat must be protected by maintaining high water quality, minimizing tideland fill and drainage projects and by restoring or improving tidal flow in wetlands to enhance feeding habitat. If water quality is reduced, fish populations upon which least terns feed could diminish or be locally extirpated, resulting in adverse impacts to tern nesting success. If tidelands are filled or drained, fish habitat will be lost thus reducing the tern's prey base. This also may affect tern nest site selection and reproductive rate.

If the quality of nearby feeding grounds can be improved, the probability that a local nesting colony can be successful may be increased. It is also very important that high quality feeding grounds adjacent to highly productive colonies be

maintained. Improving tidal flow to wetlands can be a very effective means of increasing wetland production.

2111. Mugu Lagoon.

The possibility of improving tidal actions should be explored. Any additional actions that appear feasible should be initiated.

2112. Bolsa Chica Bay.

Foraging conditions for least terns could be improved by reestablishing tidal action to restorable wetlands.

2113. Terminal Island.

Within Los Angeles Harbor, shallow water feeding habitat appears very important to the foraging needs of this tern colony. Maintaining this habitat and providing acceptable water quality are undoubtedly important to conserving Los Angeles Harbor as acceptable breeding habitat.

2114. Anaheim Bay.

Foraging conditions for least terns could be improved by enhancing tidal action in some areas of the estuary.

2115. Los Penasquitos Lagoon.

Tidal action must be restored to this area to improve foraging conditions for least terns.

2116. Tijuana River Estuary.

Least tern foraging habitat could be expanded and enhanced by restoring tidal influence in portions of the north and south reaches of the estuary that have been cutoff from tidal waters in recent years. Agricultural runoff and sewage effluent pose threats to water quality in the Tijuana River Valley. Estuarine waters should be periodically analyzed to identify potential problems and provide a basis for recommending management actions. Flooding and high tides can destroy least tern nests. The possibility of moving the colony site to higher ground should be evaluated and, if deemed feasible, the site should be relocated or modified as needed.

212. Investigate and implement actions needed to increase populations of fish eaten by terns in degraded or potential tern feeding areas.

Tern use of a particular area is partly dependent upon food resources. Sufficient populations of fish of the appropriate size must be available. If sites with low fish numbers could be restored with a concomitant increase in forage availability,

it is anticipated that terns may begin to use the area, or their current use will increase. Thus, additional individuals could be supported.

2121. Mouth of Santa Ana River, southeast area.

This is a prime area to increase the fish forage supply for least terns. A study is needed to determine the best method to enhance fish populations.

2122. San Elijo Lagoon.

This area appears to have significant potential for increasing forage supplies for least terns. Necessary actions must be determined so that efficient strategies to increase fish numbers can be developed.

2123. Batiquitos Lagoon.

See item 2121.

2124. Other areas as needed.

See item 2121.

213. Identify major feeding areas.

Providing suitable fish resources for tern foraging is essential to enhance tern survivorship.

22. Protect important non-nesting, feeding, and roosting habitats from detrimental land or water use changes in San Luis Obispo, Santa Barbara and Los Angeles Counties.

Tern habitat has been drastically reduced from what was historically available. What remains should be protected so that further potential declines in tern numbers can be arrested. Terns must be provided suitable non-nesting habitat for roosting and feeding.

221. Oso Flaco and Dune Lakes (San Luis Obispo County).

California least terns use this area for a variety of non-nesting activities. It is important that the birds can continue to use these areas without adverse disturbance. Undue stress or disturbance may affect their survivability, success at obtaining sufficient food supplies, and predator avoidance; and thus, may influence the probability of tern recovery.

222. Santa Ynez River Mouth (Santa Barbara County).

This is a traditional feeding and roosting site used during

post-breeding dispersal. Management needs should be devised to protect these values.

223. Harbor Lake (Los Angeles County).

Terns are known to roost, feed, or loaf in this area. This is a particulary important post-breeding area where young of the year congregate in substantial numbers. These birds should not be disturbed.

224. Belmont Shores (Los Angeles County).

See item 221.

225. Identify and protect other habitats as needed.

Other areas may need protective measures. Once these areas are identified, site-specific actions may be proposed.

23. Protect important non-nesting, feeding and roosting habitats from detrimental land or water use changes in San Diego County.

Tern habitat has been drastically reduced from what was historically available. What remains should be protected so that further potential declines in tern numbers can be arrested. Terns must be provided suitable non-nesting habitat for roosting and feeding.

231. Guajome Lake.

See item 221.

232. Lake Val Sereno.

See item 221.

233. Whelan Lake.

See item 221.

234. Santa Margarita River-O'Neil Lake.

See item 221.

235. San Luis Rey River.

See item 221.

236. Dairy Mart Ponds.

See item 221.

237. San Dieguito Lagoon.

See item 221.

238. Buena Vista Lagoon.

See item 221.

239. San Diego River Flood Control Channel.

See item 221.

3. Monitor least tern population to determine status, distribution and progress of species management during the breeding season by conducting annual breeding colony surveys.

Population monitoring is necessary to evaluate the success of management actions and to modify such actions or implement new ones, if necessary.

31. Determine Breeding Success.

The only way to determine whether the prime objective has been obtained is to assess the number of breeding pairs, their distribution, and reproductive success. Surveys indicate when a colony is having difficulty and can provide an opportunity for biologists to quickly try to resolve problems that may arise (e.g., removal of predators). Breeding population surveys are needed annually in California and in Baja California. These

surveys will identify active colony sites, determine colony size and evaluate breeding success. This information is necessary for evaluating management and protection efforts. There is also a need to refine census techniques to reduce the time and costs involved in data collection, yet not sacrifice the quality of data.

311. Determine colony locations.

The location of individual colony sites must be determined before a comprehensive survey can be conducted.

312. Estimate breeding population size.

The size of the breeding population usually varies throughout the nesting season. Therefore censusing during the entire season is needed to arrive at a reasonable estimate of the number of pairs. Such information is beneficial in assessing the status of the recovery effort.

313. Conduct annual breeding colony surveys.

Even if many least terns are nesting, recovery will still only be achieved if reproductive success is sufficiently high to compensate for mortality losses and provide for a long-term tern stability. Breeding success is determined by the number of young that fledge per number of least tern pairs (or nesting attempts

in the case of renesting) which is ascertained during annual breeding colony surveys.

32. Investigate population dynamics, life history, and movement of terns.

Banding and marking least tern chicks can provide information on age-class structure, mortality rates, and estimates of longevity. These factors can be used to predict long-range stability of tern populations. Such information will include the degree of colony fidelity (i.e., the extent to which birds return to the same breeding area year after year), the degree of shifts between breeding colonies or the establishment of new ones, the age at first breeding, techniques for aging young birds in colonies, life expectancy, factors affecting clutch size, renesting attempts, and breeding success.

4. Conduct research on California least tern to provide additional necessary information for tern management.

Studies are needed to provide information to make appropriate management decisions. Many of these studies will entail banding and color marking large numbers of least tern chicks.

41. Determine effects of environmental pollutants on least terns.

Adverse effects from pollutants may affect terns' egg producing

abilities, the viability of eggs, and the fish food supply on which both the adults and young depend. The recovery effort could be thwarted by environmental contaminants. More information on this aspect of tern biology is needed. A substantial pesticide threat may occur from chemicals used for mosquito larvicide control. These may have high invertebrate toxicities. It is conceivable that pesticides could alter the benthic communities to such an extent that fish production or availability could be changed drastically. Agricultural fields near estuaries could also be affected (Faatz[1], pers. comm.).

42. Determine factors affecting the choice of location for roosting, loafing, and feeding areas used during the breeding season and during post-breeding dispersal.

Because such areas need to be protected against adverse land and water uses, factors that determine site selection by the birds should be assessed.

43. Determine how much habitat is necessary to maintain the current population and the prime recovery objective.

This information will provide a more concise estimate of the amount of habitat needed to ensure recovery. Components of

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this determination include the number of hectares with the associated biomass of small fish being regularly used by the terns, the food requirements for a nesting pair, the minimum density of appropriate fish, and the amount of lagoons, bays etc. required to support a given number of terns through the nesting period (e.g., 100 pairs/40 ha of minimum fish density waters).

44. Identify potentially suitable nesting sites, including beach, landfill, salt pond and estuarine areas.

Wildlife biologists need additional information regarding what constitutes suitable nesting habitat so that they can concentrate management efforts (i.e. enhancement of potential nest sites) in such areas.

45. Identify factors causing colony disruption and nest site abandonment.

It is unfortunate that terns fairly frequently abandon nesting colonies. This tendency is especially prevalent early in the nesting season and has tentatively been correlated to disruption (mainly by predators). Early in the nesting season initial colony surveys should be done from a distance to minimize disturbance. A more detailed appraisal on the causes of disruption and abandonment of colony sites is needed so that remedial measures may be implemented.

46. Develop or refine management techniques for providing adequate nesting sites and implement techniques where needed.

Additional information is required on nest site management so that reproductive success can be enhanced.

461. Investigate nest site requirements of colonies.

If tern nest site requirements are thoroughly understood, appropriate nest enhancement procedures can be implemented.

462. Investigate methods of enhancing nesting sites of existing colonies.

Various types of nest enhancement procedures should be undertaken and evaluated so the most effective means of habitat improvement can be determined.

463. Investigate methods of constructing adequate nesting sites in potential breeding habitat.

Some areas of potential habitat will require rehabilitation. Construction techniques need to be refined so that they are economical and efficient.

5. Encourage the protection of breeding population outside the United States

Recovery of California least terns will be partly dependent on successful protection and management of those terns nesting in Baja California. Once the status, including distribution, numbers, and threats, has been determined, the importance of Mexican populations to overall least tern recovery can be ascertained.

51. Protect least tern population and habitats in Baja California.

California least terns are known to nest in Baja California. Suitable protection measures must be undertaken to ensure the terns' continued reproductive success in this area, thus aiding the recovery effort.

511. Determine colony locations and population size.

The first step in managing the Baja least terns is to determine the size and location of each colony. The number of breeding terns in Baja California is unknown, hence their potential contribution to the recovery effort can not be assessed at this time.

512. Identify least tern population and habitatprotection problems.

Each colony should be monitored and evaluated to determine what, if any, problems exist. Once the problems have been described then measures to counteract them can be developed and initiated. The security and future management plans for specific sites must be considered in the evaluation of the impact of Baja California's least terns on recovery.

513. Develop cooperative programs between the United States and Mexican governments for least tern protection and habitat preservation.

A cooperative program is necessary to coordinate the recovery effort for this subspecies and to ensure that appropriate conservation actions are taken by both parties.

52. Identify and protect key migration and winter habitats outside the United States.

Preliminary surveys have been conducted to identify wintering habitat of the California least tern. Additional work is needed to further define key migration and wintering habitat so it can be adequately protected and managed. This is particularly important because of a recent drastic (25% or more) decline in the number of terns returning from the wintering grounds to breed in the U.S. Without more precise

information on the location(s) and conditions on the wintering grounds, it is difficult to delineate the specific problems that are causing the decline in population numbers. Clearly, obtaining data on wintering birds is thus becoming increasingly important and crucial to tern conservation. The population cannot tolerate a yearly loss of such a large proportion of the adults.

6. Utilize existing laws and regulations protecting least tern and their habitat.

Recovery is dependent upon the judicious enforcement of rules and regulations designed to prevent losses of birds and to enhance population status.

61. Evaluate success of law enforcement.

To maximize least tern protection, an appraisal of the law enforcement strategy should be routinely conducted. Modifications in the strategy to increase efficiency can then be recommended.

62. Propose appropriate new regulations or revisions.

If it becomes evident that additional regulations or a modification of existing provisions are necessary to adequately protect terns, such changes should be expeditiously proposed.

7. Develop and implement a conservation education program regarding recovery of California least tern.

Public support is generally enhanced when the public is informed of the conditions of an endangered species and the steps necessary to conserve it. This may be accomplished through a series of pamphlets, informational signs posted near selected habitats and audio-visual programs for local schools.

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PART III

IMPLEMENTATION SCHEDULE

The schedule that follows is a summary of actions and costs for the California least tern recovery program. It is a guide to meet the objectives of the Recovery Plan, as elaborated upon in Part II, Action Narrative Section. This table indicates the general category for implementation, recovery plan tasks, corresponding step-down outline number, task priorities, duration of the tasks, which agencies are responsible to perform the tasks, and the estimated costs to perform the tasks. General categories and priority numbers are defined on the following page. Note that priority 3 tasks, contrary to the usual format of recovery plans, are included because recovery of this subspecies is well underway and few priority 1 items remain to be done. Implementing Part III is the action of the recovery plan, that when accomplished, will bring about the recovery of this endangered species.

GENERAL CATEGORIES FOR IMPLEMENTATION SCHEDULES

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Acquisition - A

1. Lease
2. Easement
3. Management Agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

RECOVERY ACTION PRIORITIES

1 = An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
2 = An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.
3 = All other actions necessary to provide for full recovery of the species.

[1] Continuous - once a task is begun it will continue.

Ongoing = currently underway.

[2] Agency abbreviations:

AF - U.S. Air Force

BCDC - San Francisco Bay Conservation and Development Commission

CDFG - California Department of Fish and Game

CDPR - California Department of Parks and Recreation

CE - Corps of Engineers

EPA - Environmental Protection Agency

FAA - Federal Aviation Administration

FS - Fauna Silvestre (Mexico)

LA City - Los Angeles City

LE - Law Enforcement (U.S. Fish and Wildlife Service)

NABC - Naval Amphibious Base, Coronado

OCHPBD - Orange County Harbor, Beaches and Park Department

RE - Refuges (U.S. Fish and Wildlife Service)

SDCPR - San Diego County Department of Parks and Recreation

SDGE - San Diego Gas and Electric

SDUPD - San Diego Unified Port District

SE - Endangered Species (U.S. Fish and Wildlife Service)

SLC - State Lands Commission

SWRCB - State Water Resources Control Board

USM - U.S. Marine Corps

USN - U.S. Navy

[3] TBD = to be determined

PART III
IMPLEMENTATION SCHEDULE
CALIFORNIA LEAST TERN RECOVERY PLAN

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)[1]	Responsible Agency[2] FWS Region	FWS Program	Other	Fiscal Year Costs (est.)[3] ($1,000's) 1	2	3	Comments and Notes
	Develop and implement management plans/programs for secure nesting habitat in 5 northern counties										
M3	Alameda Naval Air Station	1111	3	Ongoing			USN	10	11	12	
M3	Bair Island	1112	2	10			CDFG*	5.0	0.5	0.5	
M3	San Antonio Creek	1113	3	10			AF CDFG	2.0 2.0	1.0 1.0	0.5 0.5	
M3	Purisima Point	1114	3	Ongoing			AF*	0.5	0.6	0.7	
M3	Santa Clara River Mouth	1115	3	10			CDPR	2.0	1.0	0.5	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
M3	Mugu Lagoon	1116	3	Ongoing			USN	2	1	0.5	
M3	Venice Beach	1117	2	Ongoing			CDFG*		TBD		
							CDPR		TBD		
							LA City	0.5	0.6	0.7	
	Develop and implement least tern management plans/programs for secure nesting habitat in Orange County										
M3	Anaheim Bay (Seal Beach NWR)	1121	2	Ongoing		RE*		0.5	0.6	0.7	
M3	Huntington State Least Tern Natural Area	1122	2	Ongoing			CDPR*	0.5	0.6	0.7	
							CDFG		TBD		
M3	Bolsa Chica Ecological Reserve	1123	2				CDFG	2	1	0.5	
M3	Upper Newport Bay Ecological Reserve	1124	3	Ongoing			CDFG	75	10	1	
	Develop and implement management plans/programs for secure nesting habitat in San Diego County										

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs ($1,000's) 1	2	3	Comments and Notes
M3	San Mateo Creek	1131	3	10			CDPR USM	1 1	1 1	0.5 0.5	
M3	Aliso Creek	1132	3	Ongoing			USMC* CDFG	2	1	0.5	
M3	Santa Margarita River Mouth	1133	2	Ongoing			USM* CDFG	2	2 TBD	2	
M3	Buena Vista Lagoon	1134	3	Ongoing			CDFG* C. Oceanside	10.5	0.6 TBD	0.7	
M3	San Elijo Lagoon	1135	2	Ongoing			CDFG* SDCPR	1.5	1.6 TBD	1.7	
M3	Delta Beach	1136	3	Ongoing			USN* Leslie Salt (?)	0.5	0.6 TBD	0.7	
M3	San Diego Bay salt pond dikes	1137	2	3	1	SE	 CDFG* Western Salt Co.* SDUPD	 5	TBD 2 TBD TBD	 1	
M3	Tijuana River Estuary	1138	3	Ongoing	1	SE	 CDPR CDFG		TBD		
	Protect/secure nesting habitat now in private ownership										
A7	Aqua Hedionda Lagoon (eastern part)	11411	2	1			CDFG* SDCPR City of Carlsbad		TBD		Total cost 100K

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
A7	Los Penasquitos Lagoon	11412	2	3	1	SE	CDPR* CE CDFG C. of San Diego		TBD		
A7	Playa del Rey	11413	3	5	1	SE	CDFG* Summa Corp.		TBD		
A7	Bayfront end of "D Street Fill", Sweetwater Marsh	11414	2	5	1	SE	CDFG SDUPD	2	TBD 1 TBD	1	
A7	Oakland Airport	11415	2	5			CDFG		TBD		
	Manage when, and if, secured										
M3	Agua Hedionda (eastern part)	11421	2	Continous			CDFG*	2	1	1	
M3	Los Penasquitos Lagoon	11422	2	Continous			CDPR* SDGE	1 1	1 1	1 1	
M3	Playa del Rey	11423	3	Continous	1	SE	CDFG* Summa Corp.	0.5 1	0.5 0.5 TBD	0.5 0.5	
	Develop and implement management plans to establish secure nesting areas on public lands										

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs ($1,000's) 1	2	3	Comments and Notes
M3	North Island Naval Air Station	11431	3	Ongoing			USN	7.0	8.0	9.0	
M3	Chula Vista Wildlife Reserve	11432	3	Ongoing			SDUPD* CDFG	0.5	0.6 TBD	0.7	
M3	Oso Flaco Lake	11433	3	10			CDPR	2	1	0.5	
M7	Establish and maintain interagency coordinating team to manage breeding sites	1151	2	Continous	1	SE*	 CDFG	4 1	2 0.5	2 0.5	
M3	Annually maintain Crown Point Sanctuary	1152	3	Ongoing			CDFG City of San Diego*	3.0	0.5 TBD	0.6	
M3	Annually maintain breeding area at FAA Island	1153	1	Ongoing			FAA* CDFG	0.6	0.7 TBD	0.8	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
M3	Annually maintain and protect north Fiesta Island breeding areas.	1154	1	Ongoing			CDFG City of San Diego*		TBD		
M3	Annually maintain and protect Stoney Point nesting site.	1155	3	Ongoing			CDFG City of San Diego*	2	TBD 5	5	
M3	Establish and manage at 2 additional breeding sites at Cloverleaf and South Sea World Drive.	1156	2	Ongoing			CDFG City of San Diego*		TBD		
	Develop and implement management program that identify site protection problems for insecure colonies in Ventura, Los Angeles, and Alameda Counties										
M7	Coyote Hills	1161	3	Continous	1	SE	Leslie Salt (?)	0.5	0.6 TBD	0.7	
M7	Ormond Beach	1162	2	Ongoing			CDFG	2	1	1	
M7	Santa Clara River Mouth	1163	2	Ongoing			CDPR*	10.5	0.6	0.7	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) (1,000's) 1	2	3	Comments and Notes
M7	Cerritos Lagoon	1164	3	Ongoing			CDFG* Bixby Ranch Co.	10.5	0.6 TBD	0.7	
M7	Playa del Rey	1165	2	Ongoing			CDGF* Summa Corp.		TBD		
M7	Terminal Island-Reeves Field and the land-fill site.	1166	1	Ongoing	1	SE	 CE* CDFG	0.5 0.5 0.5	0.5 0.6 0.6	0.5 0.7 0.7	
	Develop and implement plans/programs that identify special site protection problems of insecure colonies and implement corrective action in San Diego County										
M7	San Diego International Airport	1171	3	5	1	SE	 FAA SDUPD*	0.5 0.5	0.5 0.6 TBD	0.5 0.7	
M7	Grand Caribe Island Coronado Cays	1172	3	5			CDFG*	0.7	0.6	0.5	
M7	D Street Fill	1173	2	10			CDFG* SDUPD/CE City of Chula Vista		TBD		
	Develop implement management plans/programs to construct and manage new nesting sites in protected areas										

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) (1,000's) 1	2	3	Comments and Notes
M3	Anaheim Bay (Seal Beach National Wildlife Refuge)	1211	2	5	1	RE	USN	20 10	3 2	3 2	
M3	Sunset Aquatic Park	1212	3	10			CDFG USN		TBD		
M3	Bolsa Chica Ecological Reserve	1213	3	Ongoing			CDFG* Signal Landmark Inc. (?)	1.0 1.0	1.0 1.1	1.5 1.2	
M3	Upper Newport Bay Ecological Reserve	1214	2	5			CDFG	30	10	5	
M3	Silver Strand, south end of San Diego Bay	1215	3	Ongoing			CDPR*	0.5	0.6	0.7	
M3	Naval Training Center, San Diego	1216	2	Continous			USN SDUPD	0.5	0.6 TBD	0.7	
M3	Marine Corps Recruiting Depot-San Diego	1217	3	Continous			USN		TBD		
	Develop and implement management plans/programs in non-secure habitats										
M3	Protect and manage San Dieguito Lagoon	1231	2	Ongoing			CDFG* City of Del Mar SLC		TBD		
M3	Protect and manage mouth of Santa Ana River (southeast area).	1232	3	Ongoing			CDFG CE*		TBD		

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
M3	Develop or refine management to provide nesting sites and implement techniques where needed	13	2	3			CDFG	3	3	3	
	Protect existing coastal feeding grounds of colonies										
	Maintain high water quality, minimize tideland fill and drainage projects, restore or improve tidal flow to wetlands to provide adequate feeding habitat:										
M3	Mugu Lagoon	2111	3	Ongoing			USN		TBD		
M3	Bolsa Bay	2112	3	Ongoing	1	SE	CDFG Signal-Landmark		TBD		
M3	Terminal Island	2113	2	Ongoing	1	SE	LA Port District CDFG* CE		TBD		
M3	Anaheim Bay	2114	3	Ongoing			USN CDFG		TBD		
M3	Los Penasquitos Lagoon	2115	3	Ongoing			CDPR* CDFG Landowner?		TBD TBD		

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Note
M3	Tijuana River Estuary	2116	3	Ongoing	1	SE RE*	 CDFG USN CDPR*		TBD		
M3	Investigate and implement actions to increase prey base	212	3	Ongoing	1	SE			TBD		
M3	Mouth of Santa Ana River, southeast area	2121	3	5			CE* CDFG	5	3	1	
M3	San Elijo Lagoon	2122	3	5			CDFG	5	3	2	
M3	Batiquitos Lagoon	2123	2	5			CDFG CDPR SLC	5	3 TBD TBD	2	
M3	Other areas as needed	2124	3	TBD	1		CDFG	10	5	5	
I2	Identify major feeding areas	213	2	3	1	SE	 CDFG*	2 3	2 3.5	3 4.0	
	Protect important non-nesting, feeding, and roosting habitats in San Luis Obispo and Los Angeles counties										
M3	Oso Flaco and Dunes Lakes	221	2	Ongoing	1		CDPR	2	2	2	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
M3	Santa Ynez River Mouth	222	2	Ongoing	1		CDFG	2	2	2	
M3	Harbor Lake	223	2	Ongoing	1		CDFG	2	2	2	
M3	Belmont Shores	224	3	Ongoing	1		CDFG	2	2	2	
M3	Identify and protect other habitats as needed	225	3	TBD	1	SE	CDFG		TBD		
	Protect important roosting habitat in San Diego County										
M3	Guajome Lake	231	2	Ongoing			CDFG	1	1	1	
M3	Lake Val Sereno	232	2	Ongoing			CDFG	1	1	1	
M3	Whelan Lake	233	2	Ongoing			CDFG	1	1	1	
M3	Santa Margarita River-O'Neill Lake	234	2	Ongoing			USM	1	1	1	
M3	San Luis Rey River	235	2	Ongoing			CE	1	1	1	
M3	Dairy Mart Ponds	236	2	Ongoing			CDFG	1	1	1	
M3	San Dieguito Lagoon and Buena Vista Lagoon	237	2	Ongoing			CDFG* CDPR	0.5 0.5	0.5 0.5	0.5 0.5	
M3	San Diego River Flood Control Channel	238	2	Ongoing			CDFG	1	1	1	
M3	Delta Beach	239	2	Ongoing			NABC	1	1	1	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
	Monitor population to determine status, distribution, and progress of management during breeding season										
I1	Determine breeding success	31	2	Ongoing	1	SE		8	9	10	Includes 311-313
							CDFG*	8	9	10	
I14	Investigate population dynamics, life history, and movement of terns by banding and marking	32	2	Ongoing	1	SE		2	2	2	
							CDFG*	2	2	2	
I12	Determine effects of environmental pollutants on least terns	41	3	Ongoing	1	CE		1.0	1.0	1.0	
							CDFG	1.0	1.0	1.0	
							EPA/SWRCR	1.0	1.0	1.0	
I3	Determine factors affecting choice of locations for roosting, loafing, and feeding during breeding and post-breeding seasons	42	2	Ongoing	1	SE		5	5	5	
							CDFG	5	5	5	
I2	Determine amount of habitat necessary to maintain current populations and recovery objective	43	3	TBD	1	SE					
							CDFG		TBD		
I2	Identify potentially suitable nesting sites	44	2	Ongoing	1	SE					
							CDFG		TBD		
I14	Identify factors causing colony disruption and nest site abandonment	45	2	Ongoing	1	SE					
							CDFG		TBD		

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
R3	Investigate nest site requirements	461	2	10	1	SE		5	5	5	
R4	Investigate methods to enhance nest sites in potential breeding habitat	462	2	10			CDFG*	5	5	5	
R4	Investigate methods to construct adequate nesting sites in potential breeding habitat	463	2	10			CDFG*	5	5	5	
M3	Encourage protection of population outside of U.S.	5	2	Ongoing	1	SE			TBD		
M3	Protect terns and habitat in Baja California	51	3	Ongoing	1	SE			TBD		
I1	Determine colony locations and population size in Baja	511	3	TBD	1	SE*	FS		TBD		
I14	Identify least tern population and habitat protection problems	512	2	TBD	1	SE*	FS		TBD		
O4	Develop cooperative program between U.S. and Mexico for tern protection	513	3	1	1	SE*	FS		TBD		
M3	Identify and protect key migration and winter habitat outside of U.S.	52	2	10	1	SE		5	5	5	

General Category	Plan Task	Task No.	Task Priority	Duration of Task (yrs)	Responsible Agency[1] FWS Region	FWS Program	Other	Fiscal Year Costs (est.) ($1,000's) 1	2	3	Comments and Notes
02	Utilize laws and regulations	6	2	Ongoing	1	LE	CDFG*	2.0 1.0	2.5 1.5	3.0 2.0	
02	Evaluate success of law enforcement	61	2	Ongoing	1	LE*	CDFG	0.5	0.5	0.5	
02	Propose appropriate new regulations or revisions	62	3	TBD	1	LE	CDFG		TBD		
01	Develop and implement a conservation education program	7	3	Contin-uous	1	SE	CDFG DPR	0.5 0.5 0.5	0.6 0.6 0.6	0.7 0.7 0.7	

EVALUATION OF BIOACCUMULATION FACTORS AND TRANSLATORS FOR METHYLMERCURY

March 2006

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Governor
State of California

Joan E. Denton, Ph.D.
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March 2006

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (U.S. EPA) has established an ambient water quality criterion for methylmercury in fish tissue of 0.3 ppm, for the protection of human health (U.S. EPA, 2001). A criterion based on fish tissue was considered appropriate for methylmercury, in part, because fish consumption is the major route of human exposure to this contaminant (U.S. EPA, 2001). As effluent standards are necessarily water-based, and must also account for the bioaccumulation of mercury in the aquatic environment, U.S. EPA drafted a report, National Bioaccumulation Factors for Methylmercury, (U.S. EPA, 2000) describing the derivation of national bioaccumulation factors[1] (BAFs) that can be used to convert between methylmercury tissue concentrations in various fish species and water concentrations for regulatory applications. The State Water Resources Control Board (SWRCB) funded the Office of Environmental Health Hazard Assessment to evaluate these national default bioaccumulation factors, as well as translators used to convert between different forms of mercury in water, and bioaccumulation factors derived from California data for mercury in fish and water compiled by Science Applications International Corporation (SAIC) for SWRCB into a SWRCB database.

OEHHA reviewed U.S. EPA's methods and results as presented in their report and describes their methodology, results, strengths and weaknesses of their approach, and its application to California water bodies in this report. OEHHA also reviewed the SWRCB database and BAF values, and developed alternate BAFs and translators based on California data that are analogous to those of U.S. EPA. OEHHA compared the U.S. EPA BAFs and translators to those based on California data and also tested the U.S. EPA values to determine how well they predicted fish tissue concentrations in California water bodies.

OEHHA found that U.S. EPA's methods and results met their goal of developing BAFs and translators that were broadly applicable, especially for lentic and lotic water bodies. U.S. EPA made a careful effort to compile available data and ensure quality control for the data they used. Despite their efforts, they were not able to compile data representative of all of the categories of aquatic environments and organisms. In particular, they were unable to develop BAFs for estuarine environments due to gaps in available data. U.S. EPA included some data from California in their database, but most of their data came from the Midwest United States and other areas where the source of mercury in water bodies was atmospheric deposition.

Examining data exclusively from California water bodies was an important step in evaluating whether BAFs and translators were applicable to California since the source of mercury in much of California has been legacy mercury and gold mining, and because environmental conditions in California water bodies may be different than in other areas in the U.S. EPA database. OEHHA recalculated California BAFs using the SWRCB California database. OEHHA also calculated translators for some forms of mercury using data available in this database. There were gaps in available data in the SWRCB database that prevented OEHHA from developing BAFs for some water body types (*e.g.* lentic) or trophic levels and translators for some forms of mercury in water. OEHHA developed BAFs for organisms in lotic environments and demonstrated that they

[1]A bioaccumulation factor is the ratio between the concentration of a chemical measured in an organism and the concentration of the same chemical in water. This ratio is derived from field-collected samples of organisms and water.

were very similar to the U.S. EPA BAFs. OEHHA also developed California estuarine BAFs for some trophic levels but there are no national values for comparison. OEHHA's estuarine values, however, were also similar to the national default values. Translators developed from the SWRCB California data were also similar to the U.S. EPA translators.

U.S. EPA developed translators and BAFs but did not test them to determine how accurately they predicted fish tissue mercury concentrations from water concentrations. OEHHA was able to test the U.S. EPA national translators and BAFs to see if they accurately predicted mercury levels in fish for several California lotic water bodies by using the SWRCB California database. OEHHA found that the national values predicted California values very well (*i.e.*, no statistical difference between measured and predicted mercury concentration) except for some water bodies where mercury concentrations in water were statistically higher. It was not possible to perform similar tests for fish in other types of water bodies because data were not available in the SWRCB database.

OEHHA has identified three alternatives for consideration by SWRCB when selecting BAFs and translators to use for California water bodies in order to implement the U.S. EPA ambient water quality criterion for methylmercury: 1) use the U.S. EPA BAFs and translators as developed by U.S. EPA; 2) use some BAF (*i.e.*, lotic BAFs) and translator values developed from the California database, and others developed by U.S. EPA; 3) before using BAFs and translators for a methylmercury criterion, institute a program of data gathering that would supplement existing data in the SWRCB California database and enable development and testing of additional BAFs and translators using California data from different types of water bodies throughout the state. Alternative 1 is a practical solution that could be implemented without collecting additional data and would be consistent with national implementation. Based on OEHHA's evaluation using available data, it will also yield predictions that are similar to measured concentrations of mercury in fish for many, but not all, lotic water bodies. It is unknown how well this alternative will work for other California water bodies. Alternative 2 is appealing because it would incorporate California data and values for lotic water bodies, but due to gaps in the data available in the current SWRCB database it would also require using national values for lentic water bodies and some translators. However, since OEHHA's evaluation found no significant difference between U.S. EPA and California values based on the existing database, there is no scientific basis to support this alternative over Alternative 1. Alternative 3 would require collecting additional data on mercury concentrations in water and biota before full implementation and should include establishing standards for sampling, analytical methods, and Quality Assurance/Quality Control before data collection begins. Additional data collection is important to consider because OEHHA was not able to test Alternative 1 for California lentic and estuarine water bodies using the current datasets and because some water bodies were identified where Alternative 1 did not work well.

SWRCB could consider using Alternative 1 on an immediate basis while collecting additional California data for mercury concentrations in fish and water to fill gaps in available data, help identify biogeochemical factors with the greatest impact on methylmercury production and bioaccumulation, and better characterize how these factors affect variability in BAFs and translators in a longer term effort to develop better BAFs and translators for California. In

particular more fish and water data are needed to fill gaps in available data for: 1) developing lentic BAFs and translators; 2) for developing estuarine translators and BAFs for estuarine Trophic Level 3 biota; and 3) to collect enough data to test lentic and estuarine BAFs and translators. SWRCB should consider prioritizing data collection based on which type(s) of water bodies are most impacted by regulatory implementation.

Collecting data that represent a broader geological and ecological coverage of water bodies is recommended to verify, explain, and expand OEHHA's observation that the U.S. EPA BAFs did not work well for water bodies with higher mercury concentrations (approximately $2x10^{-7}$ mg/L or more). The concentration of mercury from these water bodies was found to be more than one standard deviate from the mean for data used in testing from the SWRCB dataset. This concentration and level of variation should not be considered as screening points for outlier water bodies. Rather this observation suggests that there are water bodies and conditions in California for which the U.S. EPA BAFs and translators may not work well or be appropriate. Additional data are needed to identify these water bodies and conditions (*e.g.,* salinity or mercury source) so that the national BAFs are not applied to them and so that better translators and BAFs are developed for them.

Collecting additional California data is also recommended to better characterize variability in mercury concentration in California water bodies and biota. Natural variability in mercury concentrations will occur in water and fish from any water body. Statistical tests, such as those used by OEHHA to test BAF predictions, will account for this variability when testing for true differences among water bodies. But statistical testing is not typically used in regulatory applications and permits. One way to recognize variability in a regulatory setting would be to collect more data to separate variablility due to environmental differences from variablility common to all environments and use this to further verify predictions and set regulatory limits.

Further data and testing would put BAFs and translators on a more sound scientific footing in California and provide data to determine whether the mining source of much of the mercury in California water bodies (at least in the Central Valley, northern California, and the Coast Ranges) lead to significant differences in BAFs and translators for some parts of the state.

1. INTRODUCTION

The U.S. Environmental Protection Agency (U.S. EPA) has established an ambient water quality criterion for methylmercury in fish tissue of 0.3 ppm, for the protection of human health (U.S. EPA, 2001). This is the first ambient water quality criterion established in tissue rather than in water. A criterion based on fish tissue was considered appropriate for methylmercury, in part, because fish consumption is the major route of human exposure to this contaminant (U.S. EPA, 2001). As effluent standards are necessarily water-based, and must also account for the bioaccumulation of mercury in the aquatic environment, U.S. EPA drafted a report, National Bioaccumulation Factors for Methylmercury, (U.S. EPA, 2000) describing the derivation of national bioaccumulation factors[2] (BAFs) that can be used to convert between methylmercury tissue concentrations in various fish species and water concentrations for regulatory applications. This draft report has not been finalized, but a draft implementation plan is being developed that explains a national policy to use methylmercury bioaccumulation factors in water quality regulations and permit writing (personal communication, Diane Fleck, U.S. EPA Region 9). Although the U.S. EPA report and related policies have not been adopted, the California State Water Resource Control Board (SWRCB) has begun consideration of the national bioaccumulation factors and an implementation policy to use such factors for regulation of methylmercury in ambient waters in California.

As bioaccumulation factors for different fish species may differ significantly based on environmental pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology in individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989), the SWRCB funded the Office of Environmental Health Hazard Assessment (OEHHA) to evaluate the derivation of national bioaccumulation factors for methylmercury and the potential for using these factors, or alternate factors based on California data, for California water bodies. OEHHA has organized this evaluation into three parts: 1) a description and critique of the national bioaccumulation factors; 2) a description and critique of California bioaccumulation factors calculated from a database of California water and tissue concentrations (referred to in this report as the SWRCB database) compiled by Science Applications International Corporation (SAIC) for SWRCB; and 3) a description and critique of a simulation in which national and California bioaccumulation factors are used to predict tissue levels from water concentrations in sample California water bodies. As part of this report, OEHHA also describes and critiques national and California translators[3] for mercury and methylmercury where possible.

[2] A bioaccumulation factor is the ratio between the concentration of a chemical measured in an organism and the concentration of the same chemical in water. This ratio is derived from field-collected samples of organisms and water.

[3] Translators are ratios between one form of a chemical and another form in the same media. In this case, the translators are for different forms of mercury in water and are based on field-collected samples.

2. U.S. EPA'S DEVELOPMENT OF BAFs FOR LENTIC AND LOTIC ENVIRONMENTS

U.S. EPA's BAF report (U.S. EPA, 2000) served as the primary source of information on U.S. EPA's derivation of national bioaccumulation factors and translators for OEHHA's evaluation. A brief description of the national values for BAFs and translators was also included in the final document establishing the methylmercury tissue criterion (U.S. EPA, 2001). U.S. EPA has subsequently published a final technical support document describing methods to develop bioaccumulation factors for a variety of chemicals (U.S. EPA, 2003). U.S. EPA stated that the goals for developing national methylmercury BAFs were to "represent the long-term [central tendency] bioaccumulation potential of methylmercury in aquatic biota that are commonly consumed by humans throughout the United States," and "to be applicable under as many circumstances and to as many water bodies as possible" (U.S. EPA, 2000). The national methylmercury BAFs would serve as default values that could be used when regional or other local values are not available.

U.S. EPA selected studies containing empirical field-collected data for co-located mercury or methylmercury concentrations in fish and water from a literature search and created a database that they used to calculate BAFs for aquatic organisms in Trophic Level 2, 3, and 4 (*i.e.*, the trophic levels[4] used to set the tissue criterion). Studies of lotic, lentic, and estuarine water bodies were included in the database. Study data had to meet certain standardized criteria for analytical chemistry data (*e.g.*, be reproducible, have a low detection limit, minimal matrix interferences, and use appropriate analytical techniques) to be included in the database. In most cases, methylmercury results collected prior to 1990 were not used because they did not meet these criteria. A cutoff was set for the literature review and studies published after April 1999 were not included in the literature search or resulting database. The database itself was not available for OEHHA to review, so it was not possible to determine exactly which data were used by U.S. EPA, or to carry out calculations using the raw database data. Instead, it was necessary to use the summary information in the draft U.S. EPA document (U.S. EPA, 2000) to describe the U.S. EPA data and carry out comparative calculations.

U.S. EPA used methodology from the Ambient Water Quality Criteria Derivation Methodology Human Health Technical Support Document, Final Draft (U.S. EPA, 1998) and the Mercury Study Report to Congress (U.S. EPA, 1997a) to derive their national BAF and translator values. Fish were assigned to trophic levels based on U.S. EPA guidance (U.S. EPA, 1995) and information from the selected studies. There were some exceptions to these methods and guidelines. In some cases, zooplankton, which are not consumed by humans, were used to calculate Trophic Level 2 BAFs. And in other cases, mercury concentration data in Trophic Level 3 and 4 fish were based on whole body data or tissue samples not clearly identified as

[4] Trophic means eating. Trophic levels are steps in a food chain characterized by feeding interactions. Energy moves up the food chain from lower to higher trophic levels as a result of organisms in one level feeding on those in a lower level. Organisms in Trophic Level 1 are primary producers that fix energy in an ecosystem (*e.g.*, plants and other organisms that fix energy. Trophic Level 2 organisms are herbivorous and feed on the primary producers. In aquatic ecosystems Trophic Level 3 organisms eat the herbivores and are forage fish for the next level. Trophic Level 4 organisms are carnivorous and eat primarily Trophic Level 3 organisms. In aquatic ecosystems these are the top predatory fish. Humans mostly eat fish and other aquatic organisms from Trophic Level 3 and 4.

fillet, muscle, whole body, or other tissue types. U.S. EPA attempted to treat all samples equally when deriving trophic level BAFs by first calculating individual mean BAFs for species in Trophic Level 3 and 4 within studies and then calculating a mean for all species in the same trophic level. This was not always possible for Trophic Level 2 because zooplankton collections contain a mix of species. It is not possible to describe the treatment of data and samples in detail without the full database and associated information. U.S. EPA expressed both species and trophic level BAFs as unweighted geometric means. The U.S. EPA BAF report does not discuss statistical testing of the distributions of individual studies or the database data at the species or trophic level, but states that geometric means were used primarily because the factors underlying BAF variability were believed to be multiplicative rather than additive, and also in part for convenience (U.S. EPA, 2000).

U.S. EPA derived BAFs using the ratio of methylmercury in field-collected data from biota and water as shown in Equation 1. Mercury in biota was most often measured and reported as total mercury (which can include inorganic and methylmercury). When only total mercury was reported in studies, U.S. EPA made assumptions about the percent of total mercury that was methylmercury for organisms at Trophic Levels 2, 3, and 4 in different environments. Equation 1 is a simple empirical model estimating the magnitude of accumulation of methylmercury from water into biota (*e.g.*, zooplankton and fish). BAFs calculated using this equation only require two parameters (a tissue concentration and a water concentration) and have units of L/kg because generally mercury concentrations in water are reported in mg/L and concentrations in biota are reported in mg/kg (wet weight). More complex mechanistic models that use multiple parameters to model individual steps in methylmercury production, uptake, and accumulation have also been used to estimate the relationship between methylmercury in water and biota (Hope, 2003; Kamman, *et al.*, 2003). More complex models would require a great deal more data than was available in most studies in the U.S. EPA database.

Equation 1.

$$\text{BAF, L/kg} = \frac{\text{mercury in biota, mg/kg}}{\text{dissolved methylmercury in water, mg/L}}$$

Using Equation 1 and data in their database, U.S. EPA calculated BAFs for organisms in lentic (*e.g.*, lakes) and lotic (*e.g.*, rivers) water bodies for the trophic levels used to establish the ambient water criterion (Trophic Levels 2, 3, and 4) for methylmercury (U.S. EPA, 2001). U.S. EPA chose to combine the BAFs at the same trophic level for lentic and lotic water bodies into one national BAF for each trophic level. U.S. EPA did not derive BAFs for the estuarine environment because of insufficient data.

U.S. EPA suggests that the national BAFs are functional default values that can be used when more representative regional, local or site-specific BAFs are not available (U.S. EPA, 2003). BAFs can be used to solve for the numerator or denominator in the above equation when the other is known, *i.e.*, by using the appropriate BAF, a concentration of methylmercury in biota can be calculated from known dissolved methylmercury concentrations in water, or a water

concentration of dissolved methylmercury can be calculated from known biota methylmercury concentrations.

U.S. EPA also used data from their database to calculate national translator values to convert between various forms of mercury in water (*e.g.*, between total mercury and dissolved methylmercury). Their translator values were calculated as simple ratios between one mercury form and another. U.S EPA calculated separate geometric mean national translators for lentic and lotic environments (U.S. EPA, 2000). U.S. EPA did not discuss why they did not combine translators as they had done for national BAFs. Translators were essential to the U.S. EPA's derivation of BAFs because many measurements of water mercury concentrations in studies included in the U.S. EPA database were for a form other than dissolved methylmercury. Initially, U.S. EPA calculated BAFs based on studies that had directly measured dissolved methylmercury in water; these were "directly estimated" BAFs. U.S. EPA then used the national translators to convert water measurements from other studies into dissolved methylmercury to calculate additional BAFs. These were termed "converted" BAFs, and using them increased the number of studies and data in the U.S. EPA database. U.S. EPA combined directly estimated and converted BAFs to derive the national values. U.S. EPA's derivation of the national BAFs for Trophic Levels 2, 3, and 4 is discussed in more detail below. U.S. EPA did not develop BAFs for Trophic Level 1 as these primary consumers are not normally eaten by humans.

Directly estimated BAFs for lentic or lotic environments are those from studies where dissolved methylmercury was measured in water and then used in the calculation of the BAF. U.S. EPA defined the directly estimated BAF for each trophic level as the average methylmercury concentration (often measure as total mercury) accumulated by all possible routes of exposure in organisms of that trophic level, divided by the average directly measured dissolved methylmercury concentration in water.

Converted BAFs for lentic or lotic environments, on the other hand, were defined as the average methylmercury concentration in each trophic level (often measured as total mercury) accumulated by all possible routes of exposure, divided by the dissolved methylmercury concentration in water obtained from conversion of measured total mercury to dissolved methylmercury using the appropriate translator determined from other studies.

2.1 U.S. EPA BAFs FOR LENTIC ENVIRONMENTS

2.1.1 Directly Estimated Trophic Level 2 BAFs, Lentic Environments

The BAFs for zooplankton in lentic environments for Trophic Level 2 are listed in Table 3-1 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). Two studies were used to develop the BAFs: one, which evaluated 15 lakes in Wisconsin (Watras *et al.*, 1998), and another, which surveyed 12 lakes in northeast Minnesota (Monson and Brezonick, 1998). As noted above, total mercury, rather than methylmercury, was measured in zooplankton and Trophic Level 2 organisms in many studies. In order to calculate BAFs for these and other studies in their database, U.S. EPA assumed that 44 percent of the measured total mercury in biota in lentic environments for this trophic level was methylmercury. U.S. EPA calculated

geometric mean BAF values for the Wisconsin and Minnesota studies of 42,400 L/kg and 172, 764 L/kg, respectively, and a combined geometric mean BAF of 85,600 L/kg.

2.1.2 Directly Estimated Trophic Level 3 BAFs, Lentic Environments

The U.S. EPA assumed that 100 percent of the mercury measured as total mercury in this trophic level was methylmercury. BAFs for this trophic level (forage fish) were developed from five studies and are listed in Table 3-2 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). U.S. EPA derived a combined BAF of 504,000 L/kg for shiner and yellow perch in 15 Wisconsin lakes using data from Watras *et al.*, (1998). Using data from Becker and Bigham (1995), U.S. EPA derived a BAF of 666,666 L/kg for gizzard shad from Lake Onondaga, New York. A BAF of 1,460,000 L/kg for yellow perch at Lake Iso Valkjarvi, Finland, was generated from Rask and Verta (1995), while a combined BAF of 1,530,000 L/kg was established for silversides and juvenile bass in Clear Lake, California, using data from Suchanek *et al.* (1993). The Suchanek data include silversides, a fish not usually consumed by humans. It is, nevertheless, a species that probably falls in this trophic level. Finally, U.S. EPA used data from Mason and Sullivan (1997) to develop a BAF of 4,170,000 L/kg for bloater in Lake Michigan. The geometric mean BAF values for these five studies ranged from 504,000 L/kg to 4,170,000 L/kg, a difference of less than 10-fold despite the wide geographic distribution of these studies (United States and Finland). The overall combined geometric mean BAF determined by U.S. EPA for this trophic level was 1,260,000 L/kg.

2.1.3 Directly Estimated Trophic Level 4 BAFs, Lentic Environments

Fish in Trophic Level 4 are predatory and feed predominantly on other fish. U.S. EPA assumed that the measured total mercury in these species was 100 percent methylmercury. Four North American studies were used in the BAF calculations; results are summarized in Table 3-3 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). U.S. EPA derived a combined BAF of 4,000,000 L/kg for smallmouth bass and walleye from Lake Onondaga, New York based on data in Becker and Bigham (1995), and an overall BAF of 5,860,000 L/kg for northern pike and walleye in four lakes in Manitoba, Canada, studied by Jackson (1991). Using data from Suchanek, *et al.*, (1993) from Clear Lake, California, U.S. EPA derived a BAF of 8,060,000 L/kg for largemouth bass. And finally, U.S. EPA used data from Mason and Sullivan (1997) to derive a BAF of 11,400,000 L/kg for lake trout from Lake Michigan. The BAFs for these studies ranged from 4,000,000 L/kg to 11,400,000 L/kg, a difference of less than three-fold. The geometric mean BAF for these studies was 6,800,000 L/kg.

2.1.4 Converted Trophic Level 2 BAFs, Lentic Environments

When mercury was measured as total mercury, U.S. EPA assumed that 44 percent was methylmercury for this trophic level. Five studies, all from North America, were used in these BAF calculations. The study results are summarized in Table 5-4 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). U.S. EPA derived an aggregate BAF of 61,757 L/kg, for zooplankton from 15 Wisconsin lakes using data from Watras *et al,* (1998). A BAF of 104,405 L/kg for zooplankton collected on an 80 μm filter in several lakes in the Experimental Lakes Region in NW Ontario, Canada, was derived from Paterson *et al.* (1998). A second BAF of 283,850 L/kg for zooplankton collected on a 400 μm filter was also derived

from Paterson *et al.*, (1998). An aggregate BAF for zooplankton (filter size >300 μm) from 12 lakes in Minnesota of 127,000 L/kg was developed from Monson and Brezonick (1998); a second BAF of 326,264 L/kg for plankton (filter size[1] not reported) from Tamarack Lake, Minnesota, was derived from data from the same study. The BAFs from these studies ranged from 61,757 to 326,264 L/kg, a difference of slightly more than six-fold. The unweighted BAF geometric mean for these studies was 149,960 L/kg.

2.1.5 Converted Trophic Level 3 BAFs, Lentic Environments

U.S. EPA assumed that measured total mercury was 100 percent methylmercury for this trophic level. Data from the four studies used to derive BAFs for this trophic level are summarized in Table 5-5 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). All studies were from the Midwestern United States. An aggregate BAF of 734,095 L/kg for shiner and yellow perch from 15 Wisconsin lakes was derived from Watras *et al.* (1998). Data from Glass *et al.* (1992) were used to derive a BAF of 1,022,326 L/kg for yellow perch from Sand Point Lake, Minnesota, and a BAF of 1,297,052 L/kg for yellow perch from Crane Lake, Minnesota. Finally, a BAF of 3,262,643 L/kg was derived for young-of-the-year bluegill (*i.e.*, fish in the same age cohort that were less than one year old) at Tamarack Lake, Minnesota, based on data from Monson and Brezonick, (1998). These immature bluegill had the highest BAF in the reported studies, although they are too small for human consumption. BAFs in this age class of fish might reflect high intake prior to subsequent growth dilution. Some unknown amount of variation will be introduced when studies using fish of different ages and sizes are combined because mercury levels in fish are known to vary with age and size (Wiener, *et al.*, 2003). The geometric mean BAF value for these studies was 1,330,000 L/kg, with values ranging from 734,095 to 3,262,643 L/kg. This less than five-fold range, while still broad, is smaller than the approximately 10-fold range for directly measured BAFs in Trophic Level 3 fish. The closer geographic proximity of these studies and similarities in species used to derive BAFs might account, in part, for the tighter range. However, the results also show that there remains a broad range in BAFs from different lakes even when the lakes are from a more restricted geographic area.

2.1.6 Converted Trophic Level 4 BAFs, Lentic Environments

U.S. EPA assumed that 100 percent of measured total mercury was methylmercury for this trophic level. BAF values from two studies are summarized in Table 5-6 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). A BAF of 3,954,284 L/kg for walleye from various unspecified Lakes in Minnesota was derived from Glass *et al*. (1999), and a BAF of 4,203,000 L/kg was derived for pike from the same study. The geometric mean for these data was 4,100,000 L/kg.

[1] The US EPA did not regularly report filter sizes for each study. When they were reported, they are noted. Different size filters will capture different sizes and kinds of planktonic organisms. This introduces an unknown amount of variability in BAFs for this trophic level.

2.1.7 Combined Direct and Converted BAFs, Lentic Environments

The U.S. EPA combined the direct and converted BAFs for Trophic Levels 2, 3, and 4 for lentic ecosystems to obtain the values presented in Table 1 of this report. U.S. EPA stated that it was justified to combine the direct and converted data into a composite value because, when graphically displayed, the data appeared to be in the same range. U.S. EPA did not statistically test for differences in the means between direct and converted BAFs for each trophic level. Statistical testing may have been limited by the available small dataset.

The differences between the geometric mean direct and converted BAFs in Trophic Levels 2, 3, and 4 were less than two-fold for each trophic level. For Trophic Levels 2 and 3, the converted BAF is higher than the directly measured BAF. For Trophic Level 4, the directly measured BAF was higher than the converted BAF. The combined geometric mean for direct and converted BAFs shows that the BAF for Trophic Level 3 is about 10-fold greater than that for Trophic Level 2 (1,115,000 vs. 127,000 L/kg), and the BAF for Trophic Level 4 is about five-fold greater than the BAF for Trophic Level 3 (5,740,000 vs. 1,115,000 L/kg).

Table 1. Direct and converted Bioaccumulation Factors (L/kg) for trophic levels in the lentic environment*

Trophic level	**2**		**3**		**4**	
BAF	Direct	Converted	Direct	Converted	Direct	Converted
GM[1/]	85,600	150,000	1,260,000	1,330,000	6,800,000	4,080,000
Combined GM[2/]	127,800		1,115,000		5,740,000	

1 GM: Geometric Mean
2 Geometric Mean (GM) after combining direct and converted BAFs for the lentic environment

. *Summarized from Tables 5-12, 5-14 (U.S. EPA, 2000)

2.2 U.S. EPA BAFs FOR LOTIC ENVIRONMENTS

2.2.1 Directly Estimated Trophic Level 2 BAFs, Lotic Environments

U.S. EPA assumed that 49 percent of the total mercury measured in organisms in lotic environments at this trophic level was methylmercury. U.S. EPA used data from three studies to derive these BAFs. Data from a study in the North Florida Everglades reported by Cleckner *et al.*, (1998) for whole body fish samples from three species (*Gambusia sp*., *Heterandia formosa*, and *Lucanian goodie*) were combined to obtain a BAF of 34,474 L/kg. Another study by Miles and Fink, (1998), also in the North Florida Everglades, was used to derive a BAF of 271,831 L/kg. Finally, a BAF of 608,728 L/kg for stonerollers, which are zooplankton, was derived from a study in East Popular Creek, Tennessee (Hill *et al.*, 1996). The unweighted geometric mean for these studies was 178,678 L/kg. Since only three studies met U.S. EPA's criteria, fish and zooplankton were used for derivation of the BAF for this trophic level. These data are listed in Table 5-7 of the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000).

2.2.2 Directly Estimated Trophic Level 3 BAFs, Lotic Environments

U.S. EPA assumed that 100 percent of the measured total mercury was methylmercury for this trophic level (forage fish). Studies by Lores *et al.* (1998) in South Florida canals provided data for the following BAFs: spotted tilapia: 334,325 L/kg; bluegill: 1,286,156 L/kg; and spotted sunfish: 1,472,669 L/kg. Data for bluegills from a study in the North Florida Everglades (Miles and Fink, 1998) yielded a BAF of 577,465 L/kg. Data from studies on creeks in Tennessee yielded a BAF of 2,026,609 for shiner (Hill *et al.*, 1996) and 4,863,263 L/kg for redbreast (DOE, 1997). A second BAF for redbreast of 11,250,000 L/kg was also derived (DOE, 1997). The geometric mean for these data was 1,636, 298 L/Kg, with a substantial range of about 34-fold. These data are presented in Table 4-2 in the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000).

2.2.3 Directly Estimated Trophic Level 4 BAFs, Lotic Environments

U.S. EPA assumed that 100 percent of the measured total mercury was methylmercury for this trophic level (piscivorous fish). Two studies were used to estimate the BAF for this trophic level. One study of largemouth bass in the Florida Everglades yielded a BAF of 985,915 L/kg (Miles and Fink, 1998). Another study of largemouth bass in some South Florida Canals yielded a BAF of 6,464,028 L/kg (Lores *et al.*, 1998). The geometric mean for these data is 2,524,477 L/kg. These data are presented in Table 4-3 in the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000).

2.2.4 Converted Trophic Level 2 BAFs, Lotic Environments

U.S. EPA assumed that 49 percent of the measured total mercury was methylmercury for this trophic level. U.S. EPA used three studies to derive the BAF for this trophic level. Data from a study in the Tom River in Siberia (Papina, *et al.*, 1995) yielded a BAF of 8,661 L/kg for zooplankton. Data from Stober *et al*. (1995) yielded a BAF of 105,128 L/kg for mosquitofish in South Florida Everglade canals. Finally, data from Miles and Fink, (1998) from the north Florida Everglades yielded a BAF of 260,811 L/kg, also for mosquito fish. The unweighted geometric mean for these data was 62,000 L/kg, with a nearly 30-fold difference in converted BAF values for this trophic level. Data are listed in Table 5-8 in the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000). The small number of studies available and wide geographic range may have contributed to the difference in the BAFs between the studies.

2.2.5 Converted Trophic Level 3 BAFs, Lotic Environments

U.S. EPA assumed that 100 percent of the measured total mercury was methylmercury for this trophic level. Acceptable data from seventeen studies were used from various geographic regions for this BAF. Six studies in the Tom River in Siberia, Papina *et al.*, (1995) yielded the following BAFs for six different species: grayling: 35,238 L/kg; carp: 52,857 L/kg; roach: 70,476 L/kg; perch: 79,286 L/kg; dace: 132,143 L/kg; and bream: 211,429 L/kg. Data from Glass *et al.* (1992), for St. Louis River in Minnesota yielded the following BAFs for five different species: yellow perch: 345,622 L/kg; Johnny darter: 391,705 L/kg: log perch: 460,829 L/kg; spottail shiner: 691,244 L/kg; and emerald shiner: 921,659 L/kg. Studies in South Florida Canals by Lores *et al* (1998) yielded data to derive BAFs for spotted sunfish (524,381 L/kg),

bluegill (933,810 L/kg), spotted tilapia (1,132,656 L/kg), and mayan cichlid (1,326,049 L/kg). Data from Miles and Fink (1998) were used to derive a BAF for bluegill in the North Florida everglades of 1,130,723 L/kg. Lastly, a BAF of 1,499,688 L/kg for a perch/roach mix from the Kokenmaenjoki River Estuary, Finland, was derived from Schultz *et al.* (1995). This data set is the largest of all those used for either direct or converted estimation of BAF values and the data were listed in Table 5-9 in the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000). Although additional data might yield a more representative overall BAF, the studies do include the broadest geographic distribution of water bodies of any trophic level category. BAFs range more than 40-fold from the grayling (35,238 L/kg) in the Tom River in Siberia to 1,499,688 L/kg for the perch/roach found in the Kokenmaenjoki River Estuary, Finland. The broad geographic distribution and related environmental differences may contribute to this wide range. The geometric mean for these data is 346,613 L/kg.

2.2.6 Converted Trophic Level 4 BAFs, Lotic Environments

U.S. EPA assumed that 100 percent of the measured total mercury was methylmercury for this trophic level. Data from studies in the Tom River, Siberia (Papina *et al.*, 1995) yielded BAF values for burbot and pike of 96,905 and 352,381 L/kg, respectively. A BAF for bass from North Florida Everglades of 1,930,502 L/kg was derived based on data in Miles and Fink (1998), while a BAF value of 7,308,573 L/kg for pike from the Kokenmaenjoki River Estuary, Finland, was derived from the data of Schultz *et al*. (1995). Finally, a BAF of 10,401,681 L/kg for largemouth bass was derived from Lores *et al*., (1998). The unweighted geometric mean for these data was 1,380,361 L/kg, and the data were listed in Table 5-10 in the National Bioaccumulation Factors for Methylmercury U.S. EPA, (2000).

2.3 COMBINED DIRECT AND CONVERTED BAFs FOR LOTIC ENVIRONMENTS

The U.S. EPA combined the direct and converted data for BAFs for Trophic Levels 2, 3 and 4, respectively, in lotic ecosystems to obtain the values presented in Table 2 in this report. The rationale expressed by the U.S. EPA for the combination of the direct and converted data into a composite value for this ecosystem is that the data, when graphically displayed, appeared to be in the same range. When the direct and converted BAFs are compared for these trophic levels, all converted values are less than directly measured values with the differences ranging from about two- to four-fold. For example, the direct and converted BAFs for Trophic Level 2 are 179,000 and 61,900 L/kg, respectively, a difference of slightly less than three-fold. The combination of the direct and converted BAFs for Trophic Level 2, 3, and 4 are 105,000, 517,000 and 1,240,000 L/kg, respectively.

Table 2. Direct and converted Bioaccumulation Factors (L/kg) for trophic levels in the lotic environment*

Trophic level	2		3		4	
BAF	Direct	Converted	Direct	Converted	Direct	Converted
GM[1/]	179,000	61,900	1,640,000	346,000	2,520,000	1,380,000
Combined GM[2/]	105,000		517,000		1,240,000	

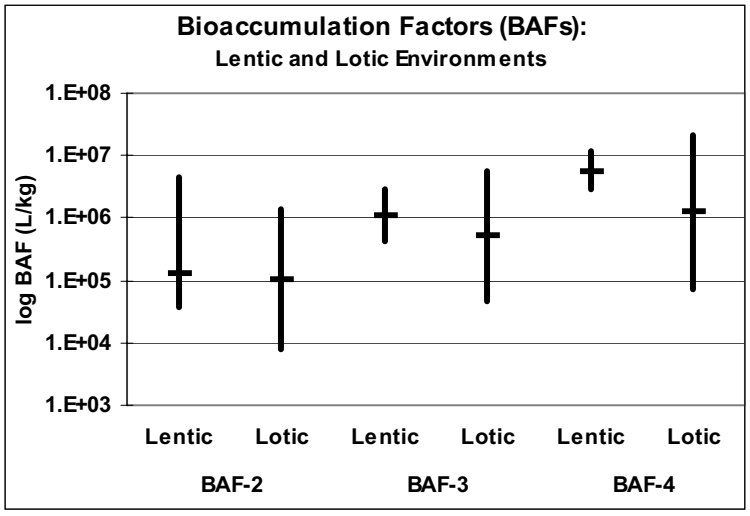
1 GM: Geometric Mean
2 Geometric Mean (GM) after combining direct and converted BAFs for the lotic environment

* Summarized from Tables 5-13 and 5-14 (U.S. EPA, 2000)

2.4 COMBINATION OF LENTIC AND LOTIC BAFs TO DERIVE NATIONAL BIOACCUMULATION FACTORS

The U.S. EPA, after examining the data for the combined lentic and lotic BAFs at each trophic level, decided that it was appropriate to combine lentic and lotic BAFs. The primary reason given by the U.S. EPA for combining BAFs for lentic and lotic environments was that there was no difference between these BAFs when tested statistically ($p > 0.05$). Figure 1 shows the overlap at the lower and upper bounds (5^{th} and 95^{th} percentiles) of the distributions of lentic and lotic BAFs at each trophic level for the U.S. EPA geometric mean BAFs.

Figure 1



BAF-2, BAF 3, and BAF-4 are for Trophic Level 2, 3, and 4 biota, respectively.
The mean values used to construct this figure above are from U.S. EPA (2000) as shown in the Table 3.
The horizontal bar is the geometric mean.
Vertical bar is the 5^{th} to 95^{th} percentile.

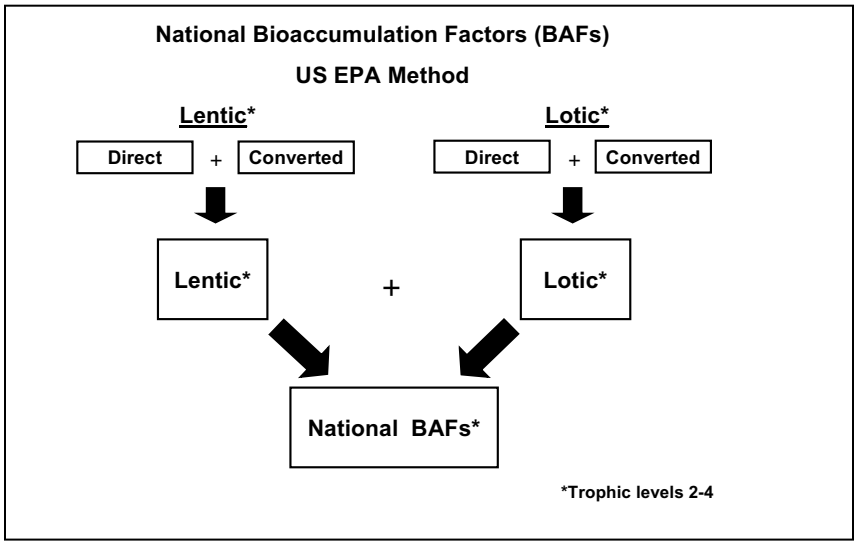
Table 3. National Bioaccumulation Factors (L/kg) for fish in Trophic Levels 2, 3 and 4

	2		3		4	
BAF	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic
GM[1/]	127,800	105,000	1,115,000	517,000	5,740,000	1,240,000
Combined GM[2/]	117,000		680,000		2,670,000	

1 GM: Geometric Mean for each environment
2 Geometric Mean (GM) after combining lentic and lotic BAFs for both environment

Figure 2 diagrams the process that U.S. EPA utilized to derive the national BAFs for Trophic Levels 2, 3 and 4. The national BAFs are applicable to both lotic and lentic aquatic environments (U.S. EPA, 2000). U.S. EPA did not develop estuarine BAFs because their data set contained insufficient data of adequate quality.

Figure 2



2.5 U.S. EPA's DEVELOPMENT OF TRANSLATORS

Mercury, like other metals in water, can occur in a number of physical and chemical forms. Physically, mercury can be freely dissolved or bound to organic matter or particles suspended in water. And chemically, mercury can be found as elemental mercury, inorganic ionic mercury, or organic mercury (*e.g.*, methylmercury or dimethylmercury). Thus, mercury in water can be separately characterized physically (*e.g.*, total suspended mercury including all chemical forms) or chemically (total methylmercury including all physical forms). In most cases "total mercury" refers to a measured total concentration of all physical and chemical forms in water. U.S. EPA determined that dissolved methylmercury was the most relevant form of mercury for bioaccumulation and calculating BAFs (U.S. EPA, 2000 and 2003). But dissolved methylmercury was not always the form measured in the studies U.S. EPA identified for

inclusion in their database. Hence, translators were necessary to convert between other forms of mercury measured in water and dissolved methylmercury for BAF calculations. In addition, U.S. EPA intends to use translators for similar conversions for regulatory purposes to "convert the dissolved criteria back to a total metal concentration for use in the waste limit calculations. The translator is the fraction of the total recoverable metal in the downstream water that is dissolved, f_d. The translator is used to estimate the concentration of the total recoverable metal in the effluent discharge that equates to the criterion concentration [methylmercury] in the receiving water body."[5]

U.S. EPA used a general equation for calculating fractional translators (f_d s) for metals. This is the ratio between the total measurable concentration (C_t) of a metal in water and the dissolved concentration (C_d) of the metal in water: $f_d = C_d/C_t$. U.S. EPA was most interested in translators that would yield the dissolved fraction of methylmercury (f_{dmHg}). These translators would always be based on a measured concentration of dissolved methylmercury (C_{dmHg}) and either a total concentration in water based on measured total mercury (C_{tHg}) or measured total methylmercury (C_{tmHg}). The best way to estimate dissolved mercury forms (either methylmercury or inorganic) is by passing the water through filters with micron-sized pores and collecting the water and the filter. The dissolved concentration of one or more mercury species is measured in the water that passes through the filter. The total concentration of the same species is the sum of the concentrations of those species measured on the filter and those in the water that passes through.

U.S. EPA used measured values for C_d and C_t determined for the mercury species of interest from studies in their database. They used data criteria to select studies for the development of translators that were similar to the data requirements for the development of BAFs. Briefly, the studies must use clean techniques, have adequate Quality Assurance/Quality Control (QA/QC) and the methods must have a detection limit that unambiguously allows the quantitation of low (10^{-7} to 10^{-9} mg/L) concentration of species such as dissolved methylmercury. The low detection requirement is especially critical for dissolved methylmercury, which may be less than 10 percent of total mercury (*i.e.*, the concentration of all physical and chemical forms) in an aquatic environment.

U.S. EPA calculated the geometric mean of the ratio, $f_d = C_d/C_t$ for several measurements in several water bodies as a measure of central tendency for deriving national translators. U.S. EPA did not specifically discuss the rationale for the selection of a geometric mean over an arithmetic mean for the estimate of mercury f_ds (translators). Using geometric means for translators was consistent with their approach for BAFs. U.S. EPA developed translators for the lentic and lotic environments but did not combine them as they did for BAFs.

The following discussion summarizes the studies that U.S. EPA utilized to derive water translators for lentic and lotic aquatic systems.

[5] Section II: Default chemical translator for mercury and methylmercury., (U.S. EPA 2000), p2

2.5.1 Translator For Conversion Of Total Mercury To Dissolved Methylmercury ($MeHg_d/Hg_t$), Lentic Environments

U.S. EPA used nine studies to derive a translator representing the fractional relationship between dissolved methylmercury and total mercury in water. Table 4 lists the studies and is based on the data in Table 2 in Appendix B of the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). Geographically, the studies were widely distributed: two were from Europe (France and Finland); the rest were from the United States, including one in California at Clear Lake, California. The data range was about 70-fold (0.002 - 0.139). The geometric mean was 0.032. This indicates that dissolved methylmercury was about 3.2 percent of total mercury, *i.e.*, physical and chemical mercury, in these water bodies.

Table 4. Lentic Environments: Dissolved methylmercury as a fraction of total mercury ($MeHg_d/Hg_t$)

$MeHg_d/Hg_t$*	Location	Comments	Author
0.002	Clearlake, CA	Only CA study	Suchanek *et al.*, 1998
0.014	Pavin Lake, France	Epilimnion @ 30-40 M	Cossa and Martin, 1991
0.020	Vandercook Lake, WI	-	Watras *et al.*, 1994
0.031	Lake Michigan	-	Mason and Sullivan, 1997
0.044	Little Rock Lake, WI	-	Watras *et al.*, 1994
0.061	Pallette Lake WI	-	Watras *et al.*, 1994
0.067	Lake Iva, Finland	-	Verta and Matilainen, 1995
0.078	North Wisconsin Lakes	15-lake composite	Watras *et al.*, 1998
0.139	Max Lake, WI	-	Watras *et al.*, 1994
Geometric Mean = 0.032			

* Dissolved methylmercury/Total mercury (all physical and chemical forms)

2.5.2 Translator For Conversion Of Total Mercury To Dissolved Methylmercury (MeHgd/Hgt), Lotic Environments

U.S. EPA selected 13 studies for the derivation of the translator for conversion between dissolved methylmercury and total mercury in lotic environments. Table 5 lists the studies utilized by the U.S. EPA. These data were taken from Table 7 in Appendix B of the National Bioaccumulation Factors for Methylmercury U.S. EPA (2000). There were no acceptable studies in the U.S. EPA database for this translator using data from California water bodies. The closest geographically to California was the study by Bonzongo *et al*., (1998) from the Carson River, Nevada. Two studies were for water bodies outside of the U.S. The translator values ranged from 0.002 to 0.051, or about 25-fold. The geometric mean for these data is 0.014, which means that 1.4 percent of total mercury (all physical and chemical forms) in these lotic systems is dissolved methylmercury.

Comparison of the lentic and lotic translators for dissolved methylmercury and total mercury in water suggests that there is more dissolved methylmercury in lentic than lotic water bodies. U.S. EPA speculated that the higher titer of organic matter in lentic systems compared to lotic environments may play some role in increasing dissolved methylmercury in lentic systems. U.S. EPA did not discuss whether they considered combining the translators for the two environments as they had done for the BAFs. OEHHA compared the data sets for the lentic and lotic environments using a two-tail t-test assuming unequal variance and calculated a statistical value of $p = 0.06$, which is just over a standard level of statistical significance ($p < 0.05$). This is not a clear reason to combine or separate lentic and lotic translators.

Table 5. Lotic Environments: Dissolved methylmercury as a fraction of total mercury

$MeHg_d/Hg_t$*	Location	Comments	Author
0.002	Fox River, WI	-	Hurley *et al.*, 1998
0.002+	Anacostia River, MD	High flow	Mason and Sullivan, 1998
0.007	Hinds Creek, TN	-	D.O.E., 1997
0.010+	Anacostia River, MD	-	Mason and Sullivan, 1998
0.012	Poplar Creek, VT	-	Campbell *et al.*, 1998
0.013	Grand River MI	-	Hurley *et al.*, 1998
0.017•	Patuxent, MD	-	Benoit, 1998
0.017	Sheboygan River, WI	-	Hurley *et al.*, 1998
0.018	Wisconsin Rivers	Composite of 39	Hurley *et al.*, 1995
0.034	Wisconsin Rivers	Composite of 7	Babiarz *et al.*, 1998
0.038	Carson River, NV	-	Bonzongo *et al.*, 1996
0.041	Pere Marquette River, MI	-	Hurley *et al.*, 1998
0.051	Manistique River, MI	-	Hurley *et al.*, 1998
Geometric Mean = 0.014			

* Dissolved methylmercury/Total mercury
\+ 0.8 um filter
• 0.2 um filter

2.5.3 Translator For Conversion Of Total Methylmercury To Dissolved Methylmercury (MeHgd/Hgt), Lentic Environments

The 13 studies U.S. EPA used to derive the translator for lentic environments are listed in Table 6. They were taken from Table 3 in the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). The translator values for water bodies in the table range from 0.303 to 1.02 with an unweighted geometric mean value of 0.613. This is only about a three-fold difference between values even though several water bodies were in Europe. Data from two studies conducted at Clear Lake, California are included. One study in the upper arm of Clear Lake found that the dissolved methylmercury was about 43 percent of the total methylmercury, while the other study observed that dissolved methylmercury and total mercury were nearly equivalent (*i.e.* dissolved methylmercury was 102 percent of total mercury), a difference of about two-fold. The high value might be related to conditions at Clear Lake associated with drainage from a

mercury mine. While mine drainage (from either mercury or gold mining using mercury) may be unusual source of mercury in most states it is a common source in California. These data show that, in some lakes, dissolved methylmercury in water can be nearly equivalent to total methylmercury.

Table 6. Lentic Environments: Dissolved methylmercury as a fraction of total methylmercury ($MeHg_d/MeHg_t$)

$MeHg_d/MeHg_t$*	Location	Comments	Author
0.303	Vandercook Lake, WI	-	Bloom *et al.*, 1991
0.353	Onondoga Lake, NY	-	Henry *et al.*, 1995
0.425	Clear Lake, CA	Upper arm	Suchanek *et al.*, 1998
0.577	Pallete Lake, WI	-	Bloom *et al.*, 1991
0.600	Lake Hako, Finland	-	Verta and Matilainen, 1995
0.645	Pavin Lake, France	Epilimnion @ 30-40 m	Cossa *et al.*, 1994
0.667	Little Rock Lake, WI	-	Bloom *et al.*, 1991
0.698	Wisconsin Lakes	15-lake composite	Watras *et al.*, 1998
0.72	Max Lake, WI	-	Bloom *et al.*, 1991
0.762	Lake Michigan, MI	-	Mason and Sullivan, 1997
0.79	Lake Iva, Finland		Verta and Matilainen, 1995
0.82	Lake Keha, Finland		Verta and Matilainen, 1995
1.02	Clear Lake, CA	-	Suchanek *et al.*, 1993

Geometric Mean = 0.613

* Dissolved methylmercury/Total methylmercury

2.5.4 Translator For Conversion Of Total Methylmercury To Dissolved Methylmercury (MeHgd/Hgt), Lotic Environments

The data and studies used by U.S. EPA for this translator are from Table 8 in Appendix B in the National Bioaccumulation Factors for Methylmercury (U.S. EPA 2000) and are presented in Table 7 in this report. Detailed discussions about each study for this table are not presented in the U.S. EPA document. The values in Table 7 ranged about five-fold (0.17 - 0.83). None of the studies took place in California; the closest study geographically was in the Carson River, Nevada (Bonzongo *et al.*, 1998). The geometric mean was 0.49, (a value similar to that found in lentic environments), indicating that about one-half of the total methylmercury is in the dissolved form in lotic environments. Filters of different pore size were used (*e.g.*, 0.20 and 0.8 μm) in some studies, which may have affected data variability. U.S. EPA (2000) did not discuss the impact of pore size on measurement of the concentration of dissolved methylmercury.

Table 7. Lotic Environments: Dissolved methylmercury as a fraction of total methylmercury ($MeHg_d/MeHg_t$)

$MeHg_d/MeHg_t$*	Location	Comments	Author
0.17+	Anacostia River, MD	High flow	Mason and Sullivan, 1998
0.32	Fox River, WI	-	Hurley *et al.*, 1998
0.36	Hinds Creek, TN	-	D.O.E., 1997
0.40•	Patuxent, MD	-	Benoit, 1998
0.46	Wisconsin Rivers	Composite of 7	Babiarz *et al.*, 1998
0.47	Sheboygan River, WI	-	Hurley *et al.*, 1998
0.49	Grand River MI	-	Hurley *et al.*, 1998
0.63	Pere Marquette River, MI	-	Hurley *et al.*, 1998
0.64	Manistique River, MI	-	Hurley *et al.*, 1998
0.68+	Anacostia River, MD	Base flow	Mason and Sullivan, 1998
0.68	Carson River, NV	-	Bonzongo *et al.*, 1996
0.80	Poplar Creek, VT	-	Campbell *et al.*, 1998
0.83	Wisconsin Rivers	Composite of 39	Hurley *et al.*, 1995

Geometric Mean = 0.49

* Dissolved methylmercury/Total methylmercury
\+ 0.8 μm filter
• 0.2 μm filter

2.5.5 Translators For Conversion Of Total Mercury To Dissolved Mercury (Hgd/Hgt), Lotic And Lentic Environments

U.S. EPA developed translators in both lentic and lotic environments for the relationship of dissolved mercury to total (physical and chemical) mercury (Hg_d/Hg_t) of 0.60 and 0.37, respectively. U.S. EPA (2000) did not discuss how these translators might be used in the implementation plan for mercury in ambient water. It appears that this ratio may be ancillary information from the analysis for total methylmercury and dissolved methylmercury in a water sample, so it will not be discussed here in further detail.

2.5.6 Translators For Estuarine Environments

U.S. EPA developed translators for this environment from very small data sets. In two cases, the ratio of dissolved methylmercury to total (physical and chemical) mercury ($MeHg_d/Hg_t$) and dissolved methylmercury to total methylmercury ($MeHg_d/MeHg_t$) data came from only two studies. Data will not be discussed individually for translators for these relationships due to small sample size. There were sufficient data in the literature to allow a derivation of the relationship between dissolved mercury and total mercury (Hg_d/Hg_t), but this translator is less useful. Table 8 lists the studies U.S. EPA used for this translator and the location where the studies occurred. Data are summarized from Appendix B Table 11 of the National Bioaccumulation Factors for Methylmercury U.S. EPA (2000). The translators from different studies range from 0.08 to 0.881, a difference of a slightly more than 10-fold. The geometric mean was 0.35, which indicates that about 35 percent of the total mercury (physical and

chemical) in estuarine environments in is in the form of dissolved total mercury. These data are primarily from studies outside the United States; eight of 11 studies were of water bodies in other locations in the world. One study supplied data from San Francisco Bay in California. However, the U.S. EPA (2000) has not proposed using this translator for regulatory of other purposes.

Table 8. Estuarine Environments: Dissolved mercury as a fraction of total mercury

Hg_d/Hg_t*	Location	Comments	Author
0.08*	Elbe Estuary, Germany	-	Coquery and Cossa, 1995
0.100	San Francisco Bay Estuary	-	SFEI, 1999
0.200•	Krka River Estuary, Croatia	Surface	Mikac and Kwakal, 1997
0.204	Galveston Bay, TX		Stordal *et al.*, 1996
0.263	DOHA (Qatar)	Costal Waters	Al-Madfa *et al.*, 1994
0.600•	Krka River Estuary, Croatia	Bottom	Mikac and Kwakal, 1997
0.642∇	Rhone, France	-	Cossa and Martin, 1991
0.648	Operto, Portugal	Coastal Sites	Vasconcelos and Leod, 1996
0.700*	Laptev Sea, Siberia	-	Coquery *et al.*, 1995
0.780+	Chesapeake Bay, MD	-	Benoit *et al.*, 1998
0.881*	Kara Sea, Siberia	-	Coquery *et al.*, 1995
Geometric Mean = 0.353			

* 0.8 um filtration, 2.5-7 m deep
\+ 0.2 um filtration
• Uncertainty of clean techniques
∇ 0.7 μm filtration

OEHHA's review noted some concerns regarding data from the estuarine environment because in several studies, it was uncertain as to whether "clean techniques" were used in the sample work-up and analysis. Another concern was that micron filters of different porosities were used in the studies. As noted above, the impact of the filter size on the magnitude of the translator values was not discussed in the U.S. EPA's summary of these values. Apparently the filter size used by the individual investigators has not been standardized for these analyses. Standardization could make the results from the studies more comparable.

2.5.7 Summary Of Translators For Lentic, Lotic And Estuarine Environments

The translators derived by the U.S. EPA for three aquatic environments are shown in Table 9. These data are summarized from Appendix B Table 15 of the National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). The translator data for estuaries for the relationships between dissolved methylmercury and total mercury and between dissolved methylmercury and total methylmercury are less robust because each was derived from only two studies, as noted above. The translator data set for estuaries for the relationship of dissolved mercury and total mercury uses 11 studies so there is some confidence in the geometric mean value of 0.35.

Table 9. Summary of U.S. EPA translators for lakes, rivers and estuaries

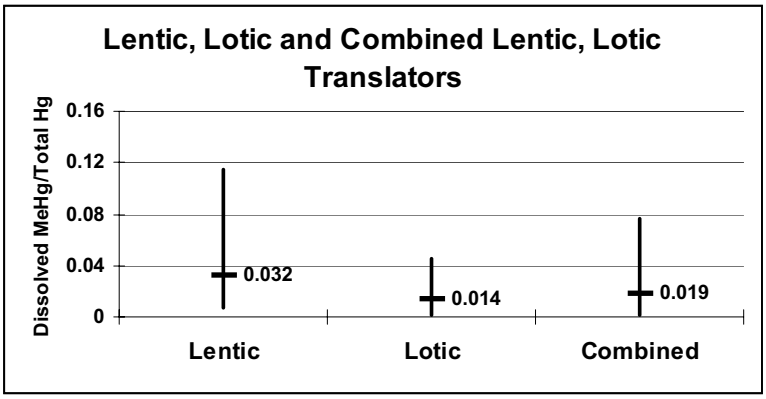
Mercury Species and Ratios	Lentic (Lake)	Lotic (River)	Estuary
f_d Hg (Hg_d/Hg_t)	0.60	0.37	0.35
f_d $MeHg_d/Hg_t$	0.032	0.014	0.19*
f_d $MeHg_d/MeHg_t$	0.61	0.49	0.61*

f_d Dissolved fraction
* These translators were developed from two sites

Examination of the summary values in Table 9 shows that, on average, the translator between dissolved methylmercury and total mercury for lakes (lentic) is slightly more than two-fold (0.032 vs. 0.014) greater than the same translator for rivers (lotic), and that the same translator for estuaries is very similar to the lotic translator. The similarity between the estuary and lotic values might be expected because rivers form a part of estuary systems. The translators between dissolved total mercury and total mercury for lotic and lentic environments, which are 0.37 and 0.60, respectively, exhibit a difference of less than two-fold, and the difference between the translators for dissolved methylmercury and total methylmercury in water for lentic (0.61) and lotic (0.49) was also less than two-fold. This is somewhat unexpected given the large variability among values from individual water bodies in the database. It may be that this is a result, in part, of the reduction in variation that occurs when one uses means of means to derive a value.

In the previous discussions of bioaccumulation factors, U.S. EPA combined lotic and lentic BAFs for three trophic levels to derive national default values that could be used if local values did not exist. It seems consistent with U.S. EPA BAF methodology that the summarized translators for the relationship of dissolved mercury species to total mercury species for lotic and lentic water body types (shown in Table 9) could be combined to provide a single value for each of the three relationships. Also, the differences are not great (geometric means less than two-fold apart) and it is likely that the distributions of the translators from lotic and lentic water bodies overlap. Through combining the data for the lentic and lotic aquatic environments, the dataset would be larger and perhaps more representative of a translator for both lentic and lotic environments. Figure 3 below shows an example of combining the U.S. EPA lentic and lotic translators for conversion between dissolved methylmercury and total mercury. The bars above and below the geometric mean are the 95^{th} and 5^{th} percentiles of the data, respectively. This shows the high degree of overlap between values for this translator in both ecosystems. However, it should be noted that there is considerably more variability in lentic water bodies.

Figure 3



The horizontal bar is the geometric mean.
Vertical bar is the 5^{th} to 95^{th} percentile.
The mean values that were used to construct the figure above are shown in the Table 9.

2.6 CRITIQUE OF U.S. EPA MERCURY BAFs AND TRANSLATORS

U.S. EPA's stated goal for deriving national BAFs values was that they would represent long-term bioaccumulation and be applicable for as many circumstances and for as many water bodies as possible (U.S. EPA, 2000). Presumably, national translators were also intended to be as broadly applicable as BAFs. However, U.S. EPA did not test the methylmercury BAF and translator values that they derived in an effort to determine whether they met this goal. The document describing how U.S. EPA derived the national values was a draft that has not been revised or finalized as a separate document. However, U.S. EPA did include peer review comments in the document (U.S. EPA, 2000) and they did use and publish the national BAFs, including peer review comments, with the final methylmercury water quality criterion (U.S. EPA, 2001). Apparently, the national BAFs and translators met U.S. EPA's goals well enough to be used in this criterion document without any changes.

A key step in evaluating whether and how to develop regional, local, or site-specific BAFs and translators for California water bodies, and whether or when to use the national BAFs and translators in California, is to understand the limitations of the methodology and data used by U.S. EPA as well as limitations or strengths of the resulting BAF and translator values. A number of strengths, weaknesses, and limitations are described below. These include observations from the original peer reviewers, OEHHA, and other authors commenting on the U.S. EPA methylmercury criterion, BAFs, and translators.

2.6.1 Comments On The U.S. EPA Methodology To Derive BAFs

2.6.1.1 BAF Equation:

U.S. EPA used a simple ratio, equivalent to a single box model, to calculate BAFs. Theoretically, the mercury concentrations in water and fish in this model should be at steady state. There are other, more complex, models that incorporate the effects of biological, environmental, and ecological factors to estimate the accumulation of methylmercury in biota (Hope, 2003; and Kamman, *et al.*, 2003); however, these models require more information than is needed for the BAF ratio calculation. These information requirements would have further restricted the number of studies that could have been used by U.S. EPA, limiting the scope of application of the national BAFs and translators. Whether or not more complex models can be used in California will depend on data readily available for California water bodies or on designing studies that would provide these data.

The theoretical basis for the BAF equation and model has been criticized by some reviewers (AMEC-ENVIRON, 2003, and Grovhoug *et al.*, 2003). Grovhoug *et al.* (2003) used data from two sampling sites on the Sacramento River and found no significant correlation between mercury in water and methylmercury in Trophic Level 3 and 4 biota, at the same site. This lack of correlation may be due, in part, to their treatment of sites as opposed to water bodies. Grovhaoug *et al.* (2003) looked for correlations between water and tissue concentration within single sites on this large water body. The studies used by U.S. EPA to derive BAFs averaged data across whole water bodies. In practice, no correlation is expected between a water sample and a Trophic Level 3 or 4 fish collected at the same site and time because the samples themselves represent different spatial and temporal scales. The water sample is a snapshot representation of daily conditions and single grab samples may fail to capture diurnal or hourly variation of dissolved methylmercury. The fish samples integrate conditions over a much longer period (months to years) and over a much greater space (everywhere the mobile fish has been exposed to mercury through water or food in its lifetime to date), so they cannot reflect differences in conditions for the time at which the water sample is taken. It would be more appropriate to look for correlations between mercury in water and fish across sites showing different tissue and water concentrations of mercury within a water body to see if the fish have integrated the differences in water concentrations. Some comparisons on a broader scale have shown a correlation between methylmercury in water and fish (Krabbenhoft, 1999).

2.6.1.2 Dissolved Methylmercury In Water:

Overall using the dissolved methylmercury fraction in water to derive BAFs was a good choice by U.S. EPA as methylmercury is the form of mercury that bioaccumulates in the aquatic food web. Methylmercury is also the form of mercury of human health concern following fish consumption. The production, availability, and accumulation of methylmercury in aquatic food webs can be affected by a number of factors including pH, alkalinity, water temperature, sulfate concentration, dissolved oxygen, organic matter, dissolved organic carbon, landscape characteristic (*e.g.*, wetlands), and trophic structure (Brumbaugh *et al.*, 2001; Greenfield *et al.*, 2001; Harris and Bodaly, 1998; Wiener *et al.*, 2003), but clearly the amount of the dissolved

methylmercury is a potentially limiting factor at an early step in food web bioaccumulation (Kelly *et al.*, 1997; Paterson *et al.*, 1998). The chief problem U.S. EPA encountered with dissolved methylmercury to derive BAFs was that data from many studies did not measure methylmercury in water and it was necessary to convert measurements of total mercury to methylmercury using national translators.

2.6.1.3 Methylmercury In Biota:

This is the best measurement to use for mercury in biota to calculate BAFs. It is the form used in the U.S. EPA tissue criterion because it is the most relevant form for human exposure via fish consumption and it is clearly associated with neurotoxicity in humans (U.S. EPA, 2001). The main problem with calculating BAFs based on methylmercury in biota is that most studies measure total mercury in this medium. This made it necessary for U.S. EPA to convert total mercury measurements in tissue to methylmercury values in tissue for various trophic levels.

2.6.1.4 Trophic Levels:

U.S. EPA apparently developed BAFs for Trophic Levels 2, 3, and 4 because this is part of their general strategy for developing BAFs for use in water quality criteria (U.S. EPA, 2003). U.S. EPA first developed BAFs for individual species and then combined them into trophic level BAFs. The reliability of the trophic level BAFs thus depends, in part, on accuracy in assigning species to the appropriate trophic level, as is discussed further below. While it is reasonable to calculate various trophic level BAFs because methylmercury does bioaccumulate up the food web through all trophic levels (Wiener *et al.* 2003), the role of the Trophic Level 2 BAF is unclear since no information is presented in the methylmercury tissue criterion (U.S. EPA, 2001) to show that people are consuming organisms from Trophic Level 2. The BAFs for Trophic Levels 3 and 4 are most relevant for fish species consumed by humans.

2.6.1.5 Classification Scheme (Lotic/Lentic/Estuarine):

U.S. EPA did not state how they assigned the studies they used to lotic, lentic, and estuarine water body classifications. Some of the peer reviewers suggested that these classifications were too broad, and that there should be more categories based on physical, chemical, and ecological differences and similarities. One reviewer suggested the following categories: oligotrophic, mesotrophic, eutrophic lakes; estuarine (deep and shallow); open ocean; streams and rivers (high and low dissolved organic carbon); and wetlands/everglades. Using additional categories could help determine whether the national BAFs are not representative of specific environments and conditions, and identify those that fall at the extremes for bioaccumulation. However, U.S. EPA's database did not contain appropriate studies to break out categories representing all of the water body types suggested by the reviewers. Also, reclassifying water bodies into more categories would further reduce the representative data for each category. Although this was a scientifically sound idea, it would have little effect if the BAFs from all environments were still combined.

2.6.1.6 Statistical Methods:

U.S. EPA used geometric means throughout their calculations of BAFs to represent the central tendency of data from studies that sometime included multiple water bodies. U.S. EPA did not discuss their choice of the geometric mean in detail. They state that geometric means were used for convenience and because the factors underlying BAF variability were believed to be multiplicative and the data sets log normally distributed (U.S. EPA, 2000). However, they did not present the distributions of the data they used or show statistical tests demonstrating that these data were log normal. One reviewer suggested that they provide a more detailed explanation of their rationale and provided some possible language. Another suggested that means could have been calculated for individual water bodies rather than using a single mean for all water bodies in the same study.

Arithmetic means could be used rather than geometric means to represent the central tendency of data when calculating BAFs. Arithmetic means generally yield higher values than geometric means. OEHHA favors using arithmetic means in human health assessments and fish consumption advisories because they are more health protective. Using arithmetic means to calculate the data summaries for methylmercury concentrations in biota and water that are used to calculate BAFs from individual studies might have little effect on the BAF values at this level. However, using arithmetic means to calculate means from studies and means after merging lentic and lotic BAFs would likely result in higher final national BAF values. BAFs based on arithmetic means are likely to yield higher tissue concentrations from the same water concentration than BAFs based on geometric means. Conversely, if BAF values are used to convert back to water concentrations, BAFs based on arithmetic means are likely to yield lower water concentrations from the same tissue concentration than BAFs based on geometric means.

Ideally, the distribution of the data sets used in BAF calculations should be tested to determine whether they are log normally distributed before choosing to use geometric means. This cannot be done for the national BAFs without the entire database, but it is recommended for any attempts to derive BAFs based on data from California water bodies.

2.6.1.7 Combining Lotic And Lentic Classifications Into Single National BAFs For Trophic Levels:

U.S. EPA based merging lentic and lotic BAFs on a qualitative rather than quantitative comparison of BAF values. They combined BAFs because the data ranges overlapped. As a result, the variability within each BAF was very large. The merging of lotic and lentic datasets to derive a single national BAF generated considerable discussion by the peer reviewers. Reviewers suggested that, instead of merging the lentic and lotic datasets for the calculation of BAFs, lentic and lotic environments should be split into more ecological categories that better reflect the aquatic chemistry of each environment. Although peer reviewers recognized U.S. EPA's purpose in deriving a single BAF, most disagreed with combining BAFs and advocated for developing separate BAFs for more environments, especially at the regional or local level. Developing specific BAFs for various categories of California water bodies (*e.g.*, lentic, lotic, and estuarine) would be consistent with this recommendation. It would also provide an

opportunity to compare the California values with the national values to see if they are really different and to look for water body characteristics associated with very different BAF values.

2.6.1.8 Standard Techniques:

Standard techniques were not used in the retrospective database compiled by U.S. EPA. Many of the peer reviewers suggested that using standard methods and uniform protocols would improve the study design and resulting data quality. This is especially true for determination of dissolved methylmercury. Different filter pore sizes were used by different researchers to separate the dissolved fraction of mercury or methylmercury in some of the studies used by U.S. EPA. As a result, some of the data for dissolved mercury or methylmercury could include some mercury bound to organic carbon or colloids. Standard sampling periods for water samples and standard ranges for fish lengths or edible sizes were not used and differences in these methods could also contribute to variation in the resulting BAFs. Standardized techniques would be essential for water and tissue measurements used in regulations.

2.6.2 Comments On The U.S. EPA Methodology To Derive Translators

2.6.2.1 Translators For Water:

U.S. EPA derived translators to convert other forms of mercury in water to dissolved methylmercury in order to calculate BAFs in a consistent manner. Again, U.S. EPA used a simple ratio between forms to calculate each translator. The translator conversion factors for water assume that there is a linear relationship between the various forms of mercury in water. This may be an over-simplification, especially of the relationship between total mercury and methylmercury in water. Methylmercury concentrations, in particular, are affected by other factors, *e.g.*, microbial communities, temperature, sulfide, and redox conditions (Ullrich *et al.* 2001), and high or low methylmercury values may not correlate well with total mercury values (Monson and Brezonik 1998; Gilmour *et al.* 1998). Many peer reviewers expressed reservations about using translators between total and methylmercury in water, and suggested that these be developed on a more local or site-specific basis. As noted in the discussion of the BAF method, the lack of standardized methods, especially standard pore sizes for determining dissolved mercury forms, may affect the variability in data used to calculate translators, as well as BAFs.

2.6.2.2 Translators For Biota:

U.S. EPA derived translators for biota to convert total mercury measurements in tissue to methylmercury values in tissue. This was fairly straightforward for higher trophic level fish (Trophic Level 3 and 4) where the conversion based on the assumption that nearly 100 percent of total mercury is methylmercury is well accepted, health protective, and consistent with most monitoring programs. U.S. EPA derived additional conversion factors for Trophic Level 2 organisms in lentic and lotic water bodies. The reliability of the Trophic Level 2 translators depends on whether the organisms used are representative of all Trophic Level 2 organisms, and whether U.S. EPA accurately assigned species to Trophic Level 2. This is discussed further below.

2.6.2.3 Separating Water Body Types:

U.S. EPA developed and retained separate translator values for lentic, lotic and estuarine water bodies. They did not explain why they did this but later combined the BAFs derived from them. Peer reviewers were in favor of separate lentic and lotic translators, and suggested that some of the water bodies in these separate classifications were actually at environmental or ecological extremes and should not be combined with other data to derive translators.

2.6.2.4 Other:

As noted in the BAF methodology discussion, U.S. EPA used geometric means to calculate translators because environmental variables tend to be log normally distributed. However, they did not show that the underlying data were log normally distributed or discuss their rationale in detail. The reviewers commented on this and one also suggested that means could have been calculated for individual water bodies rather than using a single mean for all water bodies in the same study.

2.6.3 Comments On The Data U.S. EPA Used To Derive BAFs

2.6.3.1 Representativeness Of Water Bodies In The Database:

It is not clear whether the water bodies from the studies used by U.S. EPA are representative of the range of water body types in the United States. U.S. EPA did not include specific physical and chemical information on the water bodies that might be useful in categorizing them. Many of the studies used are for seepage lakes in the Midwestern United States, whose primary source of mercury is atmospheric deposition. Conditions and BAFs from these water bodies may be different than in California water bodies where the primary source of mercury, in most cases, is gold or mercury mining. In fact, some of the peer reviewers recommended not using the data from Clear Lake, California because this site was not "typical" and had an unusual BAF. They felt that Clear Lake was not typical at the national level because its main source of mercury was runoff from a former mercury mine instead of atmospheric mercury. But legacy mining is a typical mercury source in California so these data may be especially relevant for California water bodies. Reviewers also questioned using data from other areas with unique conditions or high contamination, and they questioned U.S. EPA's inclusion of wetland data as a lotic ecosystem. U.S. EPA used international data but did not explain why they were merged with U.S. data. Using these data did broaden their database on which BAF calculations were based, however, it might also have introduced data from water bodies with variations in abiotic and biotic factors very different than those in the United States. The Papina *et al.* (1995) study from Russian was one of the studies the peer reviewers suggested had questionable data. In retrospect some reviewers were focused more on potential water body differences in physical, chemical, or ecological conditions than on U.S. EPA's attempt to derive broadly representative BAF values. These differences in perspective can only be resolved by deriving better local or regional BAFs.

2.6.3.1 Quality Assurance:

One problem with the study data was that standard collection and analytical techniques were not used. The peer reviewers commented on this and the necessity of using well-defined techniques in particular for the assessment of methylmercury in water because it is difficult to measure due to its low concentrations in water (*e.g.*, from 10^{-6} to 10^{-9} mg/L). U.S. EPA dealt with the non-standard analytical techniques, in part, by applying a set of analytical QA criteria to the chemistry data from the studies they selected. Using QA criteria increased the precision and reproducibility of the chemistry results, but had the effect of excluding studies relying on methylmercury data in water analyzed before 1990, although some studies containing total mercury results in water were included. This did not solve all problems associated with the lack of standard techniques. The peer reviewers pointed out some water data that U.S. EPA used that they felt were unreliable. Among the studies mentioned were data from Papina *et al.* (1995) where the methylmercury concentration was unusually high; data of Glass *et al.* (1990 and 1992) where the measured concentrations were very low; data from Jackson *et al.* (1991) that included data from the early 1980's using non-contemporary methods; data from Mason and Sullivan (1997) who reported values at the detection limit of the analytical method; data from Monson and Brezonik (1998 and 1999) who used a different method to measure mercury forms; and the study by Stober *et al.* (1995) where QA/QC issues were discovered after its inclusion in the U.S. EPA set. The peer reviewers felt that using data from these studies might affect the overall quality of BAF values calculated from them.

The peer reviewers also raised issues concerning the collection and interpretation of plankton and seston data noting that some samples were potentially a mixture of trophic levels (Trophic Level 1 and 2) and phylogenetically different organisms. These problems would impact the BAFs for Trophic Level 2.

2.6.3.3 Trophic Level Classification:

It is not clear if the number and kind of species from the studies used to derive each trophic BAF are representative of species in water bodies across the U.S. and those in California. Furthermore, the functional trophic level of a species can vary between water bodies and regions and this could lead to misclassifications of data assigned to a trophic level (*e.g.*, in lakes King salmon eat like Trophic Level 4 organisms, but in rivers they eat like Trophic Level 3 organisms). Trophic Level 2 organisms from the U.S. EPA studies included phytoplankton, zooplankton, microseston, mosquito fish, and stone rollers (see Table 10). Phytoplankton are Tropic Level 1 organisms, and microseston might include some primary producers, but it can be hard to separate these from zooplankton. Similar organisms are likely to be found in California. However, none of the studies included potential Trophic Level 2 organisms such as clams, mussels, crayfish, or crabs that might be harvested and eaten from water bodies in California. Although U.S. EPA has included Trophic Level 2 organisms in their water quality criteria it is not clear whether organisms at this level contribute significantly to human exposures in California. Peer reviewers questioned the assignment of mosquito fish to Trophic Level 2 rather than Trophic Level 3. Trophic Level 3 organisms from the U.S. EPA studies included shiner, perch, carp, shad, silversides, bluegill, sunfish, and juvenile bass species, which might also be found at this trophic level in California. The U.S. EPA studies did not include any trout, salmon

or catfish species in this trophic level. In California, some species of these fish are likely to be at this trophic level and these are also important game fish (*i.e.*, fish that anglers catch and consume). Trophic Level 4 organisms from the U.S. EPA studies included largemouth bass and other bass species, lake trout, walleye, northern pike, and burbot. In California, largemouth bass and other bass species are likely to be at this trophic level and some brown trout, catfish, or lake salmon may be as well. Including a more complete cross-section of data for species relevant to California consumers would improve the relevance of the trophic level BAFs. California data should be investigated to see if this is possible.

Table 10: Biota used by U.S. EPA to calculate BAFs for Trophic Level 2, 3, & 4

Trophic Level 2	Trophic Level 3	Trophic Level 4
Microseston	bass (juvenile)	bass
Mosquito fish	bloater	largemouth bass
Phytoplankton	bluegill	smallmouth bass
Stone roller	bream	burbot
Zooplankton	carp	lake trout
	dace	northern pike
	gizzard shad	pike
	grayling	walleye
	Johnny darter	
	Mayan cichlid	
	perch	
	perch/roach mix	
	log perch	
	yellow perch	
	redbreast	
	roach	
	shiner	
	spottail shiner	
	emerald shiner	
	spotted shiner	
	silversides	
	spotted sunfish	
	spotted tilapia	

Species lists from U.S. EPA (2000).

2.6.3.4 Standard Techniques:

The lack of standardized methods increases variability and decreases reproducibility of the water and fish data compiled by U.S. EPA. Sampling periods, fish age and size, and analytical preparation techniques (*e.g.* whole fish vs. fillet) differed among studies. For example, in some cases, water data were based on single grab samples while seasonal composite samples were taken in others. Thus some sampling incorporated seasonal variation while other sampling excluded it.

2.6.3.5 Compiled Data:

It is not possible to determine the actual sample size for fish and water measurements in the database compiled by U.S. EPA because the sections of the report (U.S. EPA, 2000) available to OEHHA only include summaries of the studies from which data were entered into the database. The existing database compiled by U.S. EPA is acceptable for developing broad-based BAFs despite the limitations discussed. However, as noted by the peer reviewers, the underlying spread of data may not yield BAFs that are practically very useful. The peer reviewers unanimously supported collecting more and better quality data, especially on the local and regional level. These data would be more applicable for local or regional conditions and would likely be less variable than the broad-based national data.

2.6.3.6 Other Studies:

The peer reviewers compiled lists of additional studies that they suggested U.S. EPA consider including to derive BAFs. Some of these studies were for California water bodies, and additional studies have been published in the past several years. These studies could potentially be used to derive BAFs based on California specific data.

2.6.4 Comments On The Data U.S. EPA Used To Derive Translators

2.6.4.1 Quality Assurance:

As discussed above, the lack of standard techniques (*e.g.*, using different pore size filters) to separate the dissolved fraction of mercury increases the variability and decreases the reproducibility of derived translators. Some of the study data could include mercury bound to dissolved organic carbon or colloids, while others do not. Since mercury in water can vary seasonally, non-standard sampling could also increase variation if data from different seasons were used to derive translators.

Also as noted above, reviewers suggested that data from some water bodies (*e.g.* Clear Lake, California, and others) be excluded from the U.S. EPA database because of the high total mercury, but low methylmercury concentrations in water. These studies also yielded high translator relationships, which may bias the current translator values. These studies, however, may be relevant in California where total mercury concentrations in water bodies may be higher due to mining sources.

The general comments above on the BAF data concerning representativeness of water bodies in the database, standard techniques, compiled data, and other studies are also applicable to the translator data.

2.6.5 Comments On The U.S. EPA National BAF Values

2.6.5.1 Gaps in Available Data

There were not enough good data available to U.S. EPA at the time they compiled their database to develop estuarine BAFs. This is a significant data gap for California because the San Francisco Bay-Delta is a huge estuary draining about 60-70 percent of the runoff from the Sierra Nevada Mountains. SWRCB should investigate compiling data from this estuary and/or other California estuaries to develop water body specific or a California default BAF for estuaries.

2.6.5.2 Variability

Table 11 shows the direct, converted, and combined BAFs developed by U.S. EPA for different trophic levels and water body types. The minimum, maximum, and geometric means for the studies compiled by U.S. EPA are given in the table. In order to get some measure of the data variation within each category, the maximum value is divided by the minimum value and shown in the table as the "fold variation." Standard deviation or the coefficient of variation would be better measures of variability but these cannot be calculated without the complete database. These simple calculations give some idea of the inherent variability in the BAF values.

Table 11: Relative variability in BAFs for lentic and lotic Trophic Level 2, 3, & 4

	BAF Trophic Level 2		**BAF Trophic Level 3**		**BAF Trophic Level 4**	
Direct BAFs	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic
minimum	42,400	34,474	504,000	334,325	4,000,000	985,915
mean	85,600	178,678	1,260,000	1,636,298	6,800,000	2,524,477
maximum	172,764	608,728	4,170,000	11,250,000	11,400,000	6,464,028
Fold variation	4	18	8	34	3	7
Converted BAFs						
minimum	61,757	8,661	734,095	35,238	3,954,284	96,905
mean	149,960	62,000	1,330,000	346,613	4,100,000	1,380,361
maximum	326,264	260,811	3,262,643	1,499,688	4,203,000	10,401,681
Fold variation	5	30	4	43	1	107
Combined BAFs						
minimum	34,474		35,238		96,905	
mean	117,000		680,000		2,670,000	
maximum	608,728		11,250,000		11,400,000	
Fold variation	18		319		118	

Minimum and maximum values are the mean values for the species with the lowest and highest BAF, respectively, for each water body type and indicated trophic level.
Mean values are geometric means from U.S. EPA (2000).

Examination of direct BAFs in the table showed that, for Trophic Level 2, the lotic mean and maximum are higher than the lentic mean and maximum values, but the lotic minimum was less than the lentic. This same pattern was seen for Trophic Level 3. However, for Trophic Level 4 the lentic mean and maximum values were higher than the same lotic values, and the lentic minimum was also higher than the lotic minimum. Although the trophic level pattern of BAF values was not consistent, the lotic BAFs at all trophic levels were consistently more variable based on the ratio of the maximum and minimum values. All of the lentic values show less than an order of magnitude difference, while the values for Trophic Levels 2 and 3 in lotic water bodies show greater than an order of magnitude difference.

Examination of the converted BAFs show a different pattern of high and low values for trophic levels in lentic and lotic water bodies, but a similar pattern for variation. In this case, for Trophic Level 2, the lentic mean, maximum, and minimum values are greater than the corresponding lotic values. The same pattern is seen in Trophic Level 3. In Trophic Level 4, the mean and minimum values are higher than the lotic, but the maximum value is lower. Some of the differences between direct and converted BAFs are likely to be due to effects of using translators to convert measured values. But, in all cases, the lotic BAF values are again more variable; all show more than an order of magnitude variation, and all show more variation than for direct BAFs. Lentic values, however, all show less than an order of magnitude variation, and the level of variation is similar to that seen for direct BAFs.

As seen in Table 11, combining the direct and converted BAFs for lentic and lotic water bodies to derive the national default values either retains or increases the variability from the underlying data. U.S. EPA calculated the 5^{th} and 95^{th} percentile ranges for BAFs at each trophic level in lentic and lotic water bodies and for the combined national BAFs. The lower and upper bounds also show the same pattern of variability demonstrated above: lotic BAFs are more variable than lentic, and lotic BAFs show greater than an order of magnitude difference between upper and lower bounds.

One way to decrease the inherent variability when using BAFs would be to use the direct BAFs for each trophic level and water body type, rather than using the U.S. EPA default values. SWRCB should investigate compiling data to derive California specific direct BAFs for lentic, lotic and estuarine water bodies, and other water body types of potential interest. This could be especially important because the primary source of mercury in most California water bodies is different than the atmospheric source in most of the studies U.S. EPA used to derive BAFs.

2.6.6 Comments On The U.S. EPA National Translator Values

2.6.6.1 Gaps in Available Data

U.S. EPA did develop three translators for estuarine water bodies. However, the translators between dissolved methylmercury and total mercury and dissolved methylmercury and total methylmercury were based on a relatively small sample size. Good estuarine translators are important in California because of the San Francisco Bay. SWRCB should investigate compiling

data to derive translators for San Francisco Bay and/or other California estuaries and water body types.

2.6.6.2 Variability

Table 12 shows national translator values for lentic and lotic water bodies and one based on more data for estuarine water bodies. The minimum, maximum, and geometric means for the studies compiled by U.S. EPA are given in the table. In order to get some measure of the data variation within each category the maximum value is divided by the minimum value and shown in the table as the "fold variation." Standard deviation or the coefficient of variation would be better measures of variability but these cannot be calculated without the complete database. These simple calculations give some idea of the inherent variability in the translator values.

Table 12: Relative variability in lentic, lotic, and estuarine translators

Translator	**MeHgd/Hgt**		**MeHgd/MeHgt**		**Hgd/Hgt**
Water body	Lentic	Lotic	Lentic	Lotic	Estuarine
Minimum	0.002	0.002	0.303	0.17	0.08
Mean	0.032	0.014	0.613	0.49	0.353
Maximum	0.139	0.051	1.02	0.83	0.881
Fold variation	70	26	3	5	11

MeHgd = dissolved methylmercury; MeHgt = total methylmercury; Hgd = dissolved inorganic mercury; Hgt = total mercury
Mean values are geometric means from U.S. EPA (2000).

Examination of this table shows that lotic translators have lower minimum, mean, and maximum values than translators for lentic environments. Estuarine values are similar to lotic, but are not directly comparable because they are not for the same forms of mercury as the lentic and lotic translators. The greatest variability, based on the ratio of maximum and minimum values, is seen for the translator between dissolved methylmercury and total mercury. Variability for this translator is more than an order of magnitude, similar to the variability for the estuarine translator between dissolved mercury and total mercury. Variability for the translator between dissolved methylmercury and total methylmercury is less than an order of magnitude.

Using translators to convert other mercury forms to dissolved methylmercury increases the variability in BAF calculations. Analytical methods to measure methylmercury have improved so future studies would be wise to always measure dissolved methylmercury directly, reducing the need to use translators. SWRCB should investigate compiling data or conducting new studies to derive default translators for a variety of California water bodies. This is especially important because the primary source of mercury in most California water bodies is legacy mercury or gold mining, which is different than the atmospheric source in most of the studies in the U.S. EPA database used to derive translators.

2.7 CONCLUSIONS CONCERNING U.S. EPA's DEVELOPMENT OF BAFs AND TRANSLATORS

National BAFs and translators have a number of flaws, owing largely to their derivation from a database that was compiled retrospectively from available studies. A well-designed, prospective study using standardized methods and stratified random sampling of specific types of water bodies might generate data that is less variable and possibly more useful for examining factors affecting mercury bioaccumulation for a broad scale of water bodies. Generating data using standard protocols would remove the influence of variation due to study methodology so that the effects of limnological and environmental variables could be determined. It would also require years to plan and complete but potentially yield information that could be practically applied. The external peer reviewers for the U.S. EPA document (U.S. EPA, 2000) were strongly in favor of collecting additional, higher quality data to use for BAFs and translators. To develop standard methods, factors such as the optimal sampling period for water and fish need to be determined, as well as where samples should be collected in the water column, and whether to do grab or composite samples. Standardized size or age ranges for fish or specific species to be collected for each trophic level should also be developed. The spatial relationship between fish and water samples also needs to be established for water bodies or "sites." In fact, the concept of "site-specific BAFs" should be examined. It is unlikely that BAFs for a specific site, such as a marina dock, or a specific latitude and longitude determined by GPS can be developed. Data can be collected to develop BAFs for larger water bodies (*e.g.*, Clear Lake, or Cache Creek) or perhaps segments of longer rivers (*e.g.*, the Sacramento River above Lake Shasta). The BAFs U.S. EPA developed were essentially for water bodies, not sites.

Despite these problems, the national default values for BAFs and translators were developed in a methodical manner using the best available data. These values were not tested by U.S. EPA to see how well they would predict tissue or water concentrations. This should be done to demonstrate and test their practical application, prior to using them in a policy to implement the methylmercury tissue criterion, using some criterion for goodness of fit to empirical data. Using the directly calculated BAFs (those based on measured dissolved methylmercury in water) for lentic and lotic water bodies separately can be considered as an alternative to the combined national default values. These values are less variable than the combined national values, and do not include the additional uncertainty added by using water translators and combining water body types. However, they are based on a smaller dataset. As another alternative, the California SWRCB could compile data on concentrations of mercury in fish and water for California water bodies to see if regional or local BAFs and translators could be derived that have less variability than the national values. Ideally, information on other factors known to affect methylmercury bioaccumulation (*e.g.*, pH, alkalinity, water temperature, sulfate concentration, dissolved oxygen, organic matter, dissolved organic carbon, landscape characteristic, and trophic structure) could be collected for these water bodies to aid in future classification of differences in BAFs in different types of California water bodies.

3 DERIVATION OF CALIFORNIA-SPECIFIC BAFs AND TRANSLATORS FROM THE SWRCB DATABASE

The State Water Resources Control Board (SWCRB) contracted with Science Applications International Corporation (SAIC) to compile water and biota mercury concentration data for California water bodies in an Access database titled "California Mercury Ambient Water Quality Criteria." This database contains information on water and biota data for lentic, lotic and estuarine environments. OEHHA used an Excel file version of this database[6] (refered to as the SWRCB database in this report) for this evaluation. For each of these environments, BAFs were calculated for three trophic levels in three aquatic environments, hence nine BAFs were reported in the database.
The discussion that follows will:

1) compare U.S. EPA and SAIC methods for calculating BAFs. This will include a brief discussion of the data in the SWRCB and U.S. EPA databases that were used to calculate BAFs.

2) describe an alternate method to calculate BAFs from the California data in the SWRCB database. This method will be used to make the California calculations as similar to those by U.S. EPA as possible within limits of the California data collection method. These alternative California-specific BAFs will be compared to BAFs derived by U.S. EPA.

3) investigate the SWRCB database for California water bodies to determine whether it is possible to develop translators for some aquatic environments. These California-based translators will be compared to translators derived by U.S. EPA.

3.1 U.S. EPA DATABASE FOR CALCULATION OF BIOACCUMULATION FACTORS

As previously noted, U.S. EPA carefully selected studies for inclusion in the database it used to calculate lentic and lotic BAFs. Studies had to meet certain standardized criteria for analytical chemistry data (*e.g.*, be reproducible and have a low detection limit and minimal matrix interferences) as specified in National Bioaccumulation Factors for Methylmercury (U.S. EPA, 2000). These rigorous criteria selected for high quality data, but only a limited number of studies met them and were thus included in the U.S. EPA database. In addition, U.S. EPA only included data from studies in which the same author or authors collected and measured some form of mercury in both biota and water in the same water body as part of the same investigation. These measurements, while for the same water body, were not necessarily collected at the same time or at the same site as defined by GPS coordinates. Sometimes data for water and/or biota mercury concentrations were aggregated over several years for the same water body or site by authors in the selected studies. Table 13 shows the number of studies from which U.S. EPA extracted the data entered in their database. U.S. EPA's calculations of BAFs and translators from this database have already been discussed.

[6] The database referenced in this document is dated March 2004 and referred to as the SWRCB database.

The U.S. EPA database was not available for OEHHA to determine the true number of samples and measurements included in it. Far more samples were included in the database than shown by the number of studies because some of the studies involved many water bodies and/or used data from multiple replicate measurements of mercury in biota and water in each water body. For example, Watras *et al*., (1998) studied 15 lakes in Wisconsin that were entered in the U.S. EPA database and used to calculate the BAFs. The replicate measurements within and among water bodies from each study are not evident because U.S. EPA first reduced the water and biota measurements to a single BAF for each trophic level in a study and then to a single BAF for each environment.

Table 13. Number of studies in the U.S. EPA database used to derive national BAFs[+]

Trophic Level:	**2**	**3**	**4**
Environment			
Lentic			
Direct	2	5	4
Converted	5	4	2
Total	**7**	**9**	**6**
Lotic			
Direct	3	6	2
Converted	3	15	5
Total	**6**	**21**	**7**

[+] Data from Tables 5-1 (lentic) and 5-2 (lotic), U.S. EPA, 2000
Direct: dissolved methylmercury concentration was measured in study;
Converted: the mercury form measured in water was converted into dissolved methylmercury by using the national translators derived by U.S. EPA (2000).

3.2 CALIFORNIA SWRCB DATABASE AND METHOD FOR CALCULATION OF BAFs

Table 14 summarizes information on California biota and water data contained in the Excel file used by OEHHA that contained the SWRCB dataset. SAIC entered mercury measurements for water and biota collected in California by various researchers but did not use the same criteria that U.S. EPA did when compiling their database (see Appendix 1 for criteria for SWRCB database). Unlike the U.S. EPA database data entries were not restricted to studies in which water and biota from the same water body were measured in the same study. The dataset for the lotic environment contained the most entries for both water and biota, with more than 100 entries (see Table 14) for each trophic level. The lentic environment had the fewest entries for water measurements and these were all from one water body, Standish Dam, which did not include any measurements of mercury in biota. The lentic environment also had the fewest entries for Trophic Level 2 biota, but contained a large number of Trophic Level 3 and 4 biota data.

Table 14. Number of data entries in the SWRCB database#

	Water Entries	Biota Entries		
Environment	Water*	Trophic Level 2	Trophic Level 3	Trophic Level 4
Lentic	11	9	345	814
Lotic	474	110	622	1224
Estuarine	306	211	25	240

* Data were reported for various forms of mercury. They were converted to dissolved methylmercury (DMeHg) for the purpose of calculating BAFs. The conversion to dissolved methylmercury was accomplished by using the national translators developed by the U.S. EPA.

The March 2004 version of the SWRCB database was used.

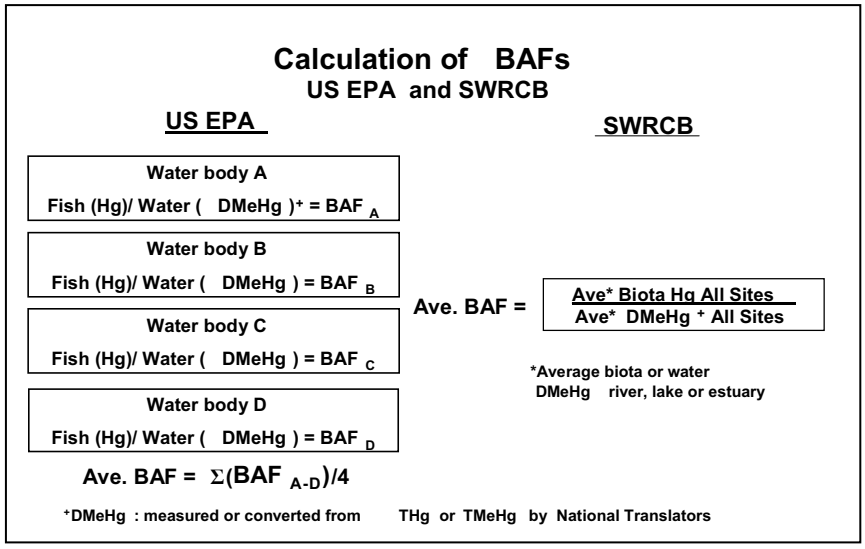
The SWRCB database was a compilation of studies for California water bodies that were reported by different investigators. Because, as noted above, the SWRCB California database was not restricted to matching biota and water samples from the same study and investigators, the compiled data, even when from the same water body, might be more variable than that in the U.S. EPA database due to differences in analytical methods or data quality. This might be expected to lead to differences between BAFs calculated from the SWRCB California and U.S. EPA databases.

SAIC used the standard BAF equation to calculate BAFs from the SWRCB California database. A concentration for methylmercury in biota was divided by a concentration for dissolved methylmercury in water. SAIC also used the national translators developed by U.S. EPA to convert water data reported as total mercury or total methylmercury to dissolved methylmercury when calculating BAFs. SAIC calculated nine statewide BAFs (three environments and three tropic levels) using the data they compiled. However, SAIC calculated BAFs from the SWRCB California database somewhat differently than that used by U.S. EPA to calculate the national BAFs.

In the Excel file SAIC used all biota and water data for each aquatic environmental type (*e.g.*, lentic) and trophic level entered in the SWRCB California database to calculate a statewide arithmetic mean value for biota and water, respectively, and then calculated a corresponding BAF from these overall means for each trophic level and environment. This process is not mathematically equivalent to the method employed by U.S. EPA. U.S. EPA first calculated mean biota and water concentrations of mercury for individual water bodies and/or studies and then calculated a BAF for the water body and/or study at each trophic level. The BAFs from multiple water bodies were averaged by U.S. EPA to derive single national values for each trophic level and aquatic environment. The SAIC method yields a point estimate for each BAF (*i.e.*, the BAF is based on one mean value in the numerator and denominator, not a sum of means from each). Consequently, it is not possible to derive information on the variability (standard deviation, etc.) of their California statewide-BAFs. In contrast, it is possible to calculate variability using the U.S. EPA method. Without repeated measures and estimates of variability it is not possible to statistically compare the SAIC BAFs with those derived by U.S. EPA. Figure 4

illustrates the methods used by the U.S. EPA and in the Excel file of the SWRCB dataset for calculation of BAFs.

Figure 4. Comparison of U.S. EPA and SAIC methods for calculation of BAFs from U.S. EPA and SWRCB datasets



U.S. EPA used fish and water data from one water body at a time to calculate a BAF for each water body (*e.g.*, water bodies A, B, C, and D). Then U.S. EPA summed these BAFs and averaged them. U.S. EPA initially did this for all three trophic levels in each type of water body. In the SWRCB Excel file dataset, SAIC summed all of data for mercury in fish from all of the water bodies of one kind in the California database they compiled and averaged the mercury concentrations. Next, they summed all of data for mercury in water from all of the water bodies of one kind in the California database they compiled and averaged the mercury concentrations. They then calculated a BAF from these grand averages. This was done for all three trophic levels in each type of water body.

3.3 ALTERNATIVE METHOD FOR THE CALCULATION OF BAFs IN CALIFORNIA

An alternative method was investigated for calculation of BAFs using the SWRCB California database. This method is similar to that used by U.S. EPA and allows for calculation of water body-specific BAFs. A preliminary survey of the three aquatic environments in this database indicated that the lotic environment contained sufficient water and biota data to use this method to calculate water body-specific BAFs. U.S. EPA used geometric means to calculate BAFs, but arithmetic means will be used for the alternate California method. Arithmetic means were used because they are more health protective than geometric means (*i.e.*, they are higher numerically) and because, in many cases, the available samples size from an individual water body was too small to test the statistical form of the data distribution. In order to use this alternative method for estimation of BAFs for California water bodies, the following unweighted arithmetic means were calculated:

1) **Numerator:** arithmetic mean mercury concentrations in biota from a water body (*e.g.*, San Joaquin River, Sacramento River, etc.) were calculated for each trophic level (2-4). Most mercury concentrations in biota (Trophic Levels 3, 4) were derived from measurements of

wet tissue samples. Since a few samples in Trophic Level 2 were dried prior to analysis, these data were converted to wet-weight mercury concentrations by using U.S. EPA translators (U.S. EPA, 2000).

2) **Denominator:** arithmetic mean mercury concentrations of dissolved methylmercury were calculated for a water body (*e.g.,* San Joaquin River, Sacramento River, etc.) matching the biota data. Measured dissolved methylmercury and concentrations converted from total mercury or methylmercury were used in this calculation. The U.S. EPA's national translators were used for the conversion of these data to dissolved methylmercury concentrations.

This alternative BAF methodology applied to data selected from the SWRCB California database aggregates biota and dissolved methylmercury concentrations, respectively, from a water body to calculate a BAF for one water body at a time. This aggregation is logical since dissolved methylmercury levels from the same water body are more likely to be similar than those from geographically separated water bodies (*e.g.*, for lakes in northern and southern California). And the same is true of aggregated biota concentrations for the same water body.

3.3.1 Application of the Alternate Method to Calculate BAFs from Data in the SWRCB California Database

This section describes the mercury levels in biota and dissolved methylmercury in water in ten rivers in California from the SWRCB California database and derives BAFs based on these data. These rivers will be used because they are the only rivers in the database that have both measurements of mercury in water and in fish. It should be noted that the ten rivers in the database are not a random sample of California rivers; they fall predominantly in the Sacramento-San Joaquin-San Francisco Bay Delta watershed.

3.3.1.1 Biota Data For Ten Rivers In California

Table 15 contains available information on the concentrations of mercury in Trophic Level 2 biota from the SWRCB California database found in four out of the ten rivers for this trophic level. Concentrations range from a low of 0.013 mg/kg in Putah Creek to a high of 0.018 mg/kg in the Sacramento River, a less than two-fold variation. The values of the arithmetic mean and the median concentrations are similar for the data, suggesting that they may be normally distributed, but the sample size is too small to test this for individual water bodies. Although data for individual water bodies are not very variable (*e.g.*, the standard deviation in all cases is less than the mean), the sample sizes are low (5-11 samples per water body) and additional data for all rivers would need to be collected to have more representative samples of mercury concentrations in Trophic Level 2 organisms in California rivers.

Table 15. Concentrations of methylmercury (mg/kg) in Trophic Level 2 biota[+]

Water Body	Arithmetic Mean	Standard Deviation	Median
Sacramento River (6)*	0.018	0.013	0.011
Mokelumne River (0)	-	-	-
Putah Creek (5)	0.013	0.004	0.013
San Joaquin River (0)	-	-	-
Napa River (11)	0.015	0.006	0.014
Bear River (0)	-	-	-
Coyote Creek (0)	-	-	-
Guadalupe River (0)	-	-	-
Alamo River (0)	-	-	-
Redwood Creek (9)	0.015	0.008	0.013

+ Methylmercury was assumed to be 49 percent of total mercury in Trophic Level 2 biota
* Number of samples collected

These data are from the SWRCB database, March 2004.

Table 16 summarizes the available mercury concentrations for Trophic Level 3 biota from nine rivers in the SWRCB California database. There are no available data for Redwood Creek. Only the Sacramento and San Joaquin River had more than ten samples. The mercury concentrations range from a low of 0.06 mg/kg in the Alamo River biota to a high of 0.53 mg/kg in fish from the Guadalupe River. The arithmetic mean and the median concentrations are similar in six out of nine cases suggesting that the data may be normally distributed for these rivers, but the sample sizes are too low to test this for individual water bodies. The mean and median are dissimilar in three cases (Sacramento, Bear, and Guadalupe River); however, the sample size for the Bear and Guadalupe Rivers is small, so this should not be over-interpreted. In seven out of nine cases, biota concentrations for individual water bodies are not very variable (*e.g.*, the standard deviation is less than the mean). But the sample sizes are low (2-10 samples per water body, and 32 for the San Joaquin River). The Sacramento River, which has the most samples, also has the greatest standard deviation. Based on these limited data, more differences in mercury bioaccumulation are shown by Trophic Level 3 biota in the Sacramento River. This is not surprising given the changes in the river ecosystem between the beginning and end of the Sacramento River. Overall, additional data for all rivers would need to be collected to have more representative samples of mercury in Trophic Level 3 organisms in California rivers.

Table 16. Concentrations of methylmercury (mg/kg) in Trophic Level 3 biota[+]

Water Body	Arithmetic Mean	Standard Deviation	Median
Sacramento River (45)*	0.34	0.45	0.17
Mokelumne River (9)	0.31	0.14	0.31
Putah Creek (10)	0.13	0.04	0.13
San Joaquin River (32)	0.14	0.07	0.12
Napa River (6)	0.26	0.09	0.26
Bear River (2)	0.21	0.21	.0.04
Coyote Creek (5)	0.14	0.06	0.11
Guadalupe River (5)	0.53	0.48	0.20
Alamo River (5)	0.06	0.02	0.06
Redwood Creek (0)	-	-	-

+ Methylmercury was assumed to be 100 percent of total mercury in Trophic Level 3 biota
* Number of samples collected

These data are from the SWRCB database, March 2004.

Table 17 summarizes the available data on mercury concentrations in Trophic Level 4 biota from seven rivers in the California database. No data were available for Trophic Level 4 for Napa River, Coyote Creek or Redwood Creek. Compared to Tropic Levels 2 and 3, the number of samples collected for Trophic Level 4 is significantly larger. Of the rivers with data, only the Alamo River had fewer than ten samples. The data range from a low of 0.04 mg/kg mercury from the Alamo River to a high of 0.98 mg/kg from the Guadalupe River.

The arithmetic mean and the median concentrations are similar in six out of seven cases, suggesting that the data may be normally distributed for these rivers. In many cases, sample sizes are great enough to test the distribution of the biota data for normality in individual water bodies. Although the mean and median values are similar for the Alamo River, the sample size for this water body is lower than for many of the others, so this should not be over-interpreted. In all cases, data for individual water bodies are not very variable (*e.g.*, the standard deviation is less than the mean). Additional collections in the rivers that lack samples and the Bear and Alamo rivers would lead to a more representative database for mercury in Trophic Level 4 organisms in California rivers. Since most of the water bodies have a similar mean concentration of mercury, it could be useful to collect enough data to determine whether bioaccumulation levels in the rivers with the lowest (Alamo and Bear rivers) and the highest (Guadalupe River) concentrations are really different from the other water bodies.

Table 17. Concentrations of methylmercury (mg/kg) in Trophic Level 4 biota[+]

Water Body	Arithmetic Mean	Standard Deviation	Median
Sacramento River (125)*	0.46	0.34	0.35
Mokelumne River (39)	0.69	0.37	0.69
Putah Creek (28)	0.38	0.19	0.34
San Joaquin River (261)	0.48	0.30	0.42
Napa River (0)	-	-	-
Bear River (15)	0.17	0.13	0.10
Coyote Creek (0)	-	-	-
Guadalupe River (41)	0.97	0.34	0.88
Alamo River (6)	0.04	0.02	0.04
Redwood Creek (0)	-	-	-

+ Methylmercury was assumed to be 100 percent of total mercury in Trophic Level 4 biota
* Number of samples collected

These data are from the SWRCB database, March 2004.

3.3.1.2 Water Data For Dissolved Methylmercury In Ten Rivers In California

The discussion that follows characterizes the dissolved methylmercury in the same ten California rivers where biota were collected. Table 18 summarizes the available dissolved methylmercury data for these rivers taken from the SWRCB California database. These mean dissolved methylmercury values for each river were derived from measured dissolved methylmercury and measurements of other forms of mercury that were converted into dissolved methylmercury. Overall, there was about three-fold greater number of converted values (223) compared to measured values (78). The total number of water samples collected (combined measured and converted) ranged from a high of 98 from the Bear River to a low of seven for the Alamo River. The standard deviations of the arithmetic means of these data were less than the means in six out of the ten rivers, indicating low variability for environmental data. The average mean value of dissolved methylmercury ranged from a low of 7.06×10^{-08} mg/L for samples collected from Putah Creek to a high of 3.78×10^{-06} mg/L for the Alamo River, a difference of slightly less than 200-fold. In eight out of ten cases, the mean and median were similar indicating that the data could be normally distributed, but statistical tests of normality were limited by the sample size. The mean and median were most dissimilar for the Guadalupe River, which had few samples, and the Bear River, which had the most samples. The source of these differences is not known.

For most water bodies, the mean dissolved methylmercury concentration was influenced by the greater number of converted values in the database. More measured dissolved methylmercury concentrations than converted concentrations were only available for the Mokelumne River and Putah Creek. Data from the Sacramento, San Joaquin and Bear rivers were selected to compare the concentration of measured vs. converted dissolved methylmercury. These rivers were selected because each had at least ten measured and ten converted values. When measured and converted concentration values in the Sacramento, San Joaquin and Bear rivers were compared (data not shown), the converted values were 2.3, 1.8, and 2.8-fold greater, respectively, than the

measured values. This indicates that using converted values can add two to three-fold to the concentration and perhaps contribute to greater variability and uncertainty in dissolved methylmercury concentrations. In order to reduce this variability and uncertainty, water samples of directly measured dissolved methylmercury should be collected in these water bodies, especially those with fewer measured values (Napa, Guadalupe, and Alamo rivers; and Coyote and Redwood creeks). Adding data for water bodies from other geographic areas of California would also improve the statewide coverage and representativeness of data for the lotic environment.

Table 18. Water dissolved methylmercury (DMeHg) concentrations for 10 rivers in California

	Sample Type[+]		**DMeHg (mg/L)**		
Location	Measured.	Converted	Mean[▽]	Standard Deviation	Median
Sacramento River (48)*	16	32	$9.00x10^{-08}$	$8.52x10^{-08}$	$7.14x10^{-08}$
Mokelumne River (18)	16	2	$9.62x10^{-08}$	$4.57x10^{-08}$	$8.45x10^{-08}$
Putah Creek (17)	15	2	$7.06x10^{-08}$	$4.08x10^{-08}$	$6.08x10^{-08}$
San Joaquin River (40)	13	28	$8.06x10^{-08}$	$4.51x10^{-08}$	$7.20x10^{-08}$
Napa River (21)	1	21	$2.66x10^{-07}$	$2.20x^{-07}$	$1.93x10^{-07}$
Bear River (98)	12	86	$3.51x10^{-07}$	$9.53x10^{-07}$	$8.70x10^{-08}$
Coyote Creek (19)	2	17	$3.07x10^{-07}$	$3.37x10^{-07}$	$2.21x10^{-07}$
Guadalupe River (9)	2	7	$2.54x10^{-06}$	$3.97x10^{-06}$	$8.79x10^{-07}$
Alamo River (7)	0	7	$3.78x10^{-06}$	$4.64x10^{-14}$	$3.78x10^{-06}$
Redwood Creek (22)	1	21	$9.09x10^{-08}$	$7.00x10^{-08}$	$8.12x10^{-08}$
Total	78	223			

\+ DMeHg measured (Meas.) or converted (Conv.) to DMeHg from total mercury or total methylmercury
* Total number of samples collected (sum of measured and converted)
▽ Arithmetic mean of measured dissolved methylmercury concentrations and converted concentrations to dissolved methylmercury from total methylmercury or total mercury

These data are from the SWRCB database, March 2004.

Table 19 shows the BAFs for Trophic Level 2 biota calculated from dissolved methylmercury in biota and methylmercury in water from the SWRCB California database. Four of the rivers or creeks have biota methylmercury concentrations that allow the calculation of a BAF for this trophic level. The mean biota and water methylmercury concentrations are from all sites and all times of sampling. The BAFs range from high of $2.01x10^{+05}$ L/kg in the Sacramento River to a low of $5.76x10^{+04}$ L/kg in the Napa River. These individual BAFs differ by less than four-fold and the standard deviation of the overall mean ($6.41x10^{+04}$ L/kg) is less than the mean BAF of all water bodies combined ($1.52x^{+05}$ L/kg). It is clear from Table 19 that more data are necessary to attain a more representative database for Trophic Level 2 biota so that additional BAFs for this trophic level for more California water bodies can be calculated.

Table 19. Concentrations of dissolved methylmercury in water, biota mercury concentrations and BAFs for Trophic Level 2

Water Body	**Water** DMeHg (mg/L)	**Biota** MeHg (mg/kg)	**BAF** (L/kg)[+]
Sacramento River (48,6)*	$9.00x10^{-08}$	0.018	$2.01x10^{+05}$
Mokelumne River (18,0)	$9.62x10^{-08}$	-	-
Putah Creek (17,5)	$7.06x10^{-08}$	0.013	$1.78x10^{+05}$
San Joaquin River (40,0)	$8.06x10^{-08}$	-	-
Napa River (21,11)	$2.66x10^{-07}$	0.015	$5.76x10^{+04}$
Bear River (98,0)	$3.51x10^{-07}$	-	-
Coyote Creek (2,0)	$3.07x10^{-07}$	-	-
Guadalupe River (9,0)	$2.54x10^{-06}$	-	-
Alamo River (7,0)	$3.78x10^{-06}$	-	-
Redwood Creek (22,9)	$9.09x10^{-08}$	0.015	$1.70x10^{+05}$
		arithmetic mean	$1.52x10^{+05}$
		Standard Deviation	$6.41x10^{+04}$

* Number of samples (water, biota)

\+ BAF = Biota MeHg (mg/kg)/Water DMeHg (mg/L)

These data are from the SWRCB database, March 2004.

Table 20 shows the BAFs for Trophic Level 3 biota calculated from dissolved methylmercury in biota and methylmercury in water from the SWRCB California database. It was not possible to develop a BAF for Redwood Creek because Trophic Level 3 biota were not collected from this water body. The BAFs range from a low of $1.59x10^{+04}$ L/kg in the Alamo River to a high $3.82x10^{+06}$ L/kg in the Sacramento River, which is a difference of about 240-fold. The standard deviation of the overall Trophic Level 3 BAF is again about as large as the mean itself ($1.36x10^{+06}$ and $1.42x10^{+06}$ L/kg, respectively), and is larger than the variation in biota or water concentrations. This variation could be due to the range of environments and biota with differing mercury levels used in these calculations. Although there are biota data for more water bodies for Trophic Level 3, as noted earlier, in many cases the biota results are based on fewer than ten samples (eight out of the ten rivers). Most of the samples in the current data set are from northern California rivers affected by mercury and gold mining. Collecting a larger database of biota samples from more lotic environments throughout the state could be useful to better characterize the range of bioaccumulation in this important trophic level that contains many fish that people catch and eat. If additional sampling takes place, it is suggested that collection of water and biota could be better coordinated to make the results more similar to the studies used by U.S. EPA in their development of BAFs.

Table 20. Concentrations of dissolved methylmercury in water, biota mercury concentrations and BAFs for Trophic Level 3

Water Body	**Water** DMeHg (mg/L)	**Biota** MeHg (mg/kg)	**BAF** (L/kg)$^{+}$
Sacramento River (48,45)*	9.00×10^{-08}	0.34	$3.82 \times 10^{+06}$
Mokelumne River 18,9)	9.62×10^{-08}	0.31	$3.25 \times 10^{+06}$
Putah Creek (17,10)	7.06×10^{-08}	0.13	$1.82 \times 10^{+06}$
San Joaquin River (40,32)	8.06×10^{-08}	0.14	$1.70 \times 10^{+06}$
Napa River (21,6)	2.66×10^{-07}	0.26	$9.66 \times 10^{+05}$
Bear River (98,2)	3.51×10^{-07}	0.21	$5.49 \times 10^{+05}$
Coyote Creek (19,5)	3.07×10^{-07}	0.14	$4.50 \times 10^{+05}$
Guadalupe River (9,5)	2.54×10^{-06}	0.53	$2.08 \times 10^{+05}$
Alamo River (7,5)	3.78×10^{-06}	0.06	$1.59 \times 10^{+04}$
Redwood Creek (22,0)	9.09×10^{-08}	-	-
		Arithmetic mean	$1.42 \times 10^{+06}$
		Standard deviation	$1.36 \times 10^{+06}$

* Number of samples (water, biota)
\+ BAF = Biota Me Hg (mg/kg)/Water DMeHg (mg/L)
These data are from the SWRCB database, March 2004.

Table 21 shows the BAFs for Trophic Level 4 biota calculated from dissolved methylmercury in biota and methylmercury in water from the SWRCB California database. BAFs for two of the water bodies, Napa River and Coyote Creek, could not be calculated because Trophic Level 4 biota were not collected. The BAFs range from a low of $1.06E^{+04}$ L/kg in the Alamo River to a high of $7.14E^{+06}$ L/kg in the Mokelumne River, which is a difference of about 670-fold. The overall mean and standard deviation for the BAFs for Trophic Level 4 biota in these rivers are $3.49E^{+06}$ and $3.07E^{+06}$ L/kg, respectively. Again there is more variation in bioaccumulation between water bodies than variation in the underlying biota and water concentrations. This variation is important to note because most of these water bodies have in common that they are in northern California in areas affected by past mercury and gold mining. Of course, there may be many environmental differences within this area, but if there is this much variation for similar water bodies, then the overall variation for a database that includes water bodies from southern California could be greater. Although the Trophic Level 4 dataset includes the highest sample sizes for biota, collecting a larger database of biota samples from more lotic environments throughout the state could be useful to better characterize the range of bioaccumulation in this important trophic level that typically shows the highest methylmercury bioaccumulation.

Table 21. Concentrations of dissolved methylmercury in water, biota mercury concentrations and BAFs for Trophic Level 4

Location	**Water** DMeHg (mg/L)	**Biota** MeHg (mg/kg)	**BAF** (L/kg)$^{+}$
Sacramento River (48,125)*	$9.00x10^{-08}$	0.46	$5.10x10^{+06}$
Mokelumne River (18,39)	$9.62x10^{-08}$	0.69	$7.14x10^{+06}$
Putah Creek (17,28)	$7.06x10^{-08}$	0.38	$5.36x10^{+06}$
San Joaquin River (40,261)	$8.06x10^{-08}$	0.48	$5.97x10^{+06}$
Napa River (21,0)	$2.66x10^{-07}$	-	-
Bear River (98,15)	$3.51x10^{-07}$	0.17	$4.79x10^{+05}$
Coyote Creek (19,0)	$3.07x10^{-07}$	-	-
Guadalupe River (9,41)	$2.54x10^{-06}$	0.97	$3.80x10^{+05}$
Alamo River (7,6)	$3.78x10^{-06}$	0.04	$1.06x10^{+04}$
Redwood Creek (22,0)	$9.09x10^{-08}$	-	-
		Arithmetic mean	$3.49x10^{+06}$
		Standard Deviation	$3.07x10^{+06}$

* Number of samples (water, biota)
\+ BAF = Biota MeHg (mg/kg)/Water DMeHg (mg/L)

These data are from the SWRCB database, March 2004.

Table 22 summarizes the BAFs for lotic environments in California calculated from the SWRCB California database using the alternative method. An unweighted arithmetic mean BAF was calculated for each trophic level from these data for the ten rivers. This is consistent with the U.S. EPA calculation, which also did not factor the number of replicates in a study into their calculations of mean BAFs. Some lotic environments have a larger dataset than others, so the BAF values from them are likely to be statistically more representative. The Bear River is an example of a dataset that is not very robust with respect to both water and biota data. In this river there were 98 water samples, and 0, 2 and 15 biota samples collected in Trophic Levels 2, 3 and 4, respectively. Other water bodies show similar data gaps especially for Trophic Level 2.

Table 22. Summary of bioaccumulation factors (BAFs) for lotic environments in California

Trophic Level:	**2**	**3**	**4**
Location (n_w;n_b)*		**BAF (L/kg)**	
Sacramento River (48;6,45,125)	$2.01x10^{+05}$	$3.82x10^{+06}$	$5.10x10^{+06}$
Mokelumne River (18;0,9,39)	-	$3.25x10^{+06}$	$7.14x10^{+06}$
Putah Creek (17;5,10,28)	$1.78x10^{+05}$	$1.82x10^{+06}$	$5.36x10^{+06}$
San Joaquin River (40;32,261,0)	-	$1.70x10^{+06}$	$5.97x10^{+06}$
Napa River (21;11,6,0)	$5.76x10^{+04}$	$9.66x10^{+05}$	-
Bear River (98;0,2,15)	-	$5.49x10^{+05}$	$4.79x10^{+05}$
Coyote Creek (19;0,5,0)	-	$4.50x10^{+05}$	-
Guadalupe River (9;0,5,41)	-	$2.08x10^{+05}$	$3.80x10^{+05}$
Alamo River (7;0,5,6)	-	$1.59x10^{+04}$	$1.06x10^{+04}$
Redwood Creek (22;9,0,0)	$1.70x10^{+05}$	-	-
Arithmetic mean	$1.52x10^{+05}$	$1.42x10^{+06}$	$3.49x10^{+06}$
Standard Deviation	$6.41x10^{+04}$	$1.36x10^{+06}$	$3.07x10^{+06}$

* n_w, n_b-sample size for water and biota (3 trophic level values), respectively

These data are from the SWRCB database, March 2004.

The BAFs for the Trophic Levels 3 and 4 differ by slightly more than two-fold (1.42-3.49x10^{+06}), but the difference between Trophic Level 2 and 3 is about 10-fold and between Trophic Level 2 and 4 about 20-fold. A pair-wise t-test (two-tail, unequal variance) was used to test whether the BAFs for these trophic levels were statistically different. The p-values are shown in Table 23. The BAFs for Trophic Levels 3 and 4 were not different (p=0.14), but the BAF for Trophic Level 2 was different than that for Trophic Level 3 (p=0.02) and Level 4 (p=0.03).

A similar pair-wise t-test comparison was performed for the U.S. EPA BAF data for the lotic environment. BAFs from U.S. EPA data were recalculated as arithmetic means for this statistical evaluation. The results of this evaluation are also shown in Table 23. Again, Trophic Level 3 and 4 BAFs are not statistically different, which might be expected since there are not consistent separations between all fish in these trophic levels. But Trophic Level 2 BAFs are different from both Trophic Level 3 and 4, showing the clearer separation between feeding behavior and bioaccumulation at these levels.

Table 23. Comparison of alternate California BAFs and recalculated arithmetic mean U.S. EPA BAFs among trophic levels for the lotic environment

	Trophic level (n)	**Trophic level comparison**	**p statistic+**
Alternate CA BAFs			
1.52x10^{+05}	2 (4)	2 vs. 3	0.02
1.42x10^{+06}	3 (9)	2 vs. 4	0.03
3.49x10^{+06}	4 (7)	3 vs 4	0.14
Recalculated* U.S. EPA BAFs			
2.15x10^{+05}	2 (6)	2 vs. 3	0.02
1.32x10^{+06}	3 (26)	2 vs. 4	0.05
3.93x10^{+06}	4 (7)	3 vs 4	0.15
(n) = number of studies or water bodies included to derive mean BAF			
*recalculated as arithmetic means			
+ two-tail, unequal variance			

Alternate CA BAFs are from Table 22. U.S. EPA BAFs are recalculated from U.S. EPA (2000).

3.4 COMPARISON OF CALIFORNIA ALTERNATIVE BAFs AND U.S. EPA BAFs RECALCULATED AS ARITHMETIC MEANS FOR THE LOTIC ENVIRONMENT

The proceeding discussion demonstrated that California water body-specific BAFs could be derived from the SWRCB California database using an alternate methodology. A statistical comparison of the California and national BAFs was done in order to provide some basis for consideration of the difference between the alternatively calculated California BAFs and the U.S. EPA BAFs. Table 24 shows the results of a two tail pair-wise t-test of the mean California and

U.S. EPA BAF values for each trophic level. This statistical evaluation indicates that the mean BAFs for lotic environments from the U.S. EPA and California river-specific values do not differ ($p>0.05$) for any of the trophic levels. Figure 5 shows this overall similarity graphically.

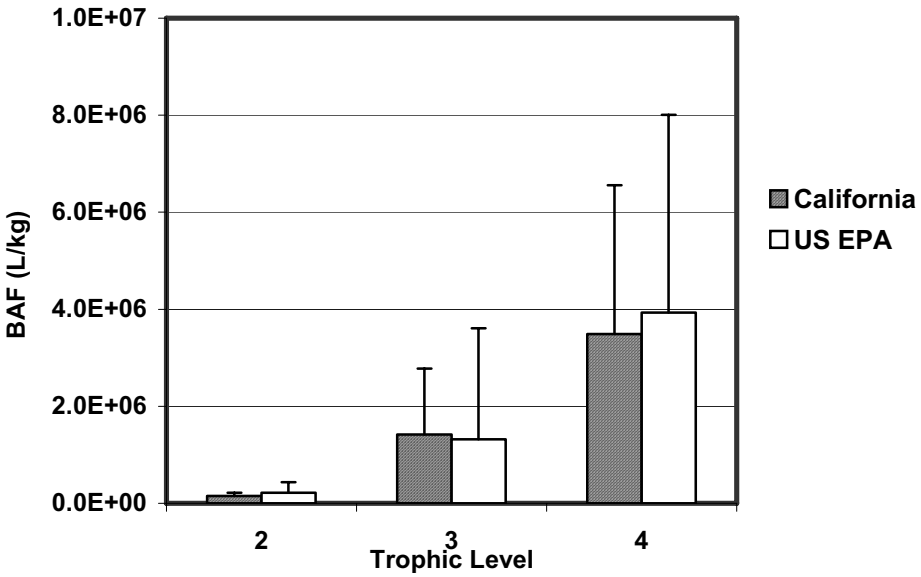
Table 24. Statistical Evaluation of California and U.S. EPA BAFs for the Lotic Environment

Trophic Level	P Statistic*
2	0.34
3	0.89
4	0.82

* Two-tail test for unequal variance

Data for comparisons are from Table 24.

Figure 5: California - U.S. EPA BAFs
Lotic Environment



Whiskers – standard deviation
Plot of data from Table 23.

3.4.1 California Lentic Environment

It is not possible to calculate an alternative BAF for the lentic environment because only a single water body (Standish Dam) had any measurements of forms of mercury in water. As was

mentioned previously, biota were not collected for the analysis of mercury concentration from this water body. Consequently, the alternate method used to calculate BAFs for the lentic environment cannot be used with the data presently compiled in the SWRCB database. In contrast to the water data, there is a large dataset for mercury concentrations in biota in the lentic environment that could be used to calculate BAFs if corresponding water measurements were available.

3.4.2 California Estuarine Environment

The estuarine dataset in the SWRCB California database contains a sufficient number of fish-water combinations to enable recalculation of BAFs for this aquatic environment, but all data are from collection sites in the San Francisco Bay-Delta Estuary. The available biota and water data for the estuary are summarized below prior to calculating BAFs. Only data for Trophic Levels 2 and 4 are presently compiled in the SWRCB California database for this estuary.

Table 25 contains biota mercury concentrations for Trophic Level 2 biota collected from nine sites around San Francisco Bay. Most sites, with the exception of the South Bay, had Trophic Level 2 biota collected. Only four sites had ten or more samples collected. The mean values for methylmercury for this tropic level span a relatively narrow range from 0.010- 0.012 mg/kg. All of the standard deviations are less than the mean values. All of the medians are less than or equal to the mean values. This suggests that the data are normally distributed but the samples sizes are too small to adequately test the distribution. Additional biota samples should be collected to create a more representative database for this trophic level.

Table 25. Summary of methylmercury in Trophic Level 2 biota[+] collected from the San Francisco estuarine environment

Location (n_b)*	**Biota** MeHg (mg/kg)		
	Mean	Standard Deviation	Median
Alameda (10))	0.010	0.003	0.010
Davis Pt (9)	0.012	0.004	0.012
Dumbarton Bridge (10)	0.011	0.002	0.010
Grizzly Bay (11)	0.011	0.004	0.010
Pinole Pt (11)	0.011	0.003	0.011
Red Rock (7)	0.012	0.002	0.013
San Pablo Bay (8)	0.010	0.005	0.008
South Bay (0)	-	-	-
Yerba Buena (7)	0.012	0.002	0.011

\+ Methylmercury was assumed to be 44 percent of total mercury in Trophic Level 2 biota
* Sample number of biota samples collected
These data are from the SWRCB database, March 2004

Trophic Level 3 biota were not collected from the San Francisco Bay estuary so it will not be possible to summarize the data for these biota with respect to mercury concentrations nor to calculate a BAF.

Summary information on Trophic Level 4 biota collected for mercury analyses are presented in Table 26. The SWRCB California database contained only four collections of Trophic Level 4 biota. Two of these collections contained ten or fewer samples, but larger sample sizes were available at two sites, San Pablo Bay (n=47) and South Bay (n=48). The mercury concentrations in these biota ranged from a low of 0.12 mg/kg at the Dumbarton Bridge to a high of 0.60 mg/kg at South Bay, a difference of five-fold. The standard deviations were less than the means, and the medians were similar to the means for collections with few samples. However, for the two collections with a larger sample size, the means and medians were more dissimilar. In order to achieve a more representative estimate of the mercury levels and BAFs for this tropic level, additional sampling should be considered.

Table 26. Summary of methylmercury in Trophic Level 4 biota[+] collected from the San Francisco estuarine environment

Location (n_b)*	**Biota** MeHg (mg/kg)		
	Mean	Standard Deviation	Median
Alameda (0)	-	-	-
Davis Pt (10)	0.55	0.17	0.50
Dumbarton Bridge (3)	0.12	0.047	0.11
Grizzly Bay (0)	-	-	-
Pinole Pt (0)	-	-	-
Red Rock (0)	-	-	-
San Pablo Bay (47)	0.39	0.28	0.28
South Bay (48)	0.60	0.40	0.40
Yerba Buena (0)	-	-	-

\+ Methylmercury was assumed to be 100 percent of total mercury in Trophic Level 4 biota
* Sample size of biota collected.
These data are from the SWRCB database, March 2004

Table 27 summarizes water data for measured and converted dissolved methylmercury for the San Francisco Bay estuarine environment. The mean values are averaged over all times that a site was monitored and may include both measured and converted values. Measured values were only available for four sites and, in these cases, only one or two measured samples were taken. Out of 185 water samples only eight (<5 percent) were for directly measured dissolved methylmercury concentration. In contrast, for the lotic environment, nearly 25 percent of water values were directly measured dissolved methylmercury. A comparison of the measured and converted values in the estuarine environment suggests that this reliance on converting other measurements to dissolved methylmercury may have biased these results. The mean concentration based on measured and converted dissolved methylmercury was 2.37×10^{-06} mg/L, but the mean concentration based on measured dissolved methylmercury only was 4.99×10^{-08} mg/L. This is about a 500-fold difference. Other reported concentrations for directly measured dissolved methylmercury in water from San Francisco Bay in the literature are more similar to the limited number of measured values in the SWRCB California database. The mean concentration from Conaway *et al.* (2003) was 4.47×10^{-08} mg/L and that from California Regional Water Quality Control Board (2000) was 3.21×10^{-08} mg/L.

The converted values for the estuarine environment based on the SWRCB California database will be discussed here and used to calculate BAFs. However, it should be noted that using just the measure concentrations of dissolved methylmercury might yield different results. And it would be important to collect additional data for measured dissolved methylmercury in the San Francisco estuary.

Nine sites had sample sizes of 17 or more in the SWRCB California database with converted water concentrations for dissolved methylmercury. The values for mean dissolved methylmercury (combining measured and converted concentrations) range from a low of $5.51x10^{-07}$mg/L at Yerba Buena to a high of $3.75x10^{-06}$ mg/L at San Pablo Bay, which is a difference of about seven-fold. In three of the nine locations, Davis Point, Dumbarton Bridge and San Pablo Bay, the standard deviation exceeded the mean suggesting that, at these sites, the data were somewhat more variable than at the other six sites. The reason for this is unknown. The overall mean dissolved methylmercury concentration was $2.37x10^{-06}$ mg/L.

Table 27. Summary of water dissolved methylmercury (DMeHg) concentration for locations in the San Francisco Estuary

	Water Samples:		**DMeHg (mg/L)**		
Location (n*)	Meas.	Conv.	Mean+	Standard Deviation	Median
Alameda (20)	2	18	$5.59x10^{-07}$	$3.95x10^{-07}$	$4.66x10^{-07}$
Davis Pt (21)	2	19	$3.31x10^{-06}$	$3.70x10^{-06}$	$2.17x10^{-06}$
Dumbarton Bridge (20)	0	20	$3.32x10^{-06}$	$3.45x10^{-06}$	$1.87x10^{-06}$
Grizzly Bay (23)	2	21	$3.72x10^{-06}$	$3.54x10^{-06}$	$2.45x10^{-06}$
Pinole Pt (20)	0	20	$2.34x10^{-06}$	$2.26x10^{-06}$	$5.06x10^{-06}$
Red Rock (18)	1	17	$9.43x10^{-07}$	$6.57x10^{-07}$	$8.36x10^{-07}$
San Pablo Bay (22)	0	22	$3.75x10^{-06}$	$4.39x10^{-06}$	$1.52x10^{-06}$
South Bay (20)	0	20	$2.83x10^{-06}$	$2.04x10^{-06}$	$2.47x10^{-06}$
Yerba Buena (22)	1	21	$5.51x10^{-07}$	$3.24x10^{-06}$	$5.61x10^{-07}$
Sum	8	178			
		Arithmetic mean	$2.37x10^{-06}$		

* Total number of samples (Measured + Converted)

\+ Arithmetic mean of measured DMeHg and converted (DMeHg from THg and DMeHg from TMeHg)

These data are from the SWRCB database, March 2004

The BAFs calculated from the biota data in Tables 25 and 26, and the dissolved methylmercury data in Table 27, are shown in Table 28. The BAFs for Trophic Level 2 range from $2.43x10^{+03}$ L/kg at San Pablo Bay to a high of $1.85x10^{+04}$ L/kg at Alameda, a difference of about eight-fold. The arithmetic mean value for Trophic Level 2 is $8.71x10^{+03}$ L/kg. The standard deviation ($7.67x10^{+03}$) is slightly less than the mean. The BAFs for Trophic Level 4 ranged from a low of 3.73 $x10^{+04}$ L/kg at Dumbarton Bridge to a high of $2.11x10^{+05}$ a South Bay, a difference of about six-fold. The arithmetic mean value for Trophic Level 4 is $1.3x10^{+05}$ L/kg and the standard deviation ($7.64x10^{+04}$) is slightly less than the mean. The BAF for Trophic Level 4 is about 15-fold greater than the Trophic Level 2 BAF. Statistical evaluation of these data using a two-tailed t-test with unequal variance shows that they were of borderline significance ($p = 0.051$). BAFs recalculated using just directly measured dissolved methylmercury (to improve data quality) are

also show in Table 28. Additional biota, especially Trophic Level 3 and 4, and water samples, especially measured dissolved methylmercury, should be considered for future collections in San Francisco Bay and other California estuarine environments. This would yield a more representative database of values. If additional biota and water sampling were to occur, it would be best to coordinate water and biota sampling to increase similarity with the methodology used by U.S. EPA.

Table 28. Summary BAFs for the Estuarine Environment

		Biota MeHg (mg/kg)		**BAF(L/kg)$^{+}$**	
Location(n*)	Water (mg/L)	TL 2	TL 4	TL 2	TL 4
Alameda (20; 10,0)	$5.59x10^{-07}$	0.010	-	$1.85x10^{+04}$	-
Davis Pt (21; 9, 10)	$3.31x10^{-06}$	0.012	0.55	$3.37x10^{+03}$	$1.70x10^{+05}$
Dumbarton Bridge (20; 10,3)	$3.32x10^{-06}$	0.011	0.12	$3.30x10^{+03}$	$3.73x10^{+04}$
Grizzly Bay (23; 11, 0)	$3.72x10^{-06}$	0.011	-	$3.00x10^{+03}$	-
Pinole Pt (20; 11, 0)	$2.34x10^{-06}$	0.011	-	$4.70x10^{+03}$	-
Red Rock (18; 7, 0)	$9.43x10^{-07}$	0.012	-	$1.30x10^{+04}$	-
San Pablo Bay (22; 8, 47)	$3.75x10^{-06}$	0.010	0.39	$2.43x10^{+03}$	$1.05x10^{+05}$
South Bay (20; 48, 48)	$2.83x10^{-06}$	-	0.60	-	$2.11x10^{+05}$
Yerba Buena (22; 7, 0)	$5.51x10^{-07}$	0.012	-	$2.13x10^{+04}$	-
		Unweighted Arithmetic Mean		$8.71x10^{+03}$	$1.30x10^{+05}$
		Standard Deviation		$7.67x10^{+03}$	$7.64x10^{+04}$
Values recalculated using just directly measured dissolved methylmercury.				$2.2x10^{+5}$	$8.3x10^{+6}$

* Sample sizes of water; biota collected (Trophic Level 2, 4)

\+ BAF = Biota (mg/kg)/Water DMeHg (mg/L)

These data are from the SWRCB database, March 2004

3.5 COMPARISON OF U.S. EPA AND CALIFORNIA TRANSLATORS

The discussion that follows compares translators derived from the SWRCB California database to the U.S. EPA translators. Only lotic translators can be directly compared because these were the only translators for which national and California data were available. Both sets of lotic translators are shown in Table 29. U.S. EPA used multiple studies that met specific analytical criteria to derive national translators. Like the studies used by U.S. EPA for BAFs, many of these studies contained replicates, so the number of U.S. EPA studies in Table 29 are not directly comparable to the number of entries from the SWRCB California database. The major difference between the U.S. EPA translators is that they came from individual studies by the same investigators, whereas, in order to calculate translators from the SWRCB California database, data from different investigators for the same water bodies were used. U.S. EPA translators have been recalculated as arithmetic means to allow comparison with the SWRCB California database translators. The differences and similarities between the U.S. EPA and translators calculated using the data compiled by SAIC in the SWRCB database will be discussed for each translator.

3.5.1 Lotic Environment

Table 29 shows the translators for lotic environment derived from the SWRCB California database and the translators from U.S. EPA for this aquatic environment.

Table 29. Translators for the Lotic Environment: California and U.S. EPA

Source	Translator:	DHg/THg		
	n*	Mean (Standard Deviation)		Range
California	117	0.31	(0.86)	0.01-6.88
U.S. EPA	19	0.44	(0.24)	0.10-0.90
		DMeHg/THg		
California	37	0.015	(0.012)	0.003-0.042
U.S. EPA	13	0.020	(0.016)	0.002-0.051
		DMeHg/TMeHg		
California	46	0.51	(0.26)	0.04-1.04
U.S. EPA	13	0.53	(0.20)	0.17-0.83

* Number of samples (U.S. EPA number of studies; California number of entries in the SWRCB database)
These data are from the SWRCB database, March 2004

3.5.1.1 Translator for DHg/THg

The arithmetic mean value for DHg/THg from U.S. EPA (0.44) is higher than the value of 0.31 derived from the SWRCB California database. The California data range is 0.01-6.88 compared to the U.S. EPA's data range of 0.10-0.90. The standard deviations for the U.S. EPA and California arithmetic means are and 0.24 and 0.86, respectively. The U.S. EPA, through its quality assurance and quality control, did not include studies that reported ratios of DHg/THg that were greater than one (unity) as it is not possible for the concentration of dissolved mercury to exceed the concentration of total mercury. Therefore, the range of values in the California dataset is unreasonable and includes some analytically invalid data. These invalid data can be eliminated by censoring (*i.e.*, deleting) any data with a ratio greater than one when calculating a translator mean. When values greater than one are removed from the DHg/THg SWRCB California dataset, the arithmetic mean becomes 0.18, which is 2.4-fold below the arithmetic mean for the U.S. EPA dataset. One reason for the lower mean value for this translator in California compared to the U.S. EPA value may be related to the absence of data less than 0.10 in the U.S. EPA dataset. In the California dataset, 28 percent of values for the ratio DHg/THg range from 0.01-0.09. This may indicate some unique environmental conditions in California lotic environments or additional problems with data quality. Statistical evaluation of the U.S. EPA and California arithmetic mean values using a two-tail t-test with unequal variance indicates that they are not different ($p = 0.17$).

3.5.1.2 Translator for DMeHg/THg

The arithmetic mean value for DMeHg/THg for U.S. EPA's translator (0.020) is higher than the value (0.015) derived from the SWRCB California dataset. The range of the values for the U.S. EPA dataset is 0.002-0.051 and the range for the California dataset is 0.003-0.042. The standard deviations for the U.S. EPA and California arithmetic means are 0.016 and 0.012, respectively. In both cases, the standard deviation is lower than but similar to the mean. Statistical evaluation of U.S. EPA and California arithmetic mean values using a two-tail t-test for unequal variance indicates that they are not different ($p = 0.29$). Given the similarity of the means for the data from California and U.S. EPA and the observation that the dataset from California contains a reasonable range of values (none greater than one), either translator would yield a similar value when converting a total mercury concentration into a dissolved methylmercury concentration.

3.5.1.3 Translator for DMeHg/TMeHg

The arithmetic mean values for this translator from U.S. EPA and SWRCB California datasets are 0.53 and 0.51, respectively. The data ranges for U.S. EPA and California are 0.17-0.83 and 0.04-1.04, respectively. The minimum values from the SWRCB California dataset are approximately four-fold lower (0.04 vs. 0.17) than the U.S. EPA dataset. The standard deviations for these data are 0.20 (U.S. EPA) and 0.26 (California). Also, there are two values in the California dataset that exceed one, suggesting that the quality of the SWRCB California dataset should be examined. Comparison of the U.S. EPA and California mean values with a two-tail t-test for unequal variance indicates that they are not different ($p = 0.70$). When the two data points in the dataset for DMeHg/TMeHg with values greater then one are removed, then the mean value for this translator becomes of 0.49, which is an insignificant change in this relationship. After censoring the values above one in the SWRCB California dataset, there is no clear reason to recommend either the California or U.S. EPA translator for TMeHg to DMeHg.

3.5.2 Lentic Environment

It is not possible to derive translators for the lentic environment because only data for one water body, Standish Dam, are compiled in the SWRCB California database. Other data exist for the lentic environment in, for example, Clear Lake and Lake Berryessa, but they were not included in the SWRCB California database as currently evaluated. If adequate values for concentrations of all forms of mercury in water in lentic environments can be compiled from other sites in California, then it may be possible to calculate these translators.

3.5.3 Estuarine Environment

3.5.3.1 Translator for DHg/THg

Sufficient data exist for derivation of a translator for DHg/THg in the estuarine environment. Table 30 summarizes these data for eight sites in the San Francisco Bay-Delta Estuary. This table contains the arithmetic mean and standard deviations for data from these sites within San Francisco Bay. The number of water samples available to calculate this translator range from a high of 19 in Grizzly Bay to a low of 12 in Alameda. The translators ranged from a low of 0.12 in two locations, Davis Point and Grizzly Bay, to a high of 0.30 in Alameda. The arithmetic

mean for these data is 0.15. The U.S. EPA reports a geometric mean translator value of 0.35 for DHg/THg in the estuarine environment. The raw U.S. EPA data for this translator are not readily available so it was not possible to recalculate the U.S. EPA value as an arithmetic mean to compare it statistically with the California-based translator.

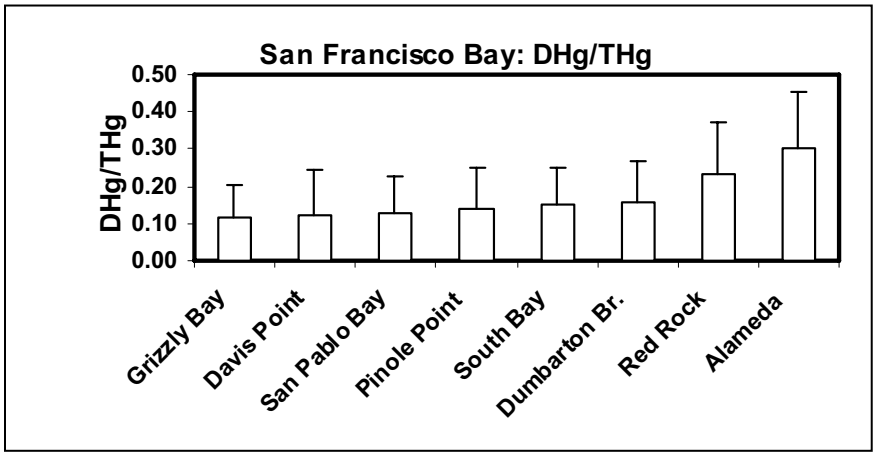
Table 30. Translator (DHg/THg) for sites in San Francisco Bay

Site (n)*	Arithmetic Mean	Standard Deviation
Alameda (12)	0.30	0.15
Davis Point (16)	0.12	0.12
Dumbarton Bridge (18)	0.16	0.11
Grizzly Bay (19)	0.12	0.09
Pinole Point (16)	0.14	0.11
Red Rock (15)	0.23	0.14
San Pablo Bay (15)	0.13	0.10
South Bay (18)	0.15	0.10
Arithmetic Mean	0.15	
n Number of samples		

These data are from the SWRCB database, March 2004

Comparison of these data using a pair-wise t-test for unequal variance showed that mean values for Alameda and Grizzly Bay or Davis Point (the two extremes of the dataset) are different ($p = 0.0012$), while the mean values for Alameda and Red Rock are not different ($p = 0.22$). The mean values of Alameda and Dumbarton are different ($p = 0.009$), while the mean values for Red Rock and Dumbarton are not different ($p = 0.11$). Therefore, the translator for Alameda is statistically greater than all other sites except for Red Rock. This can be seen graphically in Figure 6, which displays the translator mean at each site in the San Francisco Bay along with the standard deviations (whiskers) of the mean for each site. The reason for this difference at Alameda is not known.

Figure 6. DHg/THg at several sites in the San Francisco Bay



The data plotted in this figure are from the SWRCB database, March 2004, as shown in Table 30.

A San Francisco Estuary-wide translator of 0.15 for DHg/THg can be derived using data from all of the sampling sites. Even though it has been demonstrated that statistical differences exist between sites, it is consistent with the U.S. EPA translator approach to derive an estuary-wide translator. U.S. EPA combined data over broader geographic areas (*e.g.*, the United States, Europe and Siberia) than San Francisco Bay without regard to potential differences between sites for the derivation of BAFs and translators. Regardless, this California translator is of limited use because it does not yield a translator to dissolved methylmercury.

3.5.3.2 Translator for DMeHg/THg

It is not possible to develop a California-specific translator for DMeHg/THg in the estuarine environment because only eight values of measured dissolved methylmercury (DMeHg) are compiled in the SWRCB California database. Also, when DMeHg was measured, no corresponding values for THg were measured.

3.5.3.3 Translator for DMeHg/TMeHg

There are less than ten entries in the SWRCB California dataset that could be used to develop an estuarine California-specific translator for DMeHg/TMeHg. Further, the data quality in these measurements was poor, as dissolved mercury forms sometimes exceeded total mercury. Additional data could be collected to so that this translator can be derived.

3.6 CONCLUSIONS CONCERNING DERIVING BAFs AND TRANSLATORS FROM THE SWRCB CALIFORNIA DATABASE

3.6.1 Conclusions concerning California BAFs

OEHHA found a number of differences between the database and methodology used by SAIC to derive BAFs and the U.S. EPA database and methodology. Both databases used the best quality data that could be identified at the time but the U.S. EPA criteria could be more stringent due to its broader geographic scope. Some specific instances were noted in the discussion above where the values in the SWRCB database were unrealistic. Some of these problems can be overcome by censoring such data. Also, OEHHA found that, while the U.S. EPA based individual BAF calculations on water and biota data collected and measured in the same study, the water and biota data compiled in the SWRCB California database, even when collected from the same water body, were from different studies. This potentially increases data variability due to different analytical techniques and quality control measures between study researchers. Coordinating biota and water sampling in California and standardizing analytical techniques and quality control measures would help to reduce variability for future data added to this database. OEHHA also found that the method SAIC used to calculate BAFs was different than that used by U.S. EPA.

Despite these differences, OEHHA demonstrated that California-specific BAFs could be calculated using the data in the SWRCB California database by an alternative method for lotic and estuarine environments. This alternate method is very similar to the U.S. EPA method. OEHHA calculated arithmetic mean values for the alternate California-specific BAFs. U.S. EPA's national BAFs were calculated as geometric means. The U.S. EPA and California-specific BAFs are shown in Table 31. OEHHA used arithmetic means because they are more health protective and because in most cases the sample size for data for individual water bodies was insufficient to determine the form of the distribution. The alternate California-specific BAFs calculated by OEHHA were shown to be similar to U.S. EPA's BAFs, especially U.S. EPA values recalculated as arithmetic means. The alternate California-specific BAFs calculated by OEHHA and the U.S. EPA BAFs re-calculated as arithmetic means were not statistically different. This suggests that the current SWRCB California database can be used to calculate some California-specific BAFs. OEHHA also calculated estuarine BAFs although U.S. EPA could not. These BAFs when calculated using only directly measured methylmercury in water (to improve data quality) are also similar to the national default values (see values in Table 31).

OEHHA found "gaps" in the available data for the SWRCB California database that limited the aquatic environments and trophic levels for which California-specific BAFs could be calculated. Filling these data gaps could improve the application of the database. The following are some of the consequences of these gaps in data availablility:

- California-specific BAFs could not be calculated for any trophic level in lentic environments due to insufficient data. Biota data were available for one water body, but there were no corresponding water data. Water data and additional corresponding biota

data are needed from lentic water bodies throughout California in order to calculate California-specific BAFs for the lentic environment.

- A combined lentic/lotic California-specific BAF equivalent to the U.S. EPA national BAF cannot be calculated because of the lack of lentic data for California.

- California-specific BAFs could not be calculated for Trophic Level 3 in the estuarine environments due to insufficient data. Trophic Level 3 biota data are needed from San Francisco Bay in order to calculate California-specific BAFs for Trophic Level 3 in this estuarine environment. Data for dissolved methylmercury measured in water and mercury measurements in Trophic Level 2, 3, and 4 biota in other estuarine water bodies in California would also useful to develop estuarine BAFs representative of a range of California estuaries. However, a complete dataset for San Francisco Bay is especially important because of the size and importance of this water body.

- OEHHA found that the sample size for biota and water data entered into the SWRCB California database was often low. BAFs based on more samples will be more accurate than those based on fewer samples. Larger samples sizes of water and biota data are needed from water bodies throughout California in order to calculate more accurate California-specific BAFs.

- OEHHA found that the geographic range of lotic, lentic, and estuarine water bodies in California compiled in the SWRCB California database was very limited. The available water bodies are not representative of the range of California environmental conditions. Data for the lotic environment was primarily from northern California and the Sacramento-San Joaquin River watersheds. Data for the estuarine environment were exclusively from the San Francisco Bay-Delta estuary. Both of these areas are heavily impacted by runoff and deposition from mercury and gold mining. Data from Standish Dam were the only data for the lentic environment in the SWRCB California database. Additional water and biota data (for all trophic levels) are needed from water bodies throughout California in order to calculate California-specific BAFs that are representative of a range of California water bodies.

SWRCB should attempt to fill these data gaps to develop a complete spectrum of California-specific BAFs for each trophic level in lentic, lotic, and estuarine environments. Some additional new data may be available in recent literature. For example, several new studies for the San Francisco Bay Estuary are available in which multiple forms of mercury in water have been measured (Conway, *et al.*, 2003; Choe *et al.,* 2003a; b). Data from these and other studies that may become available in the future could be added to the SWRCB California database.

Based on these comparisons there is not a clear-cut scientific basis that shows that either the national or California-specific BAFs will yield more accurate results if used in a methylmercury implementation policy. California-specific BAFs calculated as arithmetic means will yield higher tissue concentrations in biota at a given concentration of dissolved methylmercury in water. Consequently, allowable water concentrations based on the OEHHA alternate California-

specific BAFs would be lower than those based on the geometric mean U.S. EPA BAFs. Thus, the California-specific BAFs will be more health protective, but could not be developed for all environments and trophic levels. U.S. EPA BAFs could be used for environments and trophic levels where California-specific BAFs are not available. In order to determine if the California-specific or U.S. EPA BAFs would work best in the methylmercury implementation policy they should be tested to see how well they predict biota tissue concentrations at different trophic levels based on water data for various water bodies in California. This is a necessary step in validating both the U.S. EPA and California-specific BAFs and determining their limitations in a practical application. This testing could also show which BAFs would be more applicable in California or help find environmental conditions for which default BAFs do not work.

Table 31: Summary of Bioaccumulation Factors (BAFs) from the U.S. EPA and California data

			Trophic Level		
Agency	Environment/Comments	Mean	2	3	4
U.S. EPA	Lentic/Lotic Combined	Geometric	$1.2x10^{+05}$	$6.8x10^{+05}$	$2.7x10^{+06}$
U.S. EPA	Lentic/Lotic Combined	Arithmetic	$1.9x10^{+05}$*	$1.4x10^{+06}$*	$5.0x10^{+06}$*
California	Lentic/Lotic Combined Alternative	Geometric	NP	NP	NP
California	Lentic/Lotic Combined Alternative	Arithmetic	NP	NP	NP
California	Lentic/Lotic Combined SAIC calculated	Arithmetic	ND	ND	ND
U.S. EPA	Lentic Only	Geometric	$1.3x10^{+05}$	$1.1x10^{+06}$	$5.7x10^{+06}$
U.S. EPA	Lentic Only	Arithmetic	$1.6x10^{+05}$*	$1.5 x10^{+06}$* !!	$6.2x10^{+06}$* !!
California	Lentic Alternative	Geometric	NP	NP	NP
California	Lentic Alternative	Arithmetic	NP	NP	NP
California	Lentic SAIC calculated	Arithmetic	$1.3x10^{+04}$	$5.5x10^{+05}$	$7.3x10^{+05}$
U.S. EPA	Lotic Only	Geometric	$1.1x10^{+05}$	$5.7x10^{+05}$	$1.2x10^{+06}$
U.S. EPA	Lotic Only	Arithmetic	$2.1x10^{+05}$*	$1.3x10^{+06}$*	$3.9x10^{+06}$*
California	Lotic Alternative	Geometric	$4.2x10^{+05}$	$6.8x10^{+05}$	$1.1x10^{+06}$
California	Lotic Alternative	Arithmetic	$1.2x10^{+06}$*!!	$1.4x10^{+06}$*	$3.5x10^{+06}$
California	Lotic SAIC calculated	Arithmetic	$2.3x10^{+04}$	$5.8x10^{+05}$	$7.4x10^{+05}$
U.S. EPA	Estuarine	Geometric	NP	NP	NP
U.S. EPA	Estuarine	Arithmetic	NP	NP	NP
California	Estuarine Alternative	Geometric	$6.1x10^{+03}$	NP	$1.1x10^{+05}$
California	Estuarine Alternative	Arithmetic	$8.7x10^{+03}$*	NP	$1.3x10^{+05}$*
California	Estuarine Alternative	Arithmetic	$2.45x10^{+05}$#	NP	$8.3x10^{+06}$#
California	Estuarine SAIC calculated	Arithmetic	$6.3x10^{+03}$	$5.6x10^{+04}$	$2.2x10^{+05}$

NP: Not possible to calculate from current California or national database.
ND: Not done.
*Maximum BAF for this trophic level and this water body environment.
!!Maximum BAF for this trophic level
These values were calculated using U.S. EPA estuarine translators. This was necessary because the SWRCB database did not contain data needed to calculate a total mercury to dissolved methylmercury translator.
These values were calculated using directly measured dissolved methylmercury concentrations from a limited number of measurements from the San Francisco estuary in the SWRCB database, March 2004.

3.6.2 Conclusions Concerning California Translators

Translators were not originally calculated from the California data compiled in the SWRCB California database. However, OEHHA determined that, in some cases, there were data in the database that could be used to calculate California-specific translators using the same method used to calculate California-specific BAFs. Just as California-specific BAFs might be more representative of California environments than national BAFs, California-specific translators

might work better to convert water data from California into dissolved methylmercury for calculating California-specific BAFs. OEHHA calculated translators from data in the database. These are shown with U.S. EPA translators in Table 32. These translators are subject to the same data quality limitations as the California-specific BAFs.

Translators are very important because they are often necessary to convert the form of mercury measured in water into dissolved methylmercury, the form needed to calculate BAFs. U.S. EPA derived three different translators for each aquatic environment (lentic, lotic, and estuarine): a translator between measured total mercury and dissolved total mercury (DHg/THg); a translator between measured total mercury and dissolved methylmercury (DMeHg/THg); and a translator between measured total methylmercury and dissolved methylmercury (DMeHg/TmeHg).

OEHHA found "gaps" in the data available for the SWRCB California database that limited which California-specific translators could be calculated. No California-specific translators could be calculated for lentic environments due to insufficient data. Water data are for all forms of mercury in water from lentic water bodies throughout California would be needed in order to calculate California-specific translators for the lentic environment. The only California-specific translator that could be calculated for the estuarine environments was DHg/THg. Data were insufficient to calculate other translators for this environment. The samples sizes for these calculations were small and the geographic range of water bodies in California was limited. It is possible to develop estuarine translators for DMeHg/THg and DMeHg/TMeHg from California-specific data from published studies in the literature (Conway *et al.*, 2003; Choe, *et al.* 2003a,b).

It was possible to calculate all three translators for lotic environments from the SWRCB database. All of these California-specific translators were similar to the corresponding U.S. EPA translator. The California and U.S. EPA translators were not statistically different. The samples sizes for these calculations were reasonable (all above 35 samples) but the geographic range of water bodies in California was limited. The limited geographic range of lotic, lentic, and estuarine water bodies compiled in the SWRCB California database (as discussed for BAFs) could also affect the California-specific translators. Additional data for all forms of mercury in water are needed from water bodies throughout California in order to calculate more representative California-specific translators.

There is no clear-cut scientific basis that shows that either the national or California-specific translators will yield more accurate results if used in a methylmercury implementation policy. The U.S. EPA data quality might be better but this cannot be proven and censoring some California data improves the overall SWRCB database quality. The chief reason to use the California-specific translators is that they may be more representative of California environmental conditions. But a significant problem is that appropriate translators could not be calculated in all environments due to a lack of data. SWRCB should also attempt to fill translator data gaps.

Table 32: Summary of Translators: comparison of U.S. EPA and California-based translators

Translator (f_d)	Data Source	Statistic	Lentic	Lotic	Estuarine
f_d Hg	U.S. EPA*	Geometric	0.60	0.37	0.35
	U.S. EPA	Arithmetic	NC	0.44	CR
	California	Arithmetic	ND	0.31	0.15
f_d $MeHg_d/MeHg_t$	U.S. EPA	Geometric	0.032	0.014	0.19
	U.S. EPA	Arithmetic	NC	0.020	NC
	California	Arithmetic	ND	0.015	ND
f_d $MeHg_d/MeHg_t$	U.S. EPA	Geometric	0.61	0.49	0.61
	U.S. EPA	Arithmetic	NC	0.53	NC
	California	Arithmetic	ND	0.51	ND

ND Data do not exist in the SWRCB database

NC Not calculated: because comparison of U.S. EPA data not possible because California data do not exist.

CR OEHHA cannot reproduce U.S. EPA's geometric mean value of 0.35 for this translator. Therefore, OEHHA is unsure that we have all of the data used by U.S. EPA and have not attempted to recalculate the arithmetic mean.

U.S. EPA values are from Table 9 and U.S. EPA (2000). California translators are calculated from the SWRCB database, March 2000. See Table 29 and 30 and text.

4 TESTING PREDICTIONS OF BIOTA MERCURY CONCENTRATIONS FROM DISSOLVED METHYLMERCURY CONCENTRATIONS IN WATER USING BIOACCUMULATION FACTORS

U.S. EPA calculated national default BAFs but did not evaluate their practical application by using them to predict fish tissue methylmercury concentrations from measured dissolved methylmercury concentrations in water. Predictions using default BAFs and translators should be tested for accuracy for multiple water bodies to evaluate their potential strengths, weaknesses and limitations. Water and tissue mercury concentrations from water bodies in the California SWRCB database compiled by SAIC will be used to test the U.S. EPA national default BAFs. Ten California lotic water bodies were selected for this testing. These water bodies were selected because data for dissolved methylmercury in water (converted and/or directly measured) and methylmercury in biota from one or more trophic levels were available from each of them for one or more trophic levels. It was not possible to perform a comparable test for lentic water bodies and BAFs due to gaps in available California data. Water and tissue measurements from all "sites" and times within each water body were used to derive a single water and tissue arithmetic mean value for that water body in this prediction exercise. Biota tissue levels for all trophic levels with BAFs (Trophic Levels 2, 3, and 4) were only available for the Sacramento River and Putah Creek. All ten lotic water bodies and their mean dissolved methylmercury levels are shown in Table 33, 34, and 35. Table 33 shows the predicted biota methylmercury level for Trophic Level 2 in all water bodies, and the actual arithmetic mean measured level, where available. Table 34 shows predicted and actual measured methylmercury levels for Trophic Level 3 from these water bodies, and Table 35 does the same for Trophic Level 4. The predicted values were derived by multiplying arithmetic mean BAFs derived from the U.S. EPA data (see discussion in the prior section) by the arithmetic mean of water concentrations of dissolved methylmercury (converted and/or directly measured) in each river.

Accompanying each table is a figure that plots the predicted and actual measured biota values for the subset of water bodies that have actual measured biota values for one trophic level at a time. Figures 7, 8, and 9 show plots corresponding to the respective trophic levels in Tables 33, 34, and 35. In each figure, some predicted values are close to the measured values. The predicted values closest to their respective measured values are indicated within a dashed circle. The drawing of the dashed circles or ovals in figures is not based on quantitative characterization of a mathematically defined cluster, but is qualitative and intended to call the reader's attention to the observation that, for the water bodies represented by the points within the dashed lines, the BAFs yielded a reasonable prediction of the actual values. Matched water and biota sampling using larger sample sizes are recommended to enable testing these observations more quantitatively.

Table 33. BAF predicted and measured biota concentrations in Trophic Level 2 Biota

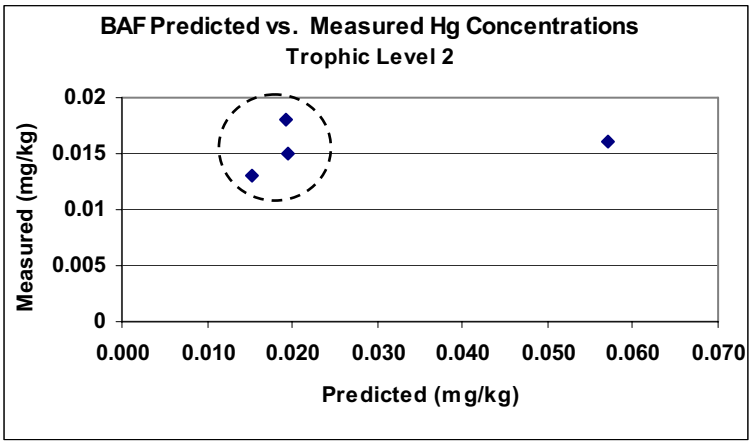
Location	**Water** (mg/L) DMeHg	**Biota (mg/kg)** Predicted[+]	Measured
Sacramento River (23)*	$9.00x10^{-08}$	0.019	0.018
Napa River (2)	$2.66x10^{-07}$	0.057	0.016
Redwood Creek (9)	9.09x10-^{08}	0.020	0.015
Putah Creek (5)	$7.06x10^{-08}$	0.015	0.013
Mokelumne River (0)	$9.62x10^{-08}$	0.021	-
San Joaquin River (0)	$8.06x10^{-08}$	0.017	-
Bear River (0)	$3.51x10^{-07}$	0.076	-
Coyote Creek (0)	$3.07x10^{-07}$	0.066	-
Guadalupe River (0)	$2.54x10^{-06}$	0.546	-
Alamo River (0)	$3.78x10^{-06}$	0.813	-

* Number of biota samples

[+] Calculated from mean measured or converted water concentration (mg/L) x arithmetic mean BAF (2.15E+05 L/kg)

Measured water and biota data from the SWRCB database, March 2004.

Figure 7.



Plotted data are from water bodies in Table 33 where data were available for water and biota. Circle indicates predicted BAF values that are closest to their respective measured BAF value.

Table 33 and Figure 7 show that estimates based on the arithmetic BAFs from U.S. EPA data predicted a tissue level similar to the measured biota methylmercury level in three out of the four water bodies selected because data were available for water and biota. The outlying point in Figure 7 is from the Napa River where the water concentration was much higher than the other three rivers, but the biota concentration was similar. The mean values for the three water bodies

with similar predicted and measured values of methylmercury in biota (excluding the Napa River outlier in Figure 7) were 0.018 and 0.015 ppm, respectively. A two-tailed t-test assuming unequal variance yielded a p = 0.27, thus indicating that these means were not statistically different.

Table 34. BAF predicted and measured biota concentrations in Trophic Level 3 biota

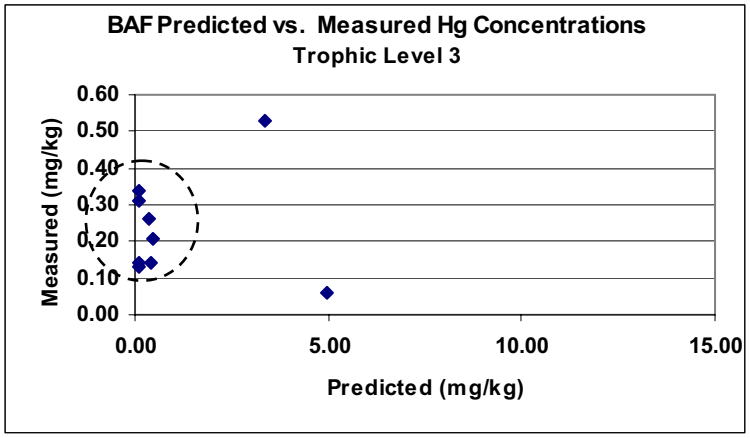
	Water (mg/L)	**Biota (mg/kg)**	
Location	DMeHg	Predicted[+]	Measured
Sacramento River (45)*	$9.00x10^{-08}$	0.119	0.340
Napa River (6)	$2.66x10^{-07}$	0.351	0.260
Redwood Creek (0)	$9.09x10^{-08}$	0.120	-
Putah Creek (10)	$7.06x10^{-08}$	0.093	0.130
Mokelumne River (9)	$9.62x10^{-08}$	0.127	0.310
San Joaquin River (32)	$8.06x10^{-08}$	0.106	0.140
Bear River (2)	$3.51x10^{-07}$	0.463	0.210
Coyote Creek (5)	$3.07x10^{-07}$	0.405	0.140
Guadalupe River (5)	$2.54x10^{-06}$	3.353	0.530
Alamo River (5)	$3.78x10^{-06}$	4.990	0.060

* Number of biota samples

[+] Calculated from mean measured or converted water concentration (mg/L) x arithmetic mean BAF $1.32E^{+06}$ (L/kg)

Measured water and biota data from the SWRCB database, March 2004.

Figure 8.



Plotted data are from water bodies in Table 34 where data were available for water and biota. Oval indicates predicted BAF values that are closest to their respective measured BAF value.

Table 34 and Figure 8 show that using the U.S. EPA arithmetic mean BAF for Trophic Level 3 fish predicted the mean mercury tissue level well in seven out of nine cases from the mean concentration of dissolved methylmercury in these water bodies selected because data were available for water and biota. Figure 8 shows two data points that fall outside of the dashed oval. Measured methylmercury in Trophic Level 3 biota was not predicted well for these two water bodies. The Guadalupe River, which is in the highly contaminated New Almaden mercury-mining district, had the highest concentration of methylmercury in water and in fish. The Alamo River had a relatively high concentration of methylmercury in water but a very low concentration in fish. This is the only river on this list that is not in northern California, and this river is not known to be associated with potential contamination from mining. In both cases the water concentrations for these outlier water bodies were higher than in the other water bodies, but in one case the predictions were off because the actual biota values were higher (*i.e.*, Guadelupe River), while in the other case they were lower (*i.e.*, Alamo River). These differences might indicate other factors specific to these water bodies are having a large effect on bioaccumulation. The variation in the measured biota data is about four-fold (0.13 to 0.53 mg/kg) compared to the higher variation in the predicted values that range >50-fold (0.09 to 5.0 mg/kg). The mean values for the similar predicted and measured values (excluding the two outlier water body in Figure 9) were 0.24 and 0.22 ppm, respectively. A two-tailed t-test assuming unequal variance yielded a $p = 0.79$, thus indicating that the means were not statistically different.

Table 35. BAF predicted and measured biota concentrations in Trophic Level 4 biota

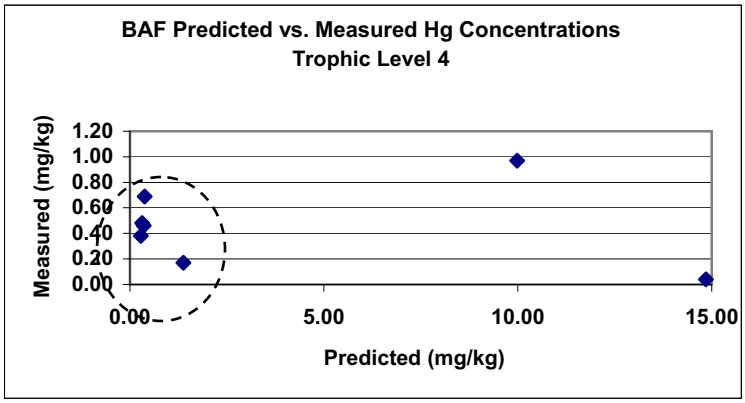
	Water (mg/L)	**Biota (mg/kg)**	
Location	DMeHg	Predicted[+]	Measured
Sacramento River (125)*	9.00×10^{-08}	0.354	0.460
Napa River (0)	2.66×10^{-07}	1.045	-
Redwood Creek (0)	9.09×10^{-08}	0.357	-
Putah Creek (28)	7.06×10^{-08}	0.277	0.380
Mokelumne River (39)	9.62×10^{-08}	0.378	0.690
San Joaquin River (261)	8.06×10^{-08}	0.317	0.480
Bear River (15)	3.51×10^{-07}	1.379	0.170
Coyote Creek (0)	3.07×10^{-07}	1.207	-
Guadalupe River (41)	2.54×10^{-06}	9.982	0.970
Alamo River (6)	3.78×10^{-06}	14.855	0.040

* Number of biota samples

[+] Calculated from mean measured or converted water concentration (mg/L) x arithmetic mean BAF ($3.93 \times 10^{+06}$ L/kg)

Measured water and biota data from the SWRCB database, March 2004.

Figure 9.



Plotted data are from water bodies in Table 35 where data were available for water and biota. Oval indicates predicted BAF values that are closest to their respective measured BAF value.

Table 35 and Figure 9 show that using the U.S. EPA mean BAF for Trophic Level 4 predicts the mean mercury tissue level well in five out of seven cases from the mean concentration of dissolved methylmercury in these water bodies selected because data were available for water and biota. The measured values range about 25-fold (0.04 to 0.97 mg/kg), whereas the predicted values range about 55-fold (0.28 to 14.9 mg/kg). If the low measured value of 0.04 mg/kg is removed from the measured data, then the range is slightly more then five-fold (0.17 to 0.97 mg/kg). This low value was for fish from the Alamo River, which is the only river in this list outside of northern California, an area where mercury from mining is typically a source of mercury in water. As in the case of Trophic Level 3, the two outliers with poor predictability were the Guadalupe and Alamo rivers. These two rivers had higher water concentrations of dissolved methylmercury than others in this list. The mean values (excluding the two outlier water bodies) for the predicted and measured levels of methylmercury in biota were 0.33 and 0.50 ppm, respectively. A two-tailed test with unequal variance for these data yielded a p value of 0.07, not quite significantly different using $p < 0.05$ as the measure of statistical difference.

4.1 OBSERVATIONS CONCERNING THE RESULTS OF TESTING LOTIC BAFs

This exercise shows that the U.S. EPA mean BAFs for Trophic Level 2, 3 and 4 predicted methylmercury tissue values from dissolved water concentrations from California lotic water bodies within qualitative limits in 15 out of 20 simulations, *i.e.*, 75 percent of the time. This is encouraging, but if BAFs are to be used in a regulatory situation it seems prudent to also test them more quantitatively. There are no clear regulatory criteria to use for "predictability," and the database used here is not necessarily complete enough for good statistical testing. One problem with doing this sort of testing is that that it would be necessary to separate natural variation in water and fish concentrations of mercury from lack of predictability. Thus, an additional step for quantifying predictability would be to establish good measurements of natural variation. Some studies have collected potentially useful data for water bodies in California. In five locations in the Sacramento River, Domalgalski (2001) observed an average of 183-fold

fluctuation in the concentration of total methylmercury measured once monthly (dissolved methylmercury is usually about 40-60 percent of total methylmercury, so it is likely that this species would vary about the same amplitude as total methylmercury). Slotton and Ayers (2003), in a study in Cache Creek, reported about four-fold maximum variation in mercury levels in four small forage fish species (red shiners, fathead minnows, green sunfish, mosquito fish) over four seasons. This is less than the observed variation in water concentrations of dissolved methylmercury (greater than biota but less than 10-fold) in Slotton *et al.* (2004). These limited data suggest that natural variability in dissolved methylmercury may be the most important variability to understand and quantify.

A second observation also shows the potential importance of understanding variation in dissolved methylmercury levels. All of the outliers in the qualitative prediction exercise were estimated from water bodies with adequate data for test that had unusually high water concentrations of dissolved methylmercury. At Trophic Level 2, the highest water concentration used in the predictions was for the Napa River. The mean dissolved methylmercury concentration for the four rivers used for prediction was 1.29×10^{-7} mg/L and the standard deviation was 0.92×10^{-7}. The water concentration in the Napa River (2.66×10^{-7} mg/L) was the only value greater than one standard deviate from the mean. This same pattern is seen for the other trophic levels and water concentrations. For Trophic Level 3, the qualitative outliers for prediction were from the Guadalupe and Alamo Rivers. In this case, the mean dissolved methylmercury concentration for the nine rivers used for prediction was 8.42×10^{-7} mg/L and the standard deviation was 13.54×10^{-7}. The water concentrations in the Guadalupe (2.54×10^{-6} mg/L) and Alamo Rivers (3.78×10^{-6} mg/L) were the only values greater than one standard deviate from the mean. For Trophic Level 4, the qualitative outliers were again from the Guadalupe and Alamo Rivers. In this case, the mean dissolved methylmercury concentration for the seven rivers used for prediction was 10.01×10^{-7} mg/L and the standard deviation was 15.21×10^{-7}. And the water concentrations in the Guadalupe and Alamo Rivers were the only values greater than one standard deviate from the mean. It appears that the BAF concept may not work well for California water bodies with dissolved methylmercury concentrations greater than about 10^{-7} mg/L. This should be tested further using more recent data not in the SWRCB database or by collecting new data.

Since the BAF used within a trophic level is the same, the failure in prediction is from applying the BAF to concentrations of dissolved methylmercury that are relatively higher than other water bodies. One standard deviate was a convenient line to use in the current examination, but it might be the wrong criteria to use for the entire distribution of dissolved methylmercury concentrations in lotic water bodies in California. In order to develop a better understanding of factors common to outliers, additional water and tissue data of this type must be subjected to this predictive paradigm and a quantitative criterion to evaluate prediction (*e.g.*, one standard deviate). More needs to be known about the distribution of dissolved methylmercury concentrations in lotic water bodies in California in order to identify important factors effecting water concentrations and bioaccumulation and to determine criteria to test predictions. Similar information should also be gathered about lentic and estuarine water bodies. This information could be used for predictive exercises and possibly to identify and exclude water bodies that are

at the extremes of the distribution of dissolved methylmercury concentrations where default BAFs should not be used because they are not predictive.

One final observation is that the lack of predictability may also be related to situations where extremes of factors that contribute to variation in methylmercury bioaccumulation are at work. The Alamo and the Guadalupe Rivers were identified as outliers in these examples at Trophic Levels 3 and 4. As noted above, the Alamo River was the only river on the list of water bodies used in this exercise that is not in northern California in an area associated with gold or mercury mining. The Alamo River is also in an area impacted by high runoff of salts from agricultural drainage. Both of these factors (salinity/alkalinity or contamination source) are known to effect bioaccumulation, and either could have contributed to the low fish concentrations of methylmercury measured in the Alamo River. On-the-other-hand, the Guadalupe River is in a former mercury mining area and this high contamination could have resulted in unusual conditions in this water body. Identifying extremes of other confounding factors may be important when attempting to test predictability.

4.2 CONCLUSIONS CONCERNING THE RESULTS OF TESTING BAF PREDICTIONS

The California SWRCB database contained data for the lotic environment that were useful for testing the accuracy of predicted biota mercury concentrations from dissolved methylmercury water levels through use of arithmetic mean BAFs, which were recalculated from the U.S. EPA BAF data. Due to gaps in available California data for lentic water bodies it was only possible to test BAFs for lentic water bodies. The test dataset contained data from 10 California rivers for which both mercury concentrations in water and biota were compiled in the database. The U.S. EPA translators and BAFs were used to convert water data into tissue concentrations. They qualitatively predicted tissue values in 75 percent of the water body examples for three trophic levels. New water and biota data would be needed to test the California BAFs developed from the SWRCB dataset in the same way. Examination of the results suggests that developing additional quantitative tests would be appropriate since BAFs will be used in a regulatory setting. Examination of the outliers suggests that additional information on natural variation, especially for dissolved methylmercury in California water bodies, is necessary to establish criterion to use to measure predictability and determine when BAFs might not be appropriate. Additional data to determine the distribution of dissolved methylmercury in lentic, lotic and estuarine water bodies in California should be collected. These data could be used to verify whether the default BAF concept works for California water bodies, in particular those with dissolved methylmercury concentrations greater than about 10^{-7} mg/L. Data to determine the distribution of mercury in biota in lentic, lotic and estuarine water bodies in California would also be useful in determining how to test and apply default BAFs.

5 SUMMARY OF EVALUATION OF BAFs AND TRANSLATORS

OEHHA found that U.S. EPA made a careful effort to compile available data and ensure quality control for the data they used to develop BAFs and translators. Despite their efforts they were not able to compile data representative of all categories of aquatic environments and organisms. In particular their database did not include enough data from which U.S. EPA could develop BAFs for estuarine environments. OEHHA and others noted problems with the U.S. EPA methodology and data. Some of the problems included: the potential for inaccurate identification of biota trophic levels; basing Trophic Level 2 BAFs on organisms that people do not eat; combining data based on different (*i.e.*, not pre-standardized) sampling and measurement techniques; using geometric means without testing the data distributions; low sample size for estuarine translators; and that their database had an uneven geographical and ecological coverage of water bodies. This last point could be especially relevant to California because most of the U.S. EPA data came from the Midwest United States and other areas where the source of mercury in water bodies was atmospheric deposition. California data included by U.S. EPA were from Clear Lake, and some scientific reviewers suggested that these data should be removed because the source of mercury in Clear Lake was different (mercury mining) than for other data. But legacy mining is the predominant source of mercury in many California water bodies, and therefore basing BAFs and translators on conditions associated with this source is important in California. It was also suggested that separate BAFs for a greater number of aquatic environmental categories should be developed and used rather than combining lotic and lentic BAFs into single national default values for each trophic level as U.S. EPA did. OEHHA did find that lotic BAFs were more variable than lentic BAFs and that combining them increased variability. OEHHA also noted that the translator for MeHgt/Hgt was more variable than that for MeHgd/MeHgt, and that directly measuring dissolved methylmercury in water, rather than using translators, helped reduce data variability. But overall OEHHA found that U.S. EPA's methods and results met their goal of developing BAFs and translators that were broadly applicable, especially for lentic and lotic water bodies.

OEHHA reviewed the SWRCB database of mercury measurements in water and biota from California as provided by SWRCB, and examined the BAFs calculated by SAIC. OEHHA found a difference between the way SAIC and U.S. EPA calculated BAFs. In the SWRCB California database measurements of mercury in water and fish were done in different studies and by different researchers. In contrast, mercury in water and biota were measured by the same researchers in the U.S. EPA database. OEHHA grouped measurements on the same water bodies and recalculated BAFs from the SWRCB database in a way analogous to that used by U.S. EPA. OEHHA also calculated translators for some forms of mercury using data available in this database. A number of gaps in available data were identified in the SWRCB database that prevented OEHHA from calculating lentic BAFs and some translators. OEHHA was able to calculate estuarine BAFs for Trophic Level 2 and 4, whereas, U.S. EPA had not calculated BAFs for the estuarine environment. In addition, OEHHA noted that the sample size on which BAFs and translators were based was variable and low in some cases, and that the location of water bodies for which data were available was not evenly distributed throughout the state (*i.e.*, more water bodies were from northern California). OEHHA compared the BAFs calculated from the SWRCB California database for organisms in lotic environments to the U.S. EPA lotic BAFs and demonstrated that they were very similar. The BAF values OEHHA calculated for the estuarine

environment were similar to the national default values, and translators developed from the SWRCB California data were also similar to the U.S. EPA translators. Based on the limited comparisons possible, BAFs and translators based on the California SWRCB dataset and international studies (U.S. EPA database) were found to be similar.

The final step in evaluation of BAFs and translators was to determine how accurately they would predict fish tissue mercury concentrations from water concentrations. U.S. EPA did not test their translators and BAFs. OEHHA was able to test the U.S. EPA national translators and BAFs to see if they accurately predicted mercury levels in fish for several California lotic water bodies by using the SWRCB California database. OEHHA found that the national values predicted California tissue concentrations very well (*i.e.,* no statistical difference between measured and predicted mercury concentration) except for some water bodies where mercury concentrations in water were statistically higher. Mercury concentrations (approximately $2x10^{-7}$ mg/L or more) in these water bodies were found to be more than one standard deviate from the mean for other data used in these tests. This suggests that translators and BAFs will work well in some lotic water bodies, but not in others, and that it will be important to identify characteristics of water bodies where they work and where they do not. This water value should not be considered a screening level because it has not been tested for enough water bodies. It was not possible to perform similar tests for fish in other types of water bodies due to gaps in the available data for the SWRCB database.

Based on OEHHA's evaluation the national default values for BAFs and translators are well established values that SWRCB can use in an implementation policy for the methylmercury tissue criterion. However, SWRCB should consider OEHHA's finding that these values may not work well for all water bodies in California. With this in mind, OEHHA has identified three alternatives for consideration by SWRCB when selecting BAFs and translators to use to implement the U.S. EPA ambient water quality criterion for methylmercury: 1) use the U.S. EPA BAFs and translators as developed by U.S. EPA for California water bodies; 2) use some BAF (*i.e.*, lotic BAFs) and translator values developed from the California database, and others developed by U.S. EPA; 3) before using BAFs and translators for a methylmercury criterion institute a program of data gathering that would fill in gaps in the California data and enable development and testing of additional BAFs and translators using data from different types of water bodies throughout the state. Alternative 1 is a practical solution that could be implemented without collecting additional data and would be consistent with national implementation. Based on OEHHA's evaluation using available data it will also yield predictions that are similar to measured concentrations of mercury in fish for many but not all lotic water bodies. It is unknown how well this alternative will work for other California water bodies. Alternative 2 is appealing because it would incorporate California data and values for lotic water bodies, but due to data gaps it would also require using national values for lentic water bodies and some translators. However, since OEHHA's evaluation found no significant difference between U.S. EPA and California values based on the existing database there is no scientific basis to support this alternative over Alternative 1. Alternative 3 would require collecting additional data on mercury concentrations in water and biota before full implementation and should include establishing standards for sampling, analytical methods, and Quality Assurance/Quality Control before data collection begins. Additional data collection is important to consider because

OEHHA was not able to test Alternative 1 for California lentic and estuarine water bodies using the current datasets and because some water bodies were identified where Alternative 1 did not work well.

OEHHA recommends that SWRCB consider collecting additional data representing a wide variety of water bodies spread throughout the state where BAFs and translators will be used as part of regulatory implementation for the methylmercury criterion. Alternative 1 could be used on a short term basis and collecting additional data could be used on a longer term basis to improve BAFs and translators used in California. Additional data for mercury concentrations in fish and water could fill data gaps, help identify biogeochemical factors with the greatest impact on methylmercury production and bioaccumulation, and better characterize how these affect variability in BAFs and translators. With enough good data it should be possible to identify water body types or geographic regions where national or California default BAFs and translators are more or less accurate. This would be a continual test of the BAF concept and default values. The results could be used to further test and verify the U.S. EPA or California values, or lead to developing better options, or options for water body types where the current values work poorly. SWRCB should consider prioritizing data collection based on which type(s) of water bodies are most impacted by regulatory implementation.

In particular more fish and water data are needed for: 1) lentic BAFs and translators; 2) to fill in data gaps for estuarine translators and Trophic Level 3 biota; and 3) to collect enough data to test lentic and estuarine BAFs and translators. Standard collection and analysis methods for mercury in water should be established as part of a program to collect more data. Measuring dissolved methylmercury directly should be considered as part of this program to reduce the variability that occurs when converting between mercury forms in water. It would be useful to also measure other forms of mercury in water (*e.g.*, total physical and chemical mercury, dissolved total mercury, etc.) to develop and test translators that might still be needed in some cases.

Collecting additional California data is also recommended to better characterize variability in mercury concentration in California water bodies and biota. Natural variability in mercury concentrations will occur in water and fish from any water body. Statistical tests such as those used by OEHHA to test BAF predictions account for variability when testing for true differences. But statistical testing is not typically used in regulatory applications and permits. One way to recognize variability in a regulatory setting would be to collect more data to separate variablility due to environmental differences from variablility common to all environments and use this to verify predictions and set regulatory limits.

Further data and testing would put BAFs and translators on a more sound scientific footing in California and provide data to determine whether the mining source of much of the mercury in California water bodies (at least in the Central Valley, northern California, and the Coast Ranges) lead to significant differences in BAFs and translators for some parts of the state.

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GLOSSARY OF TERMS

arithmetic mean (AM): is a measure of central tendency for the values in a distribution. It is commonly called the average, and is calculated by summing the data values and dividing the sum by the total number of data values.

BAF (Converted): Converted BAFs are derived from studies where the concentration of the measured mercury form in the water must be converted to dissolved methylmercury in order to calculate a BAF.

BAF (Direct): Direct BAFs are derived from studies where the concentration of dissolved methylmercury was measured and therefore can be used directly in the calculation a BAF.

bioaccumulation: The accumulation of chemicals in living organisms through the food web, *i.e.*, the accumulation of chemicals from one organism into another after it is eaten. When chemical metabolism and elimination of a chemical are slow chemicals may biomagnify through the food web. In this case the concentration increases with every step in the food web.

bioaccumulation factor (BAF): A bioaccumulation factor is the ratio between the concentration of a chemical measured in an organism and the concentration of the same chemical in water. This ratio is derived from field-collected samples of organisms and water.

biota: the living organisms (plant and animal life) in an area or ecosystem.

estuarine environment: The aquatic environment formed where freshwater from an inland river meets and mixes with saltwater from the ocean. Organisms in this environment are usually adapted to the different environmental conditions that occur where there is a mixture of fresh and saltwater. An example in California is the San Francisco Bay estuary that lies between the Pacific Ocean and the Sacramento and San Joaquin rivers.

geometric mean (GM): A geometric mean is used as a central tendency estimate for data that are log-normally distributed. The geometric mean is calculated by converting all data values to a $\log_{10}$ value, then the arithmetic mean of these transformed values is calculated. Finally the antilog of the arithmetic mean is calculated which is then geometric mean. Geometric means are used as estimates of central tendencies to reduce the influence of high values in the distribution.

lentic environment: An aquatic environment characterized by still (not flowing) water, *e.g.*, lakes and reservoirs.

log-normal data distribution: A distribution of values that is normally distributed when the raw values are transformed by taking the natural logarithm of each value. The values in log-normal distributions may range over several orders of magnitude, 1-100, 1,000, 10,000.

lotic environment: An aquatic environment characterized by flowing water, *e.g.*, streams and rivers.

mercury: dissolved: Dissolved mercury is any chemical form of mercury (inorganic or organic) measured in the water that passes through a small pore (micron) filter.

mercury: total: Total mercury is the sum of the concentrations of all chemical and physical forms of mercury in some medium. In fish tissue total mercury is the sum of inorganic and organic (methyl) mercury. In water it is the sum of all dissolved chemical and physical forms that are measured in water that flows through a filter plus the concentrations of the same forms retained on the filter. So total mercury might, in some cases, refer to the dissolved inorganic mercury plus inorganic mercury that is retained on the micron filter. The text specifies whether this term refers to all chemical and physical forms or some subset.

methylmercury: dissolved: Dissolved methylmercury is measured as the concentration of methylmercury from that passes through a micron filter. It is the form that is used in BAF calculation because it is considered the form that is most easily accumulated from water by biota, and the form which of greatest human health concern.

methylmercury: total: Total methylmercury is the sum of dissolved methylmercury that passes through a micron filter and the concentration of methylmercury mercury that is retained on a micron filter.

micron filter: Filters with small pore (hole) sizes. Micron filters used for characterizing of the forms (dissolved and non-dissolved) of mercury in water have diameters in the range 0.2-0.8 μm (2E-07 to 8E-07 meter) range.

microseston: The total suspended microscopic organic and inorganic matter in an aquatic environment.

phytoplankton: The portion of the plankton community comprised of living tiny plants (*e.g.* algae, diatoms) that are primary producers of energy.

p-value (statistic): The probability of a Type I error (*i.e.*, rejecting a true null hypothesis) occurring based on a statistical test. Typically a p-value of 0.05 (5% significance level) or below is used as the smallest level of significance to declare that there is a true difference between two data sets being compared (*e.g.*, finding that the arithmetic mean values for two data sets are different). Lower and higher p-values can be used. A p-value of $p \leq 0.05$ (5% significance) has been used in the report.

SAIC: Science Applications International Corporation. This organization compiled a database of California mercury measurements in water and biota.

SWRCB: State Water Resources Control Board.

Translators: Empirically derived factors (ratios) used for the conversion between forms of mercury. In this case, the translators are for different forms of mercury in water and are based on field-collected samples that occur in water into forms that can be used in the regulatory process. The U.S. EPA derived translators for the relationships of dissolved inorganic mercury to total inorganic mercury, dissolved methylmercury to total inorganic mercury and dissolved methylmercury to total methylmercury.

trophic level: Trophic means eating. Trophic levels are steps in a food chain characterized by feeding interactions. Energy moves up the food chain from lower to higher trophic levels as a result of organisms in one level feeding on those in a lower level. Organisms in Trophic Level 1 are primary producers that fix energy in an ecosystem (*e.g.*, plants and other organisms that fix energy. Trophic Level 2 organisms are herbivorous and feed on the primary producers. In aquatic ecosystems Trophic Level 3 organisms eat the herbivores and are forage fish for the next level. Trophic Level 4 organisms are carnivorous and eat primarily Trophic Level 3 organisms. In aquatic ecosystems these are the top predatory fish. Humans mostly eat fish and other aquatic organisms from Trophic Level 3 and 4.

zooplankton: Small (often microscopic) free-floating aquatic animals near the base of the food web (*i.e.* primary consumers).

APPENDIX 1: Criteria for Including Data in the California MeHg Database*

1. Data should be a primary source (provided by the funding organization or data collectors). It should not be from a database such as STORET where there are multiple sources combined, unless the source of the data is clearly identified.

2. The methods used (including sample preservation, sample handling, and analytical method) should be ascertainable. Note that sometimes the analytical method defines sample preservation and handling, so analytical method may sometimes be sufficient.

3. The units of all observations must be clearly identified.

4. Sampling dates – year should be specified at a minimum (day, month, and year are preferred)

5. Location of samples should be identified, including water depth, if appropriate. Location of samples should be by lat long, or other unique coordinates that locate the sample within a waterbody, not just in a waterbody or waterbody segment. May also use location naming information such as Sac River at river mile 44 or if map is available with station locations.

6. Fish Tissue Sample Type – sample must be filet either with or without skin (whole fish is not acceptable).

7. Fish Species – The common name or species name of the fish sampled must be apparent so that the trophic level can be determined.

8. Any notes on individual samples should be interpretable. We need to know what a "j," "k," or "l" means, and what samples were nondetects.

9. The analytical laboratory should be identifiable. The objective here is to ensure that data are professionally analyzed.

10. The sampling organization should be identifiable if different from the analytical laboratory. Particularly with Method 1631, sampling is complicated and should be done by fully trained and qualified staff.

*(personal communication from Diane Fleck, U.S. EPA, Region 9)

Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion

EPA 823-R-10-001 • April 2010

Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion

Final

United States Environmental Protection Agency

Office of Science and Technology (4305T)
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DISCLAIMER

This guidance provides advice on how to implement the water quality criterion recommendation for methylmercury that the U.S. Environmental Protection Agency (EPA) published in January 2001. This guidance does not impose legally binding requirements on EPA, states, tribes, other regulatory authorities, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA, state, tribal, and other decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from those in the guidance where appropriate. EPA may update this guidance in the future as better information becomes available.

The Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency has approved this guidance for publication. Mention of trade names, products, or services does not convey and should not be interpreted as conveying official EPA approval, endorsement, or recommendation for use.

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FOREWORD

On January 8, 2001, the U.S. Environmental Protection Agency (EPA) announced the availability of its recommended Clean Water Act (CWA) section 304(a) water quality criterion for methylmercury. This water quality criterion, 0.3 milligram (mg) methylmercury per kilogram (kg) fish tissue wet weight, describes the concentration of methylmercury in freshwater and estuarine fish and shellfish tissue that should not be exceeded to protect consumers of fish and shellfish among the general population. EPA recommends that states, territories, and authorized tribes use the criterion and this guidance in establishing or updating water quality standards for waters of the United States and in issuing fish and shellfish consumption advisories. States and authorized tribes remain free to adjust EPA's recommended criterion, provided that their new or revised water quality criteria protect the designated uses and are based on scientifically defensible methodology.

The publication of the 2001 methylmercury criterion was the first time EPA issued a water quality criterion expressed as a fish and shellfish tissue value rather than as a water column value. EPA recognizes that this approach differs from traditional water column criteria and might pose implementation challenges. In the January 8, 2001 Federal Register notice, EPA stated that it planned to develop more detailed guidance to help states, territories, and authorized tribes with implementation of the methylmercury criterion in water quality standards and related programs. This document provides that detailed guidance.

EPA wrote the *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* to provide technical guidance to states, territories, and authorized tribes exercising responsibility under CWA section 303(c), which provides for state review and revision of water quality standards every three years, and adoption of criteria for toxic pollutants, such as mercury, for which EPA has published criteria under CWA section 304(a). The document provides guidance on how to use the new fish tissue-based criterion recommendation in developing water quality standards for methylmercury and in implementing those standards in Total Maximum Daily Loads (TMDLs) and National Pollutant Discharge Elimination System (NPDES) permits. EPA also wrote the guidance to discuss approaches for managing the development of TMDLs for waterbodies impaired by mercury and to recommend an approach for directly incorporating the methylmercury tissue criterion into NPDES permits.

For more information on the methylmercury criterion, see the criteria page on EPA's Web site at http://www.epa.gov/waterscience/criteria/methylmercury/index.html. For more information on EPA's water quality standards program, see the standards page on EPA's Web site at http://www.epa.gov/waterscience/standards. For more information about this guidance document, contact U.S. Environmental Protection Agency, Office of Science and Technology (4305T), 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

Peter S. Silva
Assistant Administrator for Water
U.S. Environmental Protection Agency

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1 Executive Summary

In January 2001 EPA published ambient water quality criteria (AWQC) recommendations for methylmercury for the protection of people who eat fish and shellfish. This criterion, 0.3 milligram (mg) methylmercury per kilogram (kg) fish tissue wet weight, marks EPA's first issuance of a water quality criterion expressed as a fish and shellfish tissue value rather than as an ambient water column value.

Research shows that exposure to mercury and its compounds can cause certain toxic effects in humans and wildlife (USEPA 1997a). As of 2008, 50 states, 1 territory, and 3 tribes had issued fish consumption advisories for mercury covering 16.8 million lake acres and 1.3 million river miles (USEPA 2009a). Mercury is widely distributed in the environment and originates from natural and human-induced (anthropogenic) sources, including combustion and volcanoes. Methylmercury is highly bioaccumulative, especially in aquatic food webs. Nearly 100 percent of the mercury that bioaccumulates in upper-trophic-level fish (predator) tissue is methylmercury (Akagi et al. 1995; Becker and Bigham 1995; Bloom 1992; Kim 1995).

Under section 303(c) of the Clean Water Act (CWA), states and authorized tribes must adopt water quality criteria that protect designated uses. Section 303(c)(1) provides that states and authorized tribes review their water quality standards every three years and modify and adopt water quality standards as appropriate. In light of the new science used to develop the 2001 methylmercury fish tissue criterion, EPA believes that states should consider reviewing and revising their mercury human health criteria during their next triennial review. This document provides technical guidance to states and authorized tribes that exercise responsibility under CWA section 303(c) on how to use the new fish tissue-based criterion recommendation as they develop water quality standards for methylmercury.

EPA expects that, as states adopt methylmercury water quality criteria and as monitoring of effluents, receiving waters, and fish tissue with the more sensitive methods recommended by EPA increases, the number of waterbodies that states report on CWA section 303(d) lists as impaired due to methylmercury contamination might increase. This guidance is designed to assist states and authorized tribes to address those impairments. Furthermore, this guidance addresses coordination across various media and program areas in implementing the criterion, which will be important because atmospheric deposition and multimedia cycling of mercury are significant in many waterbodies.

EPA recognizes the complexity and comprehensive nature of this guidance. As is always the case when EPA issues technical guidance, EPA will provide outreach and technical assistance to states and authorized tribes in implementing this guidance.

The following tables (tables 1a through 1d) provide a brief summary of the most important recommendations applicable to states and authorized tribes that are contained in the guidance.

NOTE: These tables are provided as a convenience to the reader, but are not comprehensive and are not a substitute for the full content of the guidance contained in the other chapters of this document.

Table 1a. Recommendations for water quality standards adoption

	Most applicable to criteria expressed as…	For a full discussion see section…
Recommended form of a methylmercury criterion EPA recommends that states and authorized tribes adopt a methylmercury criterion expressed as a fish tissue value. When adopting a fish tissue criterion, states and authorized tribes will need to decide whether to:		3.1.2 and 3.1.3
• Implement the fish tissue criterion without water column translation, or	FT (fish tissue value)	
• Translate the fish tissue criterion to a water column value using bioaccumulation factors (BAFs). Three approaches include: 1. Site-specific BAFs 2. Modeled BAFs 3. BAFs derived using the results of field studies that are not site-specific (in limited circumstances); or	WC (water column value)	
• Combination (fish tissue criterion for some or all waters, combined with water column criteria for some or all waters).	Both FT and WC	
• States and authorized tribes may consider retaining their existing water column criteria, on a temporary basis, particularly for waters where there is a relatively high direct water input of mercury.	FT alone	
Adoption considerations • When adopting a fish tissue criterion, EPA encourages states and authorized tribes to develop implementation procedures.	FT or WC	3.1.2.1
• This guidance does not supersede requirements in EPA's Great Lakes Initiative (GLI) regulation for waters in the Great Lakes system.		5.1
Criterion adjustments • Adjusting for local fish consumption rates. • Adjusting for other sources of mercury (marine fish).	FT or WC	3.2.1
Mixing zones		5.3
• Not relevant when applying a fish tissue criterion that has not been translated to a water column value.	FT alone	
• If the fish tissue criterion is converted to water column values, EPA advises caution in the use of any mixing zones for mercury. Restricting or eliminating mixing zones may be appropriate.	WC	
Variances • Guidance on when variances are appropriate. • Considerations before granting a variance.	WC	3.2.2

Table 1b. Recommendations for monitoring and assessment

	Most applicable to criteria expressed as…	For a full discussion see section…
Recommended analytical methods		4.1
• Methods 1631, revision E and 245.7 for mercury in water.	WC	
• Draft Appendix A of Method 1631 for mercury in fish tissue.	FT	
• Method 1630 for methylmercury in water.	WC	
• Method 1630 (with draft modifications) for methylmercury in fish tissue.	FT	
Other available methods are listed in appendix C of this guidance.	FT or WC	App. C
Field sampling recommendations	FT alone	4.2
• Select fish for monitoring that are commonly eaten in the study area.		
• Choose large fish because these are typically highest in methylmercury.		
• If local consumption data are not available, match assumed consumption pattern to sampled species, or sample trophic level 4 species.		
• Use composite samples of fish fillets.		
• EPA recommends biennial sampling if resources allow, otherwise waterbodies should be screened a minimum of every 5 years.		
Assessing non-attainment of fish tissue criterion	FT alone	4.3
• Use statistical tests if enough data, or consider sample-by-sample comparisons if very limited data.		

Table 1c. Recommendations for total maximum daily loads (TMDLs)

	Most applicable to criteria expressed as…	For a full discussion see section…
States' timing of TMDL development • States with comprehensive mercury reduction programs in place may defer TMDLs for waters impaired by mercury mainly from atmospheric sources. (Summarizing EPA's voluntary "5m" category for listing impaired waters.) • The greater the relative contribution to a waterbody from mercury sources other than air deposition, such as water point sources, the more appropriate it may be to use the TMDL process to characterize and address those sources sooner, rather than deferring TMDL development.	FT or WC	6.2 and 7.5.2.2
Approaches in approved mercury TMDLs Examples in guidance text and appendix D discuss: • Types of mercury sources; tools for assessing point sources, atmospheric deposition, past metals mining activity, sediments, and natural sources. • Example allocation scenarios involving waters where predominant sources are air deposition or mining. • Post-TMDL monitoring.	FT or WC	6.2
Geographic scale Describes scales that have been used for developing mercury TMDLs: • Waterbody-specific. • Watershed-level. • Statewide or regional.	FT or WC	6.2.1
Available models and example TMDL applications • Example models for different situations (steady state, dynamic, detail geometry, regression). • Factors leading to model selection (methylation, BAFs, sediments). • Use of linked models without having explicit water column criteria or translations. • Other analytical approaches, e.g., proportionality approach: Where air deposition is the only significant mercury source and steady-state conditions apply, TMDLs have been developed to meet fish tissue targets by relying on a proportional relationship between mercury deposition and fish tissue methylmercury concentration.	FT or WC FT alone FT	6.2.2.2 6.2.2.2.1

Table 1d. Recommendations for permitting procedures

	Most applicable to criteria expressed as…	For a full discussion see section…
Two implementation approaches		
• If a TMDL or a water column translation derived from a fish tissue criterion or site-specific data to translate is available at time of permit issuance, implement using the approaches described in the Technical Support Document (TSD) for Water Quality-based Controls (USEPA 1991).	WC	7.4
• If a TMDL or water column translation or site-specific data to translate are not available, implement approaches described below.	FT alone	7.5
Finding "reasonable potential" (RP)[a] Depending on the particular facts, a permitting authority may reasonably conclude that a facility has RP if: • There is a quantifiable level of mercury in the discharge, using a sufficiently sensitive EPA-approved analytical method and • Fish tissue from the receiving water is close to or exceeds the criterion.	FT alone	7.5.1
Where mercury effluent levels are unknown EPA recommends that permitting authorities: • Require effluent monitoring using a sufficiently sensitive EPA-approved analytical method. • Include a reopener clause in the permit to allow permit to be modified if effluent data indicate a water quality-based effluent limit (WQBEL) is necessary.	FT alone	7.5.1.1.1
Where quantifiable amounts of mercury are not found • If the permitting authority believes the monitoring data are representative of the discharge, no further permit conditions may be necessary.	FT alone	7.5.1.1.2
Where fish tissue concentrations are unknown EPA recommends that permitting authorities: • Include a special permit condition to conduct a mercury fish tissue survey for the receiving waterbody. • Include a reopener clause in the permit to allow permit to be modified if fish tissue data become available indicating a WQBEL is necessary. • Encourage the permittee to develop and implement a mercury minimization plan (MMP) tailored to the facility's potential to discharge mercury.	FT alone	7.5.1.2.1

Table 1d. Recommendations for permitting procedures *(continued)*

	Most applicable to criteria expressed as…	For a full discussion see section…

Permits with quantifiable mercury but without RP
Where a discharge contains a quantifiable amount of mercury but fish tissue in the receiving water does not exceed the criterion:
• If the discharger will undertake an activity that could result in an increase in receiving water or fish tissue mercury concentration
  ○ Conduct tier 2 antidegradation analysis and develop appropriate permit conditions.
  ○ Require permittee to implement an MMP tailored to the facility's potential to discharge mercury.
  ○ Require effluent monitoring.
• If the discharger will not undertake an activity that could result in an increase in receiving water or fish tissue mercury concentration:
  ○ Encourage the facility to develop and implement an MMP tailored to the facility's potential to discharge mercury.
	FT alone	7.5.1.2.2

Other factors in determining RP • EPA recommends that the permitting authority account for other factors that may constitute the basis for a finding of RP. These include rising fish tissue concentrations and the impact on downstream waters.	FT alone	7.5.1.2.2
Mercury in intake water • Where the only source of mercury in a discharge may be the intake water taken directly from the same body of water, and where there are no known sources or additional contributions of mercury at the facility, the permitting authority may reasonably conclude, based on the particular facts, that there is no RP to exceed water quality standards.	FT or WC	7.5.1.3

Table 1d. Recommendations for permitting procedures *(continued)*

	Most applicable to criteria expressed as…	For a full discussion see section…
WQBELs where there is a finding of RP[b] EPA recommends that permitting authorities: • Require the permittee to implement an MMP tailored to its potential to discharge mercury. • Depending on the particular facts, the permitting authority should consider including in an MMP an effluent trigger level, a mercury reduction goal, or an enforceable numeric level representing existing effluent quality or some increment of the mercury reduction determined achievable as a result of the measures and practices specified in the MMP. • Require effluent monitoring using a sufficiently sensitive EPA-approved method to enable evaluation of the effectiveness and implementation of the MMP. • Include a reopener clause to modify the permit conditions if the MMP is found to be not effective or if a water column translation of the criterion is developed. Other considerations and requirements may be necessary: • Where a discharger undertakes an activity that could result in an increase in receiving water or fish tissue mercury concentrations, it must be consistent with applicable antidegradation requirements. Additional requirements may also be necessary under the CWA and EPA's NPDES regulations. • Include appropriate technology-based limits pursuant to CWA section 301(b) and 40 CFR sections 125.3 and 122.44(a)(1). • For modified or reissued permits with existing effluent limits for mercury, any less stringent effluent limit must be consistent with anti-backsliding requirements.	FT alone	7.5.2.1 7.2.4

Table 1d. Recommendations for permitting procedures *(continued)*

	Most applicable to criteria expressed as…	For a full discussion see section…
Permits with RP where direct water inputs are relatively high In addition to the above: • EPA recommends that states and authorized tribes specifically consider developing TMDLs in the short term. • Where a state or tribe chooses not to develop a TMDL in the short term, the state or tribe should develop an analysis of sources and loading capacity similar to what a TMDL would provide, or a water column translation of the fish tissue criterion. • EPA recommends that permitting authorities work together with mercury dischargers in the watershed to collect data necessary to develop: o A TMDL, or o An analysis of sources and loading capacity similar to what a TMDL would provide, or o A water column translation of the fish tissue criterion for future permitting. One approach is for the permitting authority to invoke its authority under CWA section 308 (or comparable state authority).	FT alone	7.5.2.2
Additional requirements that may apply • Additional requirements for: POTWs with pretreatment programs; technology-based limits; anti-backsliding; permit documentation.	FT or WC	7.5.2.3
Mercury minimization plans (MMPs) This section provides guidance on appropriate MMPs.	FT	7.5.2.4

Notes:

[a] "Reasonable potential" refers to the reasonable potential to cause or contribute to an excursion above a numeric or narrative criterion for water quality. 40 CFR 122.44(d)(1)(i). NPDES permits for discharges with "reasonable potential" must include water quality-based effluent limits (WQBELs).

[b] As noted at the beginning of table 1d, this section refers to situations where neither a TMDL nor a water column translation is available at time of permit issuance. Where a TMDL has been developed, the WQBEL for that discharge must be consistent with the TMDL's wasteload allocation. Where a TMDL is not available at the time of permit discharge, but where a water column translation of the fish tissue criterion has been developed, or where site-specific data to do so are readily available, include a numeric WQBEL.

2 Introduction

2.1 What is the interest in mercury?

Mercury occurs naturally in the earth's crust and cycles in the environment as part of natural and human-induced activities. The amount of mercury mobilized and released into the biosphere has increased since the beginning of the industrial age. Most of the mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year and therefore can be widely dispersed and transported thousands of miles from sources of emission (USEPA 1997b). Most of the mercury in water, soil, sediments, plants, and animals is in the form of inorganic mercury salts and organic forms of mercury (e.g., methylmercury). Inorganic mercury salts, when bound to airborne particles, are readily removed from the atmosphere by precipitation and are also dry deposited. Even after mercury deposits, it commonly returns to the atmosphere, as a gas or associated with particles, and then redeposits elsewhere. As it cycles between the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood (USEPA 1997b).

This guidance focuses on an organic mercury compound known as methylmercury. Methylmercury most often results from microbial activity in wetlands, the water column, and sediments, and it is the form of mercury that presents the greatest environmental risks to human health (66 FR 1344; January 8, 2001). The methylation process and methylmercury bioaccumulative patterns are discussed in more detail in section 2.3.

2.1.1 What are the health effects of methylmercury?

Exposure to methylmercury can result in a variety of health effects in humans. Children that are exposed to low concentrations of methylmercury prenatally might be at risk of poor performance on neurobehavioral tests, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory (NRC 2000; USEPA 2002a). Mercury and its compounds are listed as a "toxic" pollutant under section 307(a) of the Clean Water Act (see 40 CFR 401.15).

In 2000 the National Academy of Sciences (NAS)/National Research Council (NRC) reviewed the health studies on mercury (NRC 2000). EPA's assessment of the methylmercury reference dose (RfD) relied on the quantitative analyses performed by the NRC (USEPA 2002a). The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects during a lifetime (USEPA 2002a). In its review of the literature, NRC found neurodevelopmental effects to be the most sensitive endpoints and appropriate for establishing a methylmercury RfD (NRC 2000).

On the basis of the NRC report, EPA established an RfD of 0.0001 mg/kg-day (0.0001 milligram of methylmercury per day for each kilogram of a person's body mass) (USEPA 2002a). EPA believes that exposures at or below the RfD are unlikely to be associated with an appreciable risk of deleterious effects. It is important to note, however, that the RfD does not define an exposure level corresponding to zero risk; mercury exposure near

or below the RfD could pose a very low level of risk that EPA deems nonappreciable. It is also important to note that the RfD does not define a bright line above which individuals are at risk of adverse effects (USEPA 2005a).

The primary route by which the U.S. population is exposed to methylmercury is through the consumption of fish containing methylmercury. The exposure levels at which neurological effects have been observed in children can occur through maternal consumption of fish (rather than high-dose poisoning episodes) (USEPA 2005a).

In 2005 the National Health and Nutrition Examination Survey (NHANES) published the results of a study of blood mercury levels in a representative sample of U.S. women of childbearing age (CDC 2005). The report data for the period 1999–2002 show that all women of childbearing age had blood mercury levels below 58 μg/L, a concentration associated with neurological effects in the fetus. These data show that 5.7 percent of women of childbearing age had blood mercury levels between 5.8 and 58 μg/L; that is, levels within an order of magnitude of those associated with neurological effects. Typical exposures for women of childbearing age were generally within two orders of magnitude of exposures associated with these effects, according to data from NHANES (CDC 2005; USEPA 2005a).

With regard to other health effects of methylmercury, some recent epidemiological studies in men suggest that methylmercury is associated with a higher risk of acute myocardial infarction, coronary heart disease, and cardiovascular disease in some populations (Salonen et al. 1995, as cited in USEPA 2001a). Other recent studies have not observed this association. The studies that have observed an association suggest that the exposure to methylmercury might offset the beneficial effects of fish consumption (USEPA 2005a). There also is some recent evidence that exposures to methylmercury might result in genotoxic or immunotoxic effects ([Amorim et al. 2000; ATSDR 1999; Silva at al. 2004], as cited in USEPA 2005a). Other research with less corroboration suggests that reproductive, renal, and hematological impacts could be of concern. There are insufficient human data to evaluate whether these effects are consistent with methylmercury exposure levels in the U.S. population (USEPA 2005a).

Deposition of mercury to waterbodies can also have an adverse impact on ecosystems and wildlife. Plant and aquatic life, as well as birds and mammalian wildlife, can be affected by mercury exposure; however, overarching conclusions about ecosystem health and population effects are difficult to make. Mercury contamination is present in all environmental media; aquatic systems experience the greatest exposures because of bioaccumulation. *Bioaccumulation* refers to the net uptake of a contaminant from all possible pathways. It includes the accumulation that might occur by direct exposure to contaminated media, as well as uptake from food. Elimination of methylmercury from fish is so slow that long-term reductions of mercury concentrations in fish are often due to growth of the fish (“growth dilution“), whereas other mercury compounds are eliminated relatively quickly. Piscivorous avian and mammalian wildlife are exposed to mercury mainly through consuming contaminated fish, and as a result they accumulate mercury to levels greater than those in their prey (USEPA 1997a).

EPA's mercury Web site, at http://www.epa.gov/mercury, provides a broad range of information about mercury, including a full discussion of potential human health and ecosystem effects.

2.1.2 How frequent are the environmental problems?

As of the 2008 listing of impaired waters (i.e.: water not attaining water quality standards) under section 303(d) of the clean Water Act, 43 states and Puerto Rico reported at least one waterbody as impaired due to mercury, and more than 8,800 specific waterbodies were listed as impaired due to mercury, either solely or in combination with other pollutants. All states have numeric criteria for mercury. About seven states, plus Washington D.C. and two territories have adopted a fish tissue criterion for methylmercury. Once additional states, tribes and territories begin to adopt EPA's recommended fish tissue criterion, the number of waterbodies listed as impaired for methylmercury is expected to increase since the revised criterion is more stringent than the water concentration criteria most states currently have in their water quality standards.

In 2001 EPA mapped concentrations of mercury in fish tissue from fish collected from waterbodies all over the country (i.e., not limited to the waters identified by the states as impaired) and compared them to the 2001 national recommended water quality criterion, 0.3 mg methylmercury/kg fish tissue wet weight. These data were not randomly or systematically collected, but rather reflect fish tissue information that states had collected as part of their fish consumption advisory programs. Approximately 40 percent of the watershed-averaged fish tissue concentrations exceeded 0.3 mg methylmercury/kg fish tissue wet weight (USEPA 2001b).

Figure 1 shows fish tissue mercury concentrations averaged by watershed (by 8-digit hydrologic unit code, or HUC).

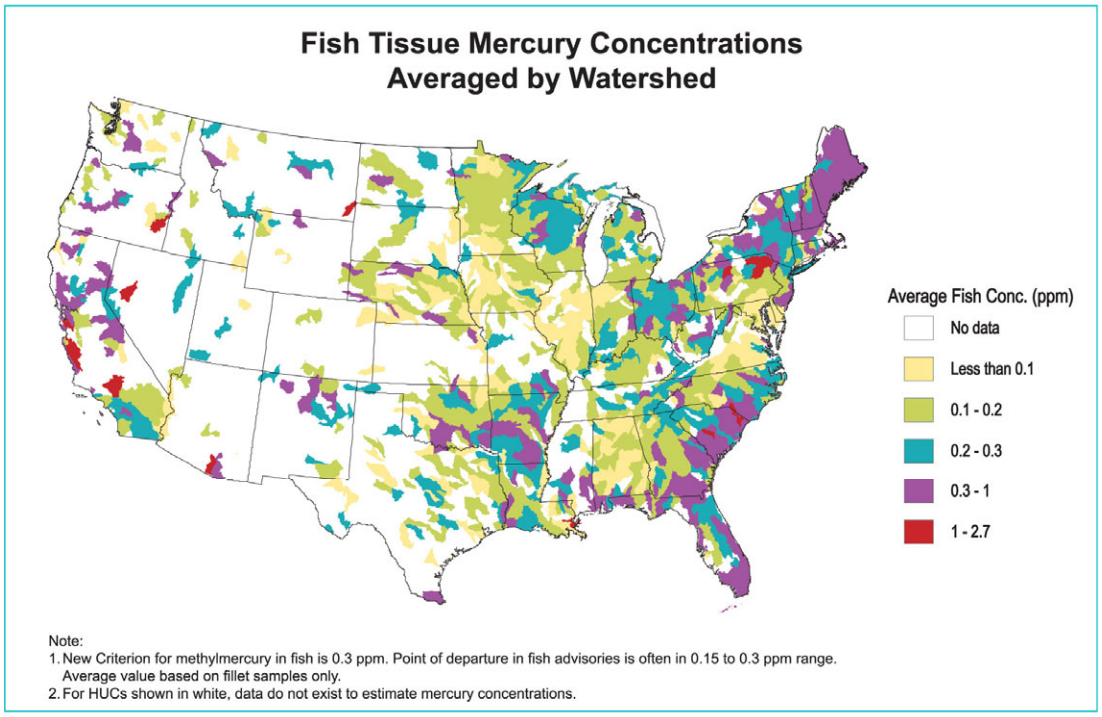


Figure 1. Average fish tissue concentrations by HUC watershed (USEPA 2005a).

In EPA's *Environmental Monitoring and Assessment Project (EMAP) Western Streams and Rivers Statistical Study* (USEPA 2005b), 626 streams and rivers were sampled in 12 states of the western United States. Mercury was detected at 100 percent of sites and samples in the study. The 0.3 mg/kg criterion (equivalent to 0.3 parts per million, ppm) was exceeded in 56.8 percent of waters surveyed, which represent 20–30 percent of all western rivers (Peterson et al. 2007). Results from the 2009 National Lake Fish Tissue Study, a statistically-based survey conducted by EPA, showed that 49% of the sampled population of lakes (76,559 lakes in the lower 48 states with surface areas greater than or equal to 1 hectare or about 2.5 surface acres) had mercury concentrations that exceeded the 0.3 ppm tissue-based mercury criterion (USEPA 2009b).

As of December 2008, 50 states, 1 territory, and 3 tribes had issued fish consumption advisories[1] for mercury covering 16.8 million lake acres and 1.3 million river miles (figure 2). Twenty-seven states had issued advisories for mercury in all freshwater lakes and rivers in the state, 13 states had statewide advisories for mercury in their coastal waters and one state had a deep sea advisory (USEPA 2009a). The thresholds for the levels of mercury in fish that trigger the issuance of an advisory for women of childbearing age vary among the states and authorized tribes, but generally range from 0.07 to 1 ppm, with most threshold values in the range of 0.1 to 0.3 ppm.

Although states, territories, tribes, and local governments continue to issue new fish advisories and most new fish advisories involve mercury, EPA believes that the increase in advisories is a result of increased monitoring and assessment of previously untested waters rather than increased domestic releases of mercury or increased levels or frequency of contamination. In fact, U.S. releases of mercury to the air have declined by more than 58 percent between 1990 and 2005 (USEPA 2008b).

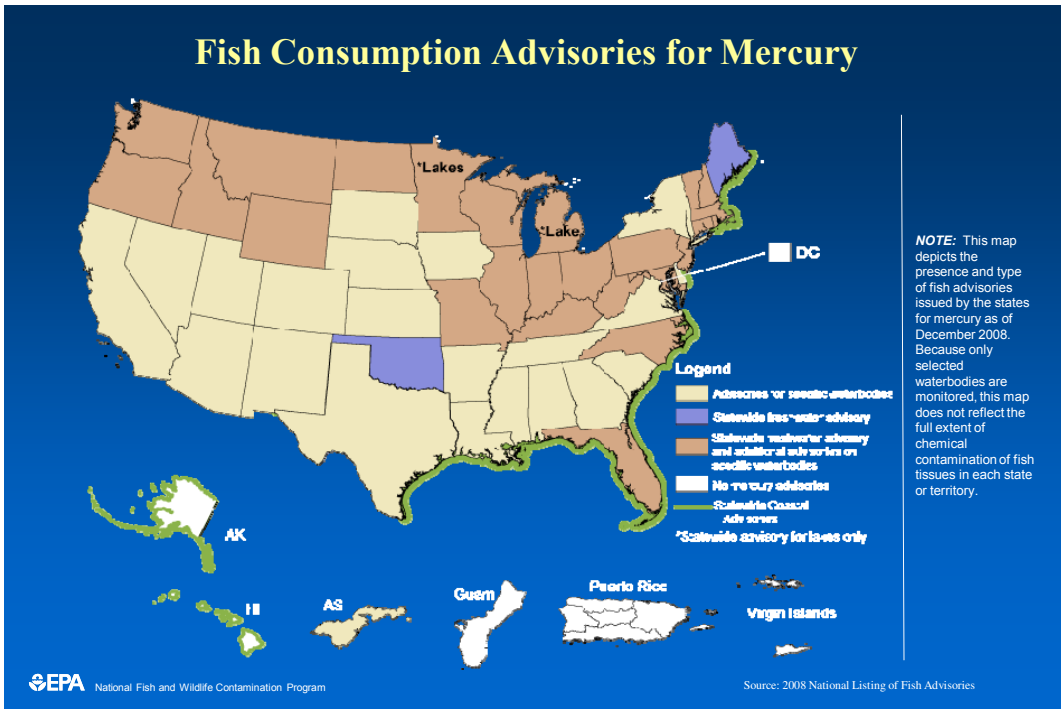


Figure 2. Fish Consumption Advisories for Mercury 2008 (USEPA 2009a).

[1] States and tribes issue their advisories and guidelines voluntarily and have flexibility in which criteria they use and how they collect data. As a result, there are significant variations in the numbers of waters tested, the pollutants tested for, and the threshold for issuing advisories. Based on self-reporting, the national trend is for states to monitor different waters each year, generally without retesting waters monitored in previous years. Note that EPA does not issue fish advisories; states and tribes issue advisories (with the exception of national advisories, regional advisories, and Superfund-related advisories). EPA issues guidance on the level of contaminants in fish, which states and tribes may use in issuing their advisories.

2.2 What are the sources of mercury in fish?

Mercury is emitted from both natural and anthropogenic sources. Its residence time in the atmosphere is much longer than that of most other metals because mercury can circulate for up to a year (USEPA 1997b). Such mobility enables elemental mercury to disperse and be transported over thousands of miles from likely sources of emission, across regions, and around the globe. As a result, the mercury detected in fish in U.S. surface waters is from both U.S. and international sources (USEPA 2005c). EPA estimates that approximately 83 percent of the atmospheric mercury deposited on land and water in the country is from a combination of sources outside the United States and Canada, as well as from natural and re-emitted sources. EPA's current air quality modeling indicates a substantial variation across the country: domestic sources influence mercury deposition much more in the East, and global sources are a more significant contributor to mercury deposition in the West, where relatively few domestic sources exist. This estimate was based on a modeling assessment of the atmospheric fate, transport, and deposition of mercury conducted by EPA for the Clean Air Mercury Rule[2] (USEPA 2005d).

Natural sources of mercury include geothermal emissions from volcanoes and crustal degassing in the deep ocean, as well as dissolution of mercury from other geologic sources (Rasmussen 1994). Anthropogenic sources of mercury in the United States include combustion (e.g., utility boilers; municipal waste combustors; commercial/industrial boilers; hospital, medical, and infectious waste incinerators), manufacturing sources (e.g., chlor-alkali and cement manufacturers), and mining (USEPA 1997b).

U.S. anthropogenic emissions of mercury to the air have declined more than 58 percent from the passage of the 1990 Clean Air Act (CAA) Amendments to 2005 (most recent data available). These amendments provided EPA new authority to reduce emissions of mercury and other toxic pollutants to the air. In 1990 more than two-thirds of U.S. human-caused mercury emissions came from just three source categories: coal-fired power plants; municipal waste combustion; and hospital, medical, and infectious waste incineration (figure 4, section 6.2.2.1). Regulations were issued in the 1990s to control mercury emissions from waste combustion. In addition, actions to limit the use of mercury—most notably voluntary and Congressional action to limit the use of mercury in batteries and EPA regulatory limits on the use of mercury in paint—contributed to the reduction of mercury emissions from waste combustion during the 1990s by reducing the mercury content of waste. Regulation of mercury emissions from chlorine production facilities that use mercury cells and regulation of industrial boilers will further reduce emissions of mercury.[3]

[2] On February 8, 2008, the D.C. Circuit Court of Appeals vacated the Section 112(n) Revision Rule and the Clean Air Mercury Rule.

[3] Rules controlling mercury emissions, which implement the 1990 CAA amendments, include standards for municipal waste combustors (40 CFR part 60, subpart Da, and parts 72 and 75); standards for hospital, medical, and infectious waste incinerators (40 CFR part 60, subpart Ce); standards for chlor-alkali plants (40 CFR part 63, subpart IIIII); standards for existing and new hazardous waste-burning incinerators (40 CFR 63.1203 [a][2] and [b][2]); standards for existing and new hazardous waste-burning cement kilns (40 CFR 63.1204 [a][2] and [b][2]); and standards for existing and new hazardous waste-burning lightweight aggregate kilns (40 CFR 63.1205 [a][2] and [b][2]). See also section 8.3 of this document.

At present, the largest single source of anthropogenic mercury emissions to the air in the country is coal-fired power plants. Mercury emissions from U.S. power plants are estimated to account for about one percent of total global mercury emissions (70 FR 15994; March 29, 2005). In May 2005, EPA adopted the Clean Air Act Section 112(n) Revision Rule and the Clean Air Mercury Rule (CAMR). CAMR regulated mercury emissions from coal-fired utilities. On February 8, 2008, the D.C. Circuit Court of Appeals vacated the Section 112(n) Revision Rule and CAMR. EPA is developing air toxics emissions standards for power plants under Clean Air Act (Section 112(d). EPA currently intends to propose and finalize air toxics standards for coal- and oil-fired electric generating units by the end of 2011. Point sources of mercury discharging into waters are also regulated by NPDES permits. Chlor-alkali facilities are subject to effluent guidelines that impose treatment levels reflective of the Best Available Technology Economically Achievable (40 CFR part 415). All NPDES permits must ensure that permitted discharges achieve water quality standards (40 CFR 122.44(d)). Nonpoint source runoff is not regulated under federal regulations, but to the extent that these sources cause a water to exceed its water quality standards, states will develop TMDLs that identify the necessary reductions from these sources for achieving the water quality standards.

Anthropogenic emissions, however, are only one part of the mercury cycle. Releases from human activities today add to the mercury reservoirs that already exist in land, water, and air, both naturally and as a result of previous human activity.

2.3 How does methylmercury get into fish and shellfish?

Mercury is widely distributed in the environment. Understanding the distribution and cycling of mercury among the abiotic (nonliving) and biotic (living) compartments of aquatic ecosystems is essential to understanding the factors that govern methylmercury uptake in fish and shellfish tissue. The following is a synopsis of the current understanding of mercury cycling in the environment.

Mercury occurs naturally in the environment as several different chemical species. Most mercury in the atmosphere (95–97 percent) is present in a neutral, elemental state, Hg^0 (Lin and Pehkonen 1999). In water, sediments, and soils, most mercury is found in the oxidized, divalent state, Hg^{II} (Morel et al. 1998). A small fraction of this pool of divalent mercury is transformed by microbes into methylmercury (CH_3Hg^{II}) (Jackson 1998). Methylmercury is retained in fish tissue and is the only form of mercury that biomagnifies in aquatic food webs (Kidd et al. 1995). Transformations among mercury species within and between environmental media result in a complicated chemical cycle.

The relative contributions of local, regional, and long-range sources of mercury to fish mercury levels in a given waterbody are strongly affected by the speciation of natural and anthropogenic emission sources. Elemental mercury is oxidized in the atmosphere to form the more soluble mercuric ion, Hg^{II} (Schroeder et al. 1989). Particulate and reactive gaseous phases of Hg^{II} are the principal forms of mercury deposited onto terrestrial and aquatic systems because they are more efficiently scavenged from the atmosphere through wet and dry deposition than is Hg^0 (Lindberg and Stratton 1998). Because Hg^{II} species or reactive gaseous mercury (RGM) and particulate mercury (Hg_p) in the atmosphere tend to be deposited more locally than Hg^0, differences in the species of

mercury emitted affect whether the mercury is deposited locally or travels longer distances in the atmosphere (Landis et al. 2004).

A portion of the mercury deposited in terrestrial systems is re-emitted to the atmosphere. On soil surfaces, sunlight might reduce deposited Hg^{II} to Hg^{0}, which might then escape back to the atmosphere (Carpi and Lindberg 1997, Frescholtz and Gustin 2004, Scholtz et al. 2003). Significant amounts of mercury can be co-deposited to soil surfaces in throughfall and litterfall of forested ecosystems (St. Louis et al. 2001), and exchange of gaseous Hg^{0} by vegetation has been observed (e.g., Gustin et al. 2004). Hg^{II} has a strong affinity for organic compounds such that inorganic mercury in soils and wetlands is predominantly bound to dissolved organic matter (Mierle and Ingram 1991). Concentrations of methylmercury in soils are generally very low. In contrast, wetlands are areas of enhanced methylmercury production and account for a significant fraction of the external methylmercury inputs to surface waters that have watersheds with a large portion of wetland coverage (e.g., St. Louis et al. 2001).

In the water column and sediments, Hg^{II} partitions strongly to silts and biotic solids, sorbs weakly to sands, and complexes strongly with dissolved and particulate organic material. Hg^{II} and methylmercury sorbed to solids settle out of the water column and accumulate on the surface of the benthic sediment layer. Surficial sediments interact with the water column through resuspension and bioturbation. The amount of bioavailable methylmercury in water and sediments of aquatic systems is a function of the relative rates of mercury methylation and demethylation. In the water, methylmercury is degraded by two microbial processes and sunlight (Barkay et al. 2003; Sellers et al. 1996). Mass balances for a variety of lakes and coastal ecosystems show that *in situ* production of methylmercury is often one of the main sources of methylmercury in the water and sediments (Benoit et al. 1998; Bigham and Vandal 1994; Gbundgo-Tugbawa and Driscoll 1998; Gilmour et al. 1998; Mason et al. 1995). Changes in the bioavailability of inorganic mercury and the activity of methylating microbes as a function of sulfur, carbon, and ecosystem-specific characteristics mean that ecosystem changes and anthropogenic "stresses" that do not result in a direct increase in mercury loading to the ecosystem, but alter the rate of methylmercury formation, might also affect mercury levels in organisms (e.g., Grieb et al. 1990).

Dissolved Hg^{II} and methylmercury accumulate in aquatic vegetation, phytoplankton, and benthic invertebrates. Unlike Hg^{II}, methylmercury biomagnifies through each successive trophic level in the benthic and pelagic food chains such that mercury in predatory, freshwater fish is found almost exclusively as methylmercury (Bloom 1992; Watras et al. 1998). In fish, methylmercury bioaccumulation is a function of several uptake pathways (diet, gills) and elimination pathways (excretion, growth dilution) (Gilmour et al. 1998; Greenfield et al. 2001). Factors such as pH, length of the aquatic food chain, temperature, and dissolved organic carbon (DOC) can affect bioaccumulation (Ullrich et al. 2001). As a result, the highest mercury concentrations for a given fish species correspond to smaller, long-lived fish that accumulate methylmercury over their life span with minimal growth dilution (e.g., Doyon et al. 1998). In general, higher mercury concentrations are expected in top predators, which are often large fish relative to other species in a waterbody.

2.4 Why is EPA publishing this document?

In a January 8, 2001, *Federal Register* notice (66 FR 1344), EPA announced the availability of its recommended water quality criterion for methylmercury. In that notice, EPA also stated that development of the associated implementation procedures and guidance documents would begin by the end of 2001. Therefore, EPA makes this guidance available to fulfill that commitment to assist states and authorized tribes to adopt into their water quality standards the recommendations set forth in *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001a), or other water quality criteria for methylmercury where such other criteria are based on scientifically defensible methods.

This nontraditional approach—developing a water quality criterion as a fish and shellfish tissue value—raises several implementation questions on both technical and programmatic fronts. Development of water quality standards, NPDES permits, and TMDLs presents many challenges because these activities have usually been based on a water concentration (e.g., as a measure of mercury levels in effluent or receiving waters). This guidance addresses issues associated with states' and authorized tribes' adoption of the new water quality criterion into their water quality standards programs and implementation of the revised water quality criterion in TMDLs and NPDES permits. Furthermore, because atmospheric deposition is a large source of mercury for many waterbodies, implementation of this criterion involves coordination across various media and program areas, which is also addressed in this guidance.

At this time, about seven states, plus Washington D.C. and two territories have adopted a fish tissue criterion for methylmercury with EPA approval. EPA expects that with the publication of this guidance, states and authorized tribes will include new or revised criteria for methylmercury in their waters as part of the next three year review of standards required by section 303(c) of the Clean Water Act. This expanded adoption of the 2001 methylmercury fish tissue criterion, together with a more sensitive method for detecting mercury in effluent and the water column and increased monitoring of previously unmonitored waterbodies, is expected to result in an increase in the number of waterbodies that states identify as impaired by mercury on CWA section 303(d) lists.

This guidance includes recommended approaches for relating a concentration of methylmercury in fish tissue to a concentration of mercury in ambient water (see chapter 3); a recommended approach for directly using the methylmercury tissue criterion as a basis for issuing NPDES permits (see chapter 7); and approaches that have been used in approved TMDLs for waterbodies impaired by mercury. This guidance includes examples of TMDL approaches for waterbodies where much of the mercury comes from atmospheric sources, as well as examples of TMDLs for waterbodies where the mercury is predominantly from past mining activity. Finally, the guidance describes ongoing EPA efforts to address sources of mercury, such as programs under the CAA and pollution prevention activities.

EPA recognizes the complexity and comprehensive nature of this guidance. As is always the case when EPA issues technical guidance, EPA will provide outreach and technical assistance to states and authorized tribes in implementing this guidance.

2.5 What is the effect of this document?

This guidance document presents suggested approaches—but not the only technically defensible approaches—to criteria adoption and implementation. The guidance is not a substitute for applicable sections of the CWA or EPA's regulations; nor is it a regulation itself. Thus, it cannot impose legally binding requirements on EPA, states, authorized tribes, or the regulated community and may not apply to a particular situation. EPA, state, territorial, and tribal decision makers retain the discretion to adopt other scientifically defensible approaches that differ from this guidance. EPA may change this guidance in the future.

3 Water Quality Criteria and Standards Adoption

3.1 What must states and authorized tribes include as they adopt the methylmercury criterion?

3.1.1 What do the CWA and EPA's regulations require?

The CWA and EPA's regulations specify the requirements for adoption of water quality criteria into state or tribal water quality standards. States and authorized tribes must adopt water quality criteria[4] that protect designated uses. See CWA section 303(c)(2)(A). Water quality criteria must be based on a sound scientific rationale and must contain sufficient parameters or components to protect the designated uses (see 40 CFR 131.11). States and authorized tribes are required to review standards every three years and submit changes to EPA for approval.

Whenever they review or revise standards, states and authorized tribes are to adopt numeric criteria for all toxic pollutants for which EPA has established national recommended ambient water quality criteria (AWQC) and where the discharge or presence of these pollutants could reasonably interfere with the designated uses (see CWA section 303(c)(2)(B)). Mercury and related compounds are identified as toxic pollutants in EPA regulations (40 CFR 401.15) and EPA published a criterion under 304(a) for methylmercury in 2001. EPA issued guidance on how states and authorized tribes may comply with CWA section 303(c)(2)(B), which is now contained in the *Water Quality Standards Handbook: Second Edition* (USEPA 1994). This document provides three options for compliance:

- Option 1: States and authorized tribes may adopt statewide or reservation-wide numeric chemical-specific criteria for all toxic pollutants for which EPA has issued CWA section 304(a) criteria guidance.
- Option 2: States and authorized tribes may adopt numeric chemical-specific criteria for those stream segments where the state or tribe determines that the priority toxic pollutants for which EPA has issued CWA section 304(a) criteria guidance are present and can reasonably be expected to interfere with designated uses (e.g., a designated use of "fishing" is interfered with by nonattainment of the mercury water quality criterion).

[4] The term *water quality criteria* has two different definitions under the CWA. Under CWA section 304(a), EPA publishes recommended water quality criteria guidance that consists of scientific information regarding concentrations of specific chemicals or levels of parameters in water that protect aquatic life and human health. The 2001 methylmercury criterion is an example of a recommended section 304(a) criterion. States may use these recommended criteria as the basis for developing water quality standards. Water quality criteria are also elements of state water quality standards adopted under CWA section 303(c).

- Option 3: States or authorized tribes may adopt a chemical-specific translator procedure[5] that can be used to develop numeric criteria as needed.

EPA considers the 2001 methylmercury criterion a sound, scientifically based approach for meeting human health designated uses. In addition, this guidance addresses a range of complex technical issues and responds to the questions that states and authorized tribes have raised. Thus, EPA strongly encourages states and authorized tribes to adopt the 2001 methylmercury criterion or any sound, scientifically based approach for methylmercury or mercury, into their water quality standards at the upcoming triennial review of standards to fulfill the requirements of section 303(c) (2)(B) of the Clean Water Act and 40 CFR part 131. Numerical criteria for mercury in water, rather than fish tissue, published by EPA and in effect prior to 2001, may be included temporarily as part of revised mercury criteria at the next triennial review as provided for below.

3.1.2 What is the recommended form of the methylmercury criterion?

EPA's current recommended CWA section 304(a) water quality criterion for methylmercury is expressed as a fish[6] tissue concentration value (0.3 milligram methylmercury per kilogram of wet-weight fish tissue, or 0.3 mg/kg). With the publication of the fish tissue criterion, EPA withdrew the previous human health water quality criterion for mercury as the recommended section 304(a) water quality criterion for states and authorized tribes to use as guidance in adopting water quality standards (USEPA 2001c). These water column criteria, however, may be temporarily part of revised mercury criteria until the triennial review that follows the criterion adoption to help the transition in implementing the fish tissue criterion.

States and authorized tribes have several options for adopting a new or revised methylmercury criterion into their water quality standards. They may:

- Adopt the 2001 criterion or other scientifically defensible criterion as a fish tissue residue concentration, and implement it without water column translation; or
- Adopt a water column concentration, using the translation methodologies outlined in section 3.1.3.1, and implement it using traditional approaches; or
- Use a combination of the above approaches. For example, states and tribes could adopt a fish tissue criterion and implement it without water column translation for some or all waters, and translate the criterion to water column values for some or all waters.

Site-specific data for translating the fish tissue criterion to water column concentration, where needed, may take time to collect. Accordingly, states and authorized tribes may

[5] A *translator procedure* is simply the detailed process adopted by a state or authorized tribe, that explains how the state or authorized tribe will interpret its narrative criteria for toxics so that a quantifiable term can be used in assessment, permitting, and TMDL development. For example, a state or tribe could use EPA's water quality criteria as the means for interpreting its narrative criteria.

[6] The criterion applies to both finfish and shellfish. For purposes of simplifying language in this document, the term *fish* means both finfish and shellfish.

consider retaining their existing water column criteria, on a temporary basis, particularly for waters where there is a relatively high direct water input of mercury. In such a case, where the state has retained the existing water column criteria, permits must include both a limit based on the existing numeric water column criterion and other requirements based on the fish tissue criterion (see chapter 7).

Where a water column translation of the fish tissue criterion has been developed or where site-specific data to do so are readily available using one of the options in Section 3.1.3.1, states and authorized tribes should translate the fish tissue criterion, and implement using traditional approaches. If site-specific data are not available to translate, the state or authorized tribe may design data collection activities to obtain the necessary data. States and authorized tribes should focus data collection activities on water bodies where methylmercury impairments are high priorities for action because of high direct water inputs. EPA recommends that states and tribes not only focus on data collection but also on the development of translators for waters with high direct water inputs of mercury. Additionally, EPA recommends that states and tribes include such translators in their criterion implementation plans.

States and authorized tribes remain free not to use EPA's current recommendations, provided that their new or revised water quality criteria for methylmercury protect the designated uses and are based on a scientifically defensible methodology. In doing this, states and authorized tribes should consider bioaccumulation and local or statewide fish consumption. EPA will evaluate criteria submitted by states and authorized tribes case by case.

If states and authorized tribes decide to adopt the tissue criterion expressed as a fish tissue concentration without translating it to a traditional water column concentration, this decision will lead to choices on how to implement the tissue criterion. A state or authorized tribe could decide to develop TMDLs and to calculate WQBELs in NPDES permits directly without first measuring or calculating a BAF. This guidance provides options for such approaches in chapters 6 and 7.

EPA does not require states and tribes to translate the fish tissue criterion into water column criteria. For waters with relatively high direct water inputs of mercury (mercury from point sources and nonpoint sources other than air deposition), EPA does recommend developing TMDLs, an analysis of sources and loading capacity similar to what would be provided in a TMDL, or a water column translation of the fish tissue criterion, to provide important information for developing appropriate permit limits. See section 7.5.2.2 for a further discussion of this situation.

3.1.2.1 Developing a methylmercury criterion implementation plan

Regardless of the approach a state decides to use to implement its criterion, EPA encourages states and authorized tribes to develop a methylmercury criterion implementation plan to ensure environmentally protective and effective administration of all water quality related programs with respect to methylmercury. Developing a methylmercury implementation plan can facilitate adoption of the tissue-based criterion and provide transparency on state or tribal approaches to the numerous implementation issues associated with this type of criterion. This benefits not only the state or tribe but the regulated community and the public.

Examples of potential implementation issues the plan could cover include criterion adoption into the water quality standards (e.g., tissue or water column value with translators, BAF development methods), reasonable potential and permitting decisions, ambient monitoring strategies, and impairment determinations.

Developing an implementation plan could also facilitate subsequent regulatory decisions. Working with stakeholders and the public to develop an appropriate implementation plan concurrent with adoption of a tissue-based criterion could facilitate subsequent implementation decisions (e.g., application of the criterion in the context of 303(d) listing decisions or NPDES permitting actions) and decrease the likelihood of legal challenges.

It may be most useful to states and tribes to develop such an implementation plan prior to the adoption of the fish tissue criterion. States and tribes could propose draft plans when they are developing updates or revisions to their water quality standards. Additionally, EPA encourages states and tribes to take public comment on their draft plan during the time when the state or tribe is proposing to adopt the fish tissue criterion.

If a state or tribe develops a methylmercury implementation plan during adoption of its criterion, the state or tribe should submit the plan to EPA with the state's new criterion. Although the plan itself is not subject to EPA review and approval, the plan could facilitate EPA's review of the new criterion.

3.1.2.2 Why is the fish tissue concentration criterion recommended?

EPA recommends that when states and authorized tribes adopt new or revised methylmercury water quality criteria, they adopt the criteria in the form of a fish tissue methylmercury concentration. This is the preferred form for the following reasons:

- A criterion expressed as a fish tissue concentration is closely tied to the "fishable" designated use goal applied to nearly all waterbodies in the United States.
- A fish tissue concentration value is expressed in the same form (fish tissue) through which humans are exposed to methylmercury.
- A fish tissue concentration value is more consistent with how fish advisories are issued.
- At environmentally relevant concentrations, methylmercury is currently easier to detect in fish tissue than in water samples.

3.1.2.3 How is the fish tissue concentration criterion calculated?

The derivation of a methylmercury water quality criterion uses a human health toxicological risk assessment (e.g., a reference dose [RfD]), exposure data (e.g., the amount of pollutant ingested, inhaled, or absorbed per day), and data about the target population to be protected. The methylmercury fish tissue residue criterion (TRC) for the protection of human health is calculated as:

$$\text{TRC} = \frac{BW \times (RfD - RSC)}{\sum_{i=2}^{4} FI} \qquad \text{(Equation 1)}$$

Where:

- *TRC* = fish tissue residue criterion (in mg/kg) for freshwater and estuarine fish and shellfish
- *RfD* = reference dose (based on noncancer human health effects); for methylmercury, it is 0.1 µg/kg body weight/day
- *RSC* = relative source contribution (subtracted from the RfD to account for methylmercury in marine fish consumed[7]), estimated to be 0.027 µg/kg body weight/day
- *BW* = human body weight (default value of 70 kg for adults)
- *FI* = fish intake at trophic level (TL)*i* (*i* = 2, 3, 4); total default intake of uncooked freshwater and estuarine fish is 17.5 g fish/day for the general U.S. adult population[8]

This equation and all values used in the equation are described in *Water Quality Criterion for the Protection of Human Health, Methylmercury* (USEPA 2001a). This equation is essentially the same equation used in the 2000 Human Health Methodology (USEPA 2000b) to calculate a water quality criterion for a pollutant that may cause noncancerous health effects. Here, it is rearranged to solve for a protective concentration in fish tissue rather than in water. Thus, it does not include a BAF or drinking water intake value (methylmercury exposure from drinking water is negligible (USEPA 2001c)).

When all the numeric values are put into the generalized equation, the TRC of 0.3 mg methylmercury/kg fish is the concentration in fish tissue that should not be exceeded on the basis of a consumption rate of 17.5 g fish/day of freshwater or estuarine fish.

EPA encourages states and authorized tribes to collect, as quickly as possible, local or regional data to modify the fish consumption rate rather than using the default values if the state or authorized tribe believes that such a fish consumption rate would be more appropriate for its target population. This gives states and tribes the flexibility to develop criteria that provide additional protection appropriate for highly exposed populations that may be at greater risk than the general population protected by the 304(a) criterion (USEPA 2000b). Where states do not have site-specific data, but intend to collect this

[7] The RSC accounts for exposures from all anticipated sources so that the entire RfD is not apportioned to freshwater/estuarine fish and shellfish consumption alone. In the assessment of human exposure in the methylmercury water quality criterion document, EPA found that human exposures to methylmercury were negligible except from freshwater/estuarine and marine fish. Therefore, in developing the criterion on the basis of consumption of freshwater/estuarine fish, EPA subtracted the exposure due to consumption of marine fish. See 66 FR 1354–1355; January 8, 2001.

[8] The consumption rate value of 17.5 grams uncooked fish per day is the 90th percentile of freshwater and estuarine fish consumed by the public according to the *1994–96 Continuing Survey of Food Intakes by Individuals* (USEPA 2000a). EPA uses this value as the default consumption rate in development of water quality criteria. The default trophic level values for the general population are 3.8 g fish/day for TL2, 8.0 g fish/day for TL3, and 5.7 g fish/day for TL4. The rationale behind the selection of this value is described in the Human Health Methodology (USEPA 2000b).

data over time to develop a more appropriate criterion, states should use EPA's default fish consumption rate on a temporary basis to be able to adopt and implement the fish tissue criterion in a timely manner.

The TRC value is not based on any default breakout of fish consumption by trophic level.The trophic levels assigned to the fish consumption value should reflect those that each target population consumes. For assessing impairment or attainment of the TRC, a state or authorized tribe may choose to assign the TRC value to only trophic level 4 or to the highest trophic level consumed. This approach is conservative in that it assumes that all fish consumed are at the highest trophic level, and it will likely protect most, if not all, populations at an uncooked freshwater or estuarine fish consumption rate of 17.5 grams/day. If a state or authorized tribe wishes to calculate the TRC value on the basis of consumption at each trophic level for monitoring and compliance purposes, it would first determine consumption patterns at each trophic level for the target population(s). (For information on determining consumption patterns, see chapter 4.) This approach might be more precise and is less likely to be overprotective; however, developing it could be resource-intensive.

3.1.3 What approaches should states or authorized tribes consider when developing a water column concentration criterion?

As described in section 3.1.2 above, there may be situations where it is appropriate to adopt a criterion expressed as a water column concentration. EPA recognizes that a fish tissue residue water quality criterion is new to states and authorized tribes and might pose implementation challenges for traditional water quality programs. Water quality standards, water quality-based effluent limits[9] (WQBELs), total maximum daily loads (TMDLs), and other activities generally employ a water column value. This section provides information for states and authorized tribes that decide to adopt a water concentration criterion derived from a fish tissue criterion.

Alternatively, a state or authorized tribe may decide to adopt a fish tissue criterion with a site-specific procedure for translating the tissue criterion to a water column concentration. Because methylmercury bioaccumulation can vary substantially from one location to another, this option allows for the tissue criterion to be translated to a water concentration using site-specific information on methylmercury bioaccumulation (i.e., site-specific BAFs). Administratively, this option might be more efficient compared to adopting a water concentration criterion for an entire state or tribal jurisdiction or adopting or approving site-specific criteria on an individual waterbody basis. Approaches for translating a tissue concentration-based criterion to a water concentration are provided in the following section (section 3.1.3.1).

Developing a water column translation of the fish tissue criterion requires assessment of methylmercury bioaccumulation at an appropriate geographic scale. The uncertainty associated with differential bioaccumulation of methylmercury across sites within a state or tribal jurisdiction will be embedded in the state or tribal water-based criterion.

[9] A WQBEL is a requirement in an NPDES permit that is derived from, and complies with, all applicable water quality standards and is consistent with the assumptions and requirements of any approved wasteload allocation (see 40 CFR 122.44(d)(1)(vii)).

Reducing such uncertainty is one of the primary reasons EPA chose to express its national recommended criterion for methylmercury as a tissue concentration rather than as a water concentration.

To express the methylmercury tissue concentration-based criterion as a water concentration, a state or authorized tribe would translate the methylmercury criterion concentration in fish tissue to methylmercury concentrations in the water column. To accomplish this, the state or authorized tribe would develop BAFs. In the 2001 *Federal Register* notice of the methylmercury criterion, EPA identified three different possible approaches for developing a BAF. These approaches are discussed in more detail in section 3.1.3.1. The basic equations used in developing a water column criterion are presented below, and additional discussion of calculating BAFs is presented in the following section.

The following equation may be used to translate the tissue concentration-based human health AWQC to a water concentration-based methylmercury criterion using a BAF as

$$AWQC = TRC / BAF \qquad \text{(Equation 2)}$$

Where:

AWQC = water concentration-based ambient water quality criterion for methylmercury in milligrams per liter (mg/L)
TRC = tissue residue concentration; the water quality criterion for methylmercury in fish tissue in mg/kg
BAF = bioaccumulation factor for trophic levels 2, 3, and 4, weighted on the basis of fish consumption rates for each trophic level in liters per kilogram (L/kg)

The BAF is the ratio of the concentration of the chemical in the appropriate tissue of the aquatic organism and the concentration of the chemical in ambient water at the site of sampling. BAFs are trophic-level-specific. EPA recommends that they be derived from site-specific, field-measured data as

$$\text{BAF} = \frac{C_t}{C_w} \qquad \text{(Equation 3)}$$

Where:

BAF = bioaccumulation factor, derived from site-specific field-collected samples of tissue and water in L/kg
Ct = concentration of methylmercury in fish tissue in mg/kg, wet tissue weight
Cw = concentration of methylmercury in water in mg/L

When such data are unavailable, other approaches for deriving BAFs may be used, as outlined in section 3.1.3.1.

In the calculation to derive an AWQC as a water column concentration, the BAFs for the different trophic levels are combined to provide a weighted BAF value. For example, if a

state wants to protect a population that eats on average 17.5 grams per day of uncooked fish from a waterbody, and 75 percent of the fish eaten are in trophic level 4 and 25 percent of the fish eaten are in trophic level 3, the weighted BAF would be the sum of 0.25 times the trophic level 3 BAF and 0.75 times the trophic level 4 BAF. Section 3.2.1.2 provides guidance on estimating fish intake rates.

3.1.3.1 How is the methylmercury fish tissue concentration translated to a water concentration?

Should a state or authorized tribe decide to translate the methylmercury fish tissue criterion into a water column concentration, it would assess the extent to which methylmercury is expected to bioaccumulate in fish tissue for the site(s) of interest. Assessing and predicting methylmercury bioaccumulation in fish is complicated by a number of factors that influence bioaccumulation. These factors include the age or size of the organism; food web structure; water quality parameters such as pH, DOC, sulfate, alkalinity, and dissolved oxygen; mercury loadings history; proximity to wetlands; watershed land use characteristics; and waterbody productivity, morphology, and hydrology. In combination, these factors influence the rates of mercury bioaccumulation in various—and sometimes competing—ways. For example, these factors might act to increase or decrease the delivery of mercury to a waterbody, alter the net production of methylmercury in a waterbody (through changes in methylation and/or demethylation rates), or influence the bioavailability of methylmercury to aquatic organisms. Although bioaccumulation models have been developed to address these and other factors for mercury, their broad application can be limited by the site- or species-specific nature of many of the factors that influence bioaccumulation and by limitations in the data parameters necessary to run the models.

The bioaccumulation of nonionic organic chemicals[10] such as methylmercury can also be affected by a number of these same physicochemical factors (e.g., loading history, food web structure, dissolved oxygen, DOC). However, a substantial portion of the variability in bioaccumulation for nonionic organic chemicals can be reduced by accounting for lipid content in tissues and organic carbon content in water and "normalizing" BAFs using these factors (Burkhard et al. 2003; USEPA 2003). Normalizing to the age or size (length, weight) of fish has been shown to reduce variability in measures of bioaccumulation (Brumbaugh et al. 2001; Glass et al. 2001; Sonesten 2003; Sorensen et al. 1990; Wente 2004).

The United States Geological Survey (USGS) developed a procedure called the National Descriptive Model for Mercury in Fish Tissue (NDMMF) (Wente 2004). This model provides a translation factor to convert a mercury concentration taken from one species/size/sample method to an estimated concentration for any other user-predefined species/size/sample method.

[10] Nonionic organic compounds are those organic compounds that do not ionize substantially when dissolved in water and therefore are more likely to associate with sediment compounds, lipids, or other compounds in water (USEPA 2000b).

Mercury Terminology

For the purposes of this document, the following definitions apply:

Mercury (or total mercury): The sum of all forms of mercury, including methylmercury, other organic forms, inorganic, and elemental mercury. All of these are toxic, and inorganic and elemental mercury can be methylated in the environment.

Methylmercury: The organic form of mercury, that bioaccumulates in the food chain. (Other organic forms of mercury exist, but exposure to them through environmental pathways is not significant.)

Dissolved mercury (or filtered mercury): The portion of mercury that passes through a filter.

Dissolved methylmercury (or filtered methylmercury): The portion of methylmercury which passes through a filter.

Total recoverable mercury (or unfiltered mercury): The dissolved portion plus the particulate portion of mercury in a water sample.

Total recoverable methylmercury (or unfiltered methylmercury): The dissolved portion plus the particulate portion of methylmercury in a water sample.

Taking into account the previous discussion, EPA has outlined in this document three different approaches that could be considered for relating a concentration of methylmercury in fish tissue to a concentration of methylmercury in ambient water, should a state decide to develop or implement its standard in this manner:

1. Use site-specific methylmercury BAFs derived from field studies.

2. Use a scientifically defensible bioaccumulation model.

3. Where appropriate, use BAFs derived using the results of field studies that are not site-specific. Appropriate situations for using such BAFs include waters where direct water inputs are relatively high and where ambient fish tissue data are unavailable, where deriving site-specific, field-measured BAFs is not feasible, or where using a model is not feasible. Such BAFs may include the draft national BAFs presented in appendix A of Water Quality Criterion for the Protection of Human Health: Methylmercury (USEPA 2001a) and discussed in more detail below. Alternatively, BAFs may be derived using other approaches, such as a combination of national and site-specific data in conjunction with other, non-site-specific data, to create better estimates.

Of these approaches, 1 and 2 are preferred over 3. Because of the significant uncertainties inherent in non-site-specific estimates of BAFs (including the draft national BAFs), they should be used as defaults only in limited circumstances such as:

- When a state determines that use of the draft national BAFs are appropriate (for example, where direct water inputs are relatively high, where no other data are available to derive site-specific field-measured BAFs, and use of an appropriate BAF model is not feasible)

- When a state can show that such BAFs are appropriate for its situation (e.g., a state has data or analyses that demonstrate that the draft national BAFs would be appropriate)

- As an interim approach until more appropriate BAFs can be developed using other data and/or an alternate approach

The reasons for preferring approaches 1 and 2 are discussed in more detail below. However, the hierarchy assigned to the approaches is not intended to be inflexible. For example, in some cases, the site-specific information available may be so limited in quality or quantity that BAFs derived using other data may be preferable. In other cases, there might be enough site-specific information to indicate that the local conditions approximate the draft national values.

In situations where the state or tribe has some data available on fish tissue and water column levels in its jurisdiction, but data are insufficient to support broad development of site-specific translations, the state or tribe may be able to use these data in combination with an evaluation of the draft national BAFs to help develop water column translations. For example, California's Office of Environmental Health Hazard Assessment compiled mercury concentration data for water and biota, and calculated state-specific BAFs for different types of waters and different trophic levels. The office found enough similarities between the state-specific BAFs and EPA's draft national BAFs that it recommended using EPA's draft national values as an interim approach until more complete state-specific data becomes available (Sanborn and Brodberg 2006). The state is in the process of deciding whether to adopt this approach.

If the state or tribe chooses to derive BAFs using the third approach above, the state or tribe should provide an accompanying rationale that acknowledges an understanding of the potential limitations of the approach.

Developing site-specific data to support approaches 1 and 2 can be facilitated by efforts involving stakeholders, states, and authorized tribes. Developing site-specific data is one possible approach EPA recommends permitting authorities consider to help develop NPDES permits in watersheds where mercury loadings from point sources are relatively high. See section 7.5.2.2.

3.1.3.1.1 Site-specific bioaccumulation factors derived from field studies

The use of site-specific BAFs based on data obtained from field-collected samples of tissue from aquatic organisms that people eat and water from the waterbody of concern—referred to as a "field-measured site-specific BAF"—is the most direct and most relevant measure of bioaccumulation. This approach is consistent with EPA's bioaccumulation guidance contained in the 2000 Human Health Methodology (USEPA 2000b) and the Technical Support Document for developing national BAFs (USEPA 2003). Although a BAF is actually a simplified form of a bioaccumulation model, the field-measured site-specific BAF approach is discussed separately here because of its widespread use and application.

A field-measured site-specific BAF is derived from measurements of methylmercury concentrations in tissues of aquatic organisms and the ambient water they inhabit. Because the data are collected from a natural aquatic ecosystem, a field-measured BAF reflects an organism's exposure to a chemical through all relevant exposure routes (e.g., water, sediment, diet). Although a BAF can be measured for the aggregate of fish in a location, site-specific BAFs are often specific to trophic level and species of fish. The BAF can also be measured based on a predatory indicator species with a high propensity

for bioaccumulation, such as largemouth bass. A field-measured site-specific BAF also reflects biotic and abiotic factors that influence the bioavailability and metabolism of a chemical that might occur in the aquatic organism or its food web at a given location. By incorporating these factors, field-measured site-specific BAFs account for the actual uptake and accumulation of the chemical.

States and authorized tribes should exercise caution, however, in developing a site-specific BAF for a migratory fish because its exposure to methylmercury occurred in part in areas other than where the fish was caught and therefore might not accurately predict the water column mercury concentrations associated with the fish tissue concentration of mercury. States and tribes should consider the life history of the migratory fish and the consumption patterns of the local population when considering BAFs for migratory species. States and tribes should also review how the applicable RSC considers migratory fish when considering including those species in BAF calculations (see section 3.2.1.1).

For the purposes of developing a criterion expressed as a water concentration, states and authorized tribes should calculate the BAF as the ratio of the concentration of methylmercury in the tissue of aquatic organisms that people eat to the concentration of methylmercury in water[11] (Equation 3). To predict the corresponding methylmercury concentration in water for a site, the tissue-based methylmercury criterion would then be divided by the site-specific BAF (Equation 2). Using the site-specific BAF approach assumes that at steady state, the accumulation of methylmercury by the aquatic organism varies in proportion to the methylmercury concentration in the water column.

As an example, California is currently employing a site-specific BAF approach in its Central Valley Region. In this approach, the state evaluated graphs of average concentrations of methylmercury in water and the corresponding concentrations in fish at multiple sites in a watershed. Researchers found statistically significant, positive relationships between concentrations of unfiltered methylmercury in water and in various trophic levels of the aquatic food chain (Slotton et al. 2004). California linearly regressed fish tissue methylmercury concentrations for specific trophic level (TL) 3 and 4 fish against aqueous methylmercury concentrations ($P < 0.001$, $R^2 = 0.98$, and $P < 0.01$, $R^2 = 0.9$, respectively) and determined methylmercury concentrations in unfiltered water that correspond to the fish tissue criteria used in the TMDL analyses (0.15 ng/L for TL3 fish and 0.14 ng/L for TL4 fish) (Central Valley Water Board 2005). California assumed that sites that fit in a statistically significant regression have similar processes controlling methylmercury accumulation. In other words, site-specific BAFs for such sites are nearly identical.

Strengths associated with using a site-specific BAF approach include simplicity, widespread applicability (i.e., site-specific BAFs can be derived for any waterbody, fish species, and the like), and that the net effects of biotic and abiotic factors that affect

[11] Although BAFs are sometimes calculated to represent the relationship between methylmercury in fish tissue and dissolved methylmercury in the water column, data can be collected to determine the relationship between methylmercury in fish tissue and total recoverable methylmercury or dissolved or total recoverable mercury in the water column. The Great Lakes Water Quality Initiative (GLI) used site-specific BAFs to convert directly from methylmercury in fish to total recoverable mercury in the water column. See 40 CFR part 132, and appendix B to part 132, Methodology for Deriving Bioaccumulation Factors.

bioaccumulation are incorporated within the measurements used to derive the BAF. Specifically, it is not required that the exact relationship between methylmercury accumulation and the factors that can influence it be understood or quantified to derive a site-specific BAF. By measuring the methylmercury concentrations empirically, these factors have been incorporated such that site-specific BAFs provide an accounting of the uptake and accumulation of methylmercury for an organism in a specific location and at a specific point in time.

Limitations to the site-specific BAF approach relate primarily to its cost and empirical nature. For example, the level of effort and associated costs of developing site-specific BAFs increase as the spatial scale of the site of interest increases. Furthermore, the amount of data necessary to obtain a representative characterization of methylmercury in the water and fish might take considerable time to gather. (For a discussion on sampling considerations for developing a site-specific BAF, see section 3.1.3.2.) The strictly empirical nature of this approach is also a barrier to extrapolating BAFs among species, across space, and over time because the site-specific factors that might influence bioaccumulation are integrated within the tissue concentration measurement and thus cannot be individually adjusted to extrapolate to other conditions.

3.1.3.1.2 Bioaccumulation models

Bioaccumulation models for mercury vary in the technical foundation on which they are based (empirically or mechanistically based), spatial scale of application (specific to waterbodies, watersheds or regions, and species of fish), and level of detail in which they represent critical bioaccumulation processes (simple, mid-level, or highly detailed representations). Thus, it is critical that states and tribes use a model that is appropriately developed, validated, and calibrated for the species and sites of concern.

Empirical bioaccumulation models that explicitly incorporate organism-, water-chemistry-, and waterbody/watershed-specific factors that might affect methylmercury bioaccumulation (e.g., fish species, age, length, pH, DOC, sulfate, alkalinity, sediment acid-volatile sulfide concentration, proximity to wetlands, land use, morphology, hydrology, productivity) usually take the form of multivariate regression models. Many examples of such models are available in the literature (e.g., Brumbaugh et al. 2001; Kamman et al. 2004; Sorensen et al. 1990). The model developed by Brumbaugh et al. (2001) is based on a national pilot study of mercury in 20 watersheds throughout the United States. Specifically, Brumbaugh et al. (2001) developed a multiple regression relationship between five factors: length-normalized mercury concentration in fish, methylmercury concentration in water, percentage of wetland area in the watershed, pH, and acid-volatile sulfide concentration in sediments ($r^2 = 0.45$; all fish species). When data were restricted to a single species (e.g., largemouth bass) and a single explanatory variable (e.g., methylmercury in water), a highly significant relationship was found ($p < 0.001$) with a similar degree of correlation ($r^2 = 0.50$). This demonstrates the importance of species specificity in the strength of such regression relationships and, in this case, methylmercury in water as an explanatory variable.

States and tribes should consider several important issues when using regression-based bioaccumulation models for translating from a tissue concentration to a water column concentration. First, a number of such regression models have been developed without

explicitly incorporating methylmercury (or mercury) concentrations in the water column. Instead, the models relate fish tissue methylmercury concentrations to variables that serve as proxies for methylmercury exposure (e.g., atmospheric deposition rates, ratio of the watershed drainage to the wetland area, pH, lake trophic status), often because of the costs associated with obtaining accurate measurements of mercury in the water column. Obviously, such models cannot be directly solved for the parameter of interest (methylmercury in water). Second, correlation among independent or explanatory variables in these multiple regressions is common and expected (e.g., pH and methylmercury concentration in water). Such correlations among explanatory variables can cause bias and erroneous estimates of an explanatory variable (in this case, methylmercury concentration in water) when back-calculated from the regression equation (Neter et al. 1996). In such cases, using the underlying data set to develop a separate regression model with methylmercury concentration in water as the dependent variable is more appropriate. Last, because these regression models are based on empirical data, uncertainty is introduced when the results are extrapolated to aquatic ecosystems with different conditions. Only in a few cases have such models been tested using independent data sets (e.g., Kamman et al. 2004).

Mechanistic bioaccumulation models are mathematical representations of the natural processes that influence methylmercury bioaccumulation. The process of methylation itself is incompletely understood, and general models for reliably predicting rates of methylation do not exist, although EPA's WASP model might be useful in some environments. Three examples of mechanistic bioaccumulation models are the Dynamic Mercury Cycling Model, or D-MCM (EPRI 2002); the Bioaccumulation and Aquatic System Simulator, or BASS (Barber 2002), and the Quantitative Environmental Analysis Food Chain model, or QEAFDCHN (QEA 2000). A conceptual advantage of mechanistically based bioaccumulation models is that methylmercury bioaccumulation can be predicted under different conditions (e.g., different growth rates of fish, different water chemistry conditions, and different mercury loading scenarios) because the models include mathematical representations of various processes that affect bioaccumulation. This advantage comes at the cost of additional input data necessary to run the model. Notably, only a few models have been used to predict methylmercury bioaccumulation. Such models have not been widely used and have been applied only to mercury in a few aquatic ecosystems under specific environmental conditions. Of the examples listed above, only the D-MCM was developed specifically for mercury. The D-MCM has not been applied to lotic systems (i.e. streams, rivers, estuaries) and therefore probably should be used only for static environments (lakes) at this time. The other models have been developed more generally, for nonionic organic chemicals that bioaccumulate, and require substantial modification and validation for application to mercury.

Most mechanistic bioaccumulation models use a chemical mass balance approach to calculate bioaccumulation in fish or other aquatic organisms. This approach requires considerable understanding of mercury loadings to and cycling within the environment. None of the example models presented can predict bioaccumulation without considerable site-specific information, at least some degree of calibration to the waterbody of interest, and, in some cases, considerable modification of the model. The amount and quality of data necessary for proper model application may equal or exceed that necessary to develop site-specific methylmercury BAFs, although these models might also help in

determining BAFs if the kinetic condition in the waterbody is not steady state. Because of the need for site-specific data and calibration, these models are likely to cost as much to implement as a site-specific BAF. Their value comes from the ability to represent a wider range of explanatory and policy-relevant variables.

Regardless of the type of model used, states' and authorized tribes' methodologies should be consistent with the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (section 5.6: National Bioaccumulation Factors for Inorganic and Organometallic Chemicals; USEPA 2000b) and *Technical Support Document Volume 2: Derivation of National Bioaccumulation Factors* (USEPA 2003). These documents provide detailed discussion of topics such as BAF derivation procedures, bioavailability, and the steps involved in procedures 5 and 6 of the Human Health Methodology. States and tribes should document how they derive the site-specific parameters used in the bioaccumulation models and should describe the uncertainty associated with the BAFs derived using any of the models.

3.1.3.1.3 Draft national bioaccumulation factors

EPA acknowledges that using site-specific BAFs or model-derived BAFs might not be feasible in all situations. Without site-specific methylmercury bioaccumulation data or an appropriate bioaccumulation model, another approach is to use EPA's empirically derived draft national methylmercury BAFs as defaults. EPA used *Technical Support Document Volume 3: Development of Site-Specific Bioaccumulation Factors* of the 2000 Human Health Methodology (USEPA 2000b, 2003) and the BAF methods in volume III, appendix D, of the *Mercury Study Report to Congress* (USEPA 1997c) to derive draft methylmercury BAFs as part of its initial efforts to derive a water column-based recommended section 304(a) ambient water quality criterion for methylmercury. These draft national BAFs were developed from field data collected from across the United States and reported in the published literature. The draft national BAFs and the uncertainties associated with them are discussed in appendix A, section I, of *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001a). The draft national BAFs (50th percentile values) are listed by trophic level in table 2.

Table 2. Draft national BAFs for dissolved methylmercury

BAF trophic level 2 (L/kg)	BAF trophic level 3 (L/kg)	BAF trophic level 4 (L/kg)
120,000	680,000	2,700,000

Source: USEPA 2001a.

Note: Expressed as milligrams methylmercury/kilogram fish tissue per milligram methylmercury/liter water, or liters per kilogram (L/kg).

To develop the draft national BAFs for each trophic level, EPA calculated the geometric mean of the field-measured BAFs obtained from the published literature. EPA believes the geometric mean BAFs are the best available central tendency estimates of the magnitude of BAFs nationally, understanding that the environmental and biological conditions of the waters of the United States are highly variable. Specifically, the data presented in *Water Quality Criterion of the Protection of Human Health: Methylmercury* (USEPA 2001a) indicate that BAFs for trophic levels 3 and 4 vary by a factor of 100

(two orders of magnitude) between the 5th and 95th percentiles. EPA does not recommend basing an AWQC on BAF values associated with the extremes of the distribution (e.g., 10th or 90th percentile), unless supported by site-specific data. Such values might introduce an unacceptable level of uncertainty into the calculation of a water column-based AWQC. States and authorized tribes should consider the magnitude of the potential error when proposing to use the draft national BAFs.

When states and authorized tribes calculate a water column-based criterion using draft national BAFs that differ greatly from the BAFs for the waterbody of concern, the resulting water column-based criterion will be either over- or under-protective. As a result, evaluation of the results of the analysis of water samples might result in the false conclusion that a fish tissue concentration has been exceeded (when it actually has not) or a false conclusion that a fish tissue concentration has not been exceeded (when it actually has). For more information on the draft national BAFs, see chapter 6 and appendix A, section I, of EPA's 304(a) water quality criterion for methylmercury (USEPA 2001a). The following examples illustrate the potential impact of calculating a water quality criterion using a BAF that is substantially different from the actual BAF.

- *Underprotective scenario*
  A state uses the draft national BAF of 2,700,000 L/kg for trophic level 4 fish, but the BAF based on site-specific data for the trophic level 4 fish in the waterbody is three times that, or 8,100,000 L/kg. In using the draft national BAF, a state would consider water column concentrations up to 0.11 nanogram per liter (ng/L) (0.3 mg/kg / 2,700,000 L/kg) to indicate attainment of the water quality column criterion. Using the BAF based on site-specific data, however, a water column criterion of 0.11 ng/L would correspond to a fish tissue concentration of 0.9 mg/kg, which is three times the 0.3 mg/kg criterion recommended to protect human health. Thus, load reductions or permits using the draft national BAF of 2,700,000 L/kg would be underprotective.

- *Overprotective scenario*
  A state uses the draft national BAF of 2,700,000 L/kg for trophic level 4 fish, but the BAF based on site-specific data for the trophic level 4 fish in the waterbody is one-third that, or 900,000 L/kg. As a result, a state would consider water column concentrations up to 0.11 ng/L (0.3 mg/kg / 2,700,000 L/kg) to indicate attainment of the water quality criterion. Using the BAF based on site-specific data, however, attainment of the water quality criterion could be achieved at a higher water column concentration, 0.33 ng/L. Thus, load reductions or permits using the draft national BAF of 2,700,000 L/kg would be overprotective.

EPA cautions water quality managers that methylmercury bioaccumulation is generally viewed as a site-specific process and that BAFs can vary greatly across ecosystems. The uncertainty in the estimates of a draft national BAF comes from uncertainty arising from natural variability, such as size of individual fish, and from uncertainty due to measurement error, such as error in measurements of mercury in water or lack of knowledge of the true variance of a process (e.g., methylation). Users of the draft national BAFs are encouraged to review appendix A of *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001a), which describes the uncertainties

inherent in these values. The following is a synopsis of the discussion of uncertainty in that appendix.

- *Uncertainty due to sampling and chemical analysis:* In many cases, water methylmercury concentrations reported in the available studies incorporated limited or no cross-seasonal variability, incorporated little or no spatial variability, and were often based on a single sampling event. Because fish integrate exposure of mercury over a lifetime, comparing fish concentrations to a single sample or mean annual concentrations introduces bias to the estimates. The geographic range represented by the waterbodies was also limited.

- *Uncertainty due to estimation method:* The approaches used to estimate the draft national BAFs have their own inherent uncertainties. The approaches assume that the underlying process and mechanisms of mercury bioaccumulation are the same for all species in a given trophic level and for all waterbodies. They are also based on a limited set of data.

- *Uncertainty due to biological factors:* With the exception of deriving BAFs on the basis of river or lake waterbody type, there were no distinctions in the BAFs as to the size or age of fish, waterbody trophic status, or underlying mercury uptake processes. In reality, methylmercury bioaccumulation for a given species can vary as a function of the age (body size) of the organisms examined.

- *Uncertainty due to universal application of BAFs:* There is uncertainty introduced by failure of a single trophic-level-specific BAF to represent significant real-world processes that vary from waterbody to waterbody. The simple linear BAF model relating methylmercury in fish to mercury in water simplifies a number of nonlinear processes that lead to the formation of bioavailable methylmercury in the water column and subsequent accumulation. Much of the variability in field data applicable to the estimation of mercury BAFs can be attributed to differences in biotic factors (e.g., food chain, organism age or size, primary production, methylation or demethylation rates) and abiotic factors (e.g., pH, organic matter, mercury loadings, nutrients, watershed type or size) between aquatic systems. Unfortunately, although the concentration of methylmercury in fish tissue is presumably a function of these varying concentrations, published BAFs are typically estimated from a small number of measured water values whose representativeness of long-term exposure is not completely understood. Furthermore, although it is known that biotic and abiotic factors control mercury exposure and bioaccumulation, the processes are not well understood, and the science is not yet available to accurately model bioaccumulation on a broad scale.

Peer reviewers expressed concerns about the use of the draft national BAFs as defaults to predict bioaccumulation across all ecosystems and about using them to derive a national recommended section 304(a) water quality criterion for methylmercury that would suitably apply to waterbodies across the nation. EPA recognized the peer reviewers' concerns and acknowledges that these draft national BAF values might significantly over- or underestimate site-specific bioaccumulation. As a result, EPA decided not to use the draft national BAFs to develop a national water-column-based AWQC for methylmercury. Furthermore, the draft national BAFs are EPA's least preferred means

for assessing the BAF. States and tribes should also consider whether more recent data and/or data that are more reflective of local conditions are available to supplant or supplement the limited database used to derive the draft national BAFs.

Risk managers should also understand that in using the draft national BAFs as defaults, one assumes that the biotic and abiotic processes affecting mercury fate and bioaccumulation are similar across different waterbodies, and therefore using the draft national BAFs does not address site-specific factors that might increase or decrease methylation and bioaccumulation. A state's or tribe's decision to use the draft national BAFs would be a risk management decision. The decision would reflect the state's or tribe's judgment that, for specific reasons, translating the fish tissue criterion to a water column value using such a BAF is preferable to implementing the fish tissue criterion directly (e.g., using the approaches discussed in this guidance), or conducting studies to develop a site-specific BAF (e.g., site-specific field studies or bioaccumulation modeling).

3.1.3.2 What are the sampling considerations for deriving site-specific field-measured BAFs?

For both fish tissue and water, states and authorized tribes should analyze for methylmercury when deriving site-specific BAFs. EPA has not yet published analytical methods to measure methylmercury in water or fish in 40 CFR part 136. A discussion of analytical methods for mercury and methylmercury can be found in section 4.1. For fish tissue, however, states and authorized tribes can estimate methylmercury concentrations and determine attainment by using the same analytical method used to measure for mercury, at least for upper-trophic-level fish (levels 3 and 4). This is because 80 to 100 percent of the mercury found in the edible portions of freshwater fish greater than three years of age from these two trophic levels is in the form of methylmercury (USEPA 2000c). In fish greater than approximately three years of age, mercury has had sufficient time to bioaccumulate to roughly steady levels in the fish. Appendix A summarizes eight studies of the relative proportion of the mercury concentration in North American freshwater fish that is in the form of methylmercury. In six of the eight studies, methylmercury on average accounted for more than 90 percent of the mercury concentration in fish tissue. In the remaining two studies, methylmercury on average accounted for 80 to 90 percent of the mercury concentration in trophic level 3 and 4 fish.

States and tribes should consider a number of issues when sampling aquatic organism tissue and water to derive a site-specific BAF. The goal of deriving site-specific methylmercury BAFs is to reflect or approximate the long-term bioaccumulation of methylmercury in commonly consumed aquatic organisms of a specified trophic level. Hence, an important sample design consideration is how to obtain samples of tissue and water that represent long-term, average accumulation of methylmercury. Methylmercury is often slowly eliminated from fish tissue. Therefore, concentrations of methylmercury in fish tissue tend to fluctuate much less than the concentration of methylmercury in water. Thus, for calculating representative site-specific BAFs, states and tribes should consider how to integrate spatial and temporal variability in methylmercury concentrations in both water and tissue. States and tribes should address the variability in methylmercury concentrations in fish tissue with age or size of the organism either by restricting sample collection to organisms of similar age or size classes or by using

appropriate normalization techniques. EPA's fish sampling guidance recommends that fish should be of similar size so that the smallest individual in a composite is no less than 75 percent of the total length (size) of the largest individual (USEPA 2000c). One way of normalizing data is by using the National Descriptive Model for Mercury in Fish Tissue, or NDMMF (Wente 2004). The NDMMF is a statistical model that normalizes Hg fish tissue concentration data to control for species, size, and sample type variability. An example use of the NDMMF is in the combination of mercury fish tissue data from two databases (USEPA 2005a).

States and tribes should assess the fish consumption patterns of the exposed human population when designing a site-specific sampling plan. Because the age and size of aquatic organisms are correlated with the magnitude of methylmercury accumulation, the types and sizes of aquatic organisms being consumed should be considered when determining which fish to sample for deriving BAFs. States and tribes should consider the fish being consumed by various subpopulations (e.g., sport anglers, subsistence fishers) as well as culturally and economically diverse communities. This information should also guide the decision on whether the site-specific BAF should be based on a single trophic level (e.g., trophic level 4) or on multiple trophic levels.

States and authorized tribes should review site-specific data used to calculate field-measured BAFs and thoroughly assess the quality of the data and the overall uncertainty in the BAF values. States and authorized tribes should also consider the following general factors when determining the acceptability of field-measured BAFs reported in the published scientific literature. The same general issues and questions should also be addressed when designing a field study to generate site-specific field-measured BAFs.

- Calculate a field-measured BAF using aquatic organisms that are representative of the aquatic organisms commonly consumed at the site of interest (e.g., river, lake, ecoregion, state). Review information on the ecology, physiology, and biology of the target organisms when assessing whether an organism is a reasonable surrogate of a commonly consumed organism.

- Determine the trophic level of the study organism by taking into account its life stage, its diet, and the food web structure at the study location. Information from the study site (or similar sites) is preferred when evaluating trophic status. If such information is lacking, states and authorized tribes can find general information for assessing the trophic status of aquatic organisms in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*, volume 1, *Fish Sampling and Analysis* (USEPA 2000c).

- Collect length, weight, and age data for any fish used in deriving a field-measured BAF because current information suggests that variability in methylmercury accumulation is dependent on fish age and size (USEPA 2001a). This information helps normalize the BAF to a standardized fish size within the range of fish sizes and species known to be consumed by the human population of interest.

- Verify that the study used to derive the field-measured BAF contains sufficient supporting information from which to determine that tissue and water samples were collected and analyzed using appropriate, sensitive, accurate, and precise analytical methods.

- Verify that the water concentrations used to derive a BAF reflect the average exposure of the aquatic organism of concern that resulted in the concentration measured in its tissue. Concentrations of methylmercury in a waterbody vary seasonally and diurnally (Cleckner et al. 1995) because of a variety of biological and physical factors.

- Attempt to design a field sampling program that addresses potential temporal and spatial variability and that allows estimation of average exposure conditions. The study should be designed to sample an area large enough to capture the more mobile organisms and also to sample across seasons or multiple years when methylmercury concentrations in waters are expected to have large fluctuations. Longer sampling durations are necessary for waters experiencing reductions in mercury loadings, changes in water chemistry that affect methylation, and changes in the composition of the food web.

Volume I of the *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000c) provides additional guidance on selecting target species to sample, specific sampling design procedures, analytical measurement procedures, and quality assurance guidance. Chapter 10 of EPA's *Exposure Factors Handbook* provides additional guidance on collecting information about local species (USEPA 1997d). Additional guidance on evaluating existing site-specific bioaccumulation studies for use in deriving trophic-level-specific BAFs and designing sampling plans for obtaining data for deriving site-specific BAFs is provided in *Technical Support Document—Volume 2: Developing National Bioaccumulation Factors* (USEPA 2003). A publication by Burkhard (2003) is also a good source of information on designing BAF field studies and on deriving field-measured site-specific BAFs.

3.1.3.3 How is methylmercury in water translated into its mercury equivalent in water?

Given that permit limits are often derived using a mercury water column concentration criterion, a state or tribe may wish to take another step after using a BAF to determine a methylmercury water concentration criterion to derive a mercury water column concentration criterion. Although not necessary to develop a water quality criterion, a state can translate a methylmercury water concentration into a mercury water concentration criterion by converting the concentration of methylmercury in water to the equivalent concentration of mercury in water. This step might be necessary because although the BAF is typically based on the concentration of methylmercury in water, the assessment of water quality is typically based on an evaluation of mercury concentrations since other forms of mercury are converted to methylmercury in the environment. As a result, a relationship between (dissolved or total recoverable) methylmercury and (dissolved or total recoverable) mercury in the water needs to be developed. NPDES permits and other water quality-based pollution control activities traditionally rely on the total recoverable concentration of mercury, not the dissolved methylmercury form.

Many of the issues surrounding the uncertainty in predicting and transferring methylmercury BAFs across different waterbodies also apply to translating methylmercury concentrations to mercury concentrations. As with BAFs, one approach for translating between methylmercury and mercury concentrations is for states and

authorized tribes to measure site-specific concentrations of methylmercury and mercury to determine the relative amounts of each form. This field-measured, site-specific approach is the most direct and the most appropriate approach to the translation.

Where a site-specific approach is not feasible, states and authorized tribes may consider applying EPA's draft national methylmercury-to-mercury translator factors. In the 2001 methylmercury criterion document (USEPA 2001c), EPA derived these translator factors for rivers/streams and lakes as geometric means from data collected from the literature reporting concentrations of mercury in aquatic environments. Thus, like the draft national BAFs, the methylmercury-to-mercury translators were empirically derived based on various water data from across the United States. As with the draft national BAFs, the draft national methylmercury-to-mercury translator factors vary greatly across ecosystems and are subject to many of the same uncertainties. Therefore, EPA suggests that states and tribes that may be considering using the draft national translator values as defaults carefully review the discussion in the 2001 criterion document, particularly the discussions concerning uncertainty and limitations, before deciding to apply them in a regulatory context (see appendix A, section II, USEPA 2001a). States and tribes should consider whether more recent data and/or data that are more reflective of local conditions are available to supplant or supplement the limited database used to derive the draft national translators.

Alternatively, states and tribes that choose to develop water column criteria can consider collecting data to develop BAFs that relate methylmercury in fish tissue directly to total mercury in the water column. See the footnote to section 3.1.3.1.1 for more information.

3.2 What options are available to address site-specific conditions and concerns?

3.2.1 How can the methylmercury water quality criterion be modified for site-specific conditions?

The 2000 Human Health Methodology (USEPA 2000b) describes how states and authorized tribes can adopt site-specific modifications of a section 304(a) criterion to reflect local environmental conditions and human exposure patterns. "Local" may refer to any appropriate geographic area where common aquatic environmental or exposure patterns exist. Thus, it may signify a statewide or regional area, a river reach, or an entire river. Such site-specific criteria may be developed as long as the site-specific data, either toxicological or exposure-related, are justifiable. For example, when using a site-specific fish consumption rate, a state or authorized tribe should use a value that represents at least the central tendency for the consumption rate of the population surveyed. When defining a target population, a state or authorized tribe should focus on protecting populations with high rates of fish consumption from the local area.

States and authorized tribes may modify EPA's recommended 304(a) criterion for methylmercury by using different assumptions for certain components of EPA's criterion to derive a criterion that maintains and protects the designated uses. For example, states and authorized tribes may:

- Use an alternative RSC factor or

- Use a daily uncooked freshwater and estuarine fish consumption rate that is more reflective of local or regional consumption patterns than the 17.5 grams/day default value. EPA encourages states and authorized tribes to consider using local or regional consumption rates instead of the default values if the former would better reflect the target population.

If a state or authorized tribe intends to modify both the RSC and the fish consumption rate, it might find collecting the data at the same time advantageous.

3.2.1.1 How does one modify the RSC?

Section 5 of the methylmercury criterion document (USEPA 2001a) provides detailed discussions on how EPA assessed exposure to methylmercury and how EPA derived the RSC factor used in calculating the criterion. The methylmercury RSC is an exposure, subtracted from the RfD to account for exposure to methylmercury from sources other than freshwater or estuarine fish. By accounting for other known exposures, the RSC seeks to ensure that methylmercury exposures do not exceed the RfD.

If a state or tribe proposes to change the RSC, it should document the modifications with data supporting the modifications and share the proposed modifications to the RSC with EPA prior to recalculating the criterion. See appendix B for the tables from the methylmercury criterion document. States and authorized tribes should review section 5 of the methylmercury criterion document and modify the media-specific exposure estimates using local data that reflect the exposure patterns of their populationsTo modify this factor, states and authorized tribes should review the amount of marine fish and shellfish estimated to be consumed (table 5-1, USEPA 2001a) and the concentration of methylmercury in the commonly consumed marine species (table 5-14, USEPA 2001a).

3.2.1.2 How does one modify the daily fish intake rate?

EPA derived the recommended methylmercury water quality criterion on the basis of a default fish intake rate for the general population (consumers and nonconsumers) of 17.5 grams/day[12], uncooked (USEPA 2001a). States and authorized tribes may use a different intake rate based on local or regional consumption patterns and are encouraged to use consumption rates that are protective of a range of culturally and economically diverse communities. The fish consumption value in the TRC equation may be changed if the target population eats a higher or lower amount of fish. For example, if the 90th percentile of a target population eats approximately 15 grams/day of freshwater and estuarine fish of various trophic levels, the fish intake value in equation 1 would simply be 15 grams/day, rather than the national default value of 17.5 grams/day used in calculating the 0.3 mg/kg TRC.

EPA encourages states and authorized tribes to develop a water quality criterion for methylmercury using local or regional fish consumption data rather than the default values if they believe that such a water quality criterion would be more appropriate for

[12] This value represents the 90th percentile of freshwater and estuarine finfish and shellfish consumption reported by the 1994–1996 *Continuing Survey of Food Intakes by Individuals*. For more information, see *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (USEPA 2000b).

their target population. However, states and authorized tribes should consider whether the fish consumption rates reflect existing public concern about contamination of fish when collecting survey data, rather than local preference for fish consumption (i.e., the presence of fish advisories limits the consumption of fish). In this instance, the state or authorized tribe should take this into account and try to conduct surveys in a manner that accounts for the effects of fish advisories on the consumption of fish. Where there is afish consumption advisory, surveys should be designed to evaluate how much fish a local population would consume if the fish were safe to eat and incorporate that consumption level into the criterion.

EPA suggests that states and authorized tribes follow a hierarchy when deriving fish intake estimates (USEPA 2000b). From highest preferred to lowest preferred, this hierarchy is as follows (1) use local data protective of culturally and economically diverse communities when available, (2) use data reflecting similar geography or population groups, (3) use data from national surveys, and (4) use EPA's default fish intake rates. Additional discussion of these four preferences is provided below.

When a state or authorized tribe develops a site-specific criterion on the basis of local fish consumption, site-specific BAFs, or a site-specific RSC, states and authorized tribes might want to include EPA in the development of the study plan and submit the data supporting the site-specific criterion for EPA's consideration when EPA approves or disapproves state or tribal water quality standards under CWA section 303(c). Including EPA at the study plan development stage may help to avoid problems and facilitate development of a defensible site-specific criterion.

3.2.1.2.1 Use local data

If a state or authorized tribe believes a fish consumption rate other than the default would be appropriate for their target population, EPA's first preference is that they use fish intake rates derived from studies of consumption of local fish. Such studies could include results of surveys designed to obtain information on the consumption of freshwater or estuarine species caught from local watersheds within the state or tribal jurisdiction. When estimating the fish intake rate, all freshwater fish, whether caught recreationally or bought commercially, should be included. States and authorized tribes may choose to develop either fish intake rates for the local population as a whole, or individual fish intake rates for various subpopulations (e.g., sport anglers, subsistence fishers) as well as culturally and economically diverse consumers.

States and authorized tribes might wish to conduct their own surveys of fish intake. *Guidance for Conducting Fish and Wildlife Consumption Surveys* (USEPA 1998a) provides EPA guidance on methods for conducting such studies. States and authorized tribes should take care to ensure that the local data are of sufficient quality and scope to support development of a criterion and are representative of the population of people that eat local fish. EPA's consumption survey guidance offers recommendations on how to develop appropriate quality assurance and quality control procedures to help ensure the quality of the survey. Results of studies of the broader geographic region in which the state or authorized tribe is located can also be used, but they might not be as applicable as study results for local watersheds. Because such studies would ultimately form the basis of a state's or authorized tribe's methylmercury criterion, EPA would consider any surveys of

fish intake as part of its review of the methylmercury criterion's scientific defensibility as part of the Agency's review of water quality standards under CWA section 303(c).

States and authorized tribes may use either high-end (such as 90th or 95th percentile) or central tendency (such as median or mean) consumption values for the population of interest (e.g., subsistence fishers, sport fishers, or the general population). EPA generally recommends that a central tendency value be the lowest value states or authorized tribes should use when deriving a criterion. When considering median values from fish consumption studies, states and tribes should ensure that the distribution is based on survey respondents that reported consuming fish because surveys of both consumers and nonconsumers can often result in median values of zero. EPA believes the approach described above is a reasonable procedure and is also consistent with other Agency positions such as that of the Great Lakes Water Quality Initiative, known as the GLI (USEPA 1995a).

3.2.1.2.2 Use similar geography or population groups

If surveys conducted in the geographic area of the state or authorized tribe are not available, EPA's second preference is that states and authorized tribes consider results from existing surveys of fish intake in similar geographic areas and population groups (e.g., from a neighboring state or authorized tribe or a similar watershed type) and follow the method described above regarding target values to derive a fish intake rate. For instance, states or tribes with subsistence fisher populations might wish to use consumption rates from studies that focus specifically on these groups, or use rates that represent high-end values from studies that measured consumption rates for a range of types of fishers (e.g., recreational or sport fishers, subsistence fishers, minority populations). A state or authorized tribe in a region of the country might consider using rates from studies that surveyed the same region; for example, a state or authorized tribe that has a climate that allows year-round fishing might underestimate consumption if it uses rates from studies taken in regions where people fish for only one or two seasons per year. A state or authorized tribe that has a high percentage of an age group (such as older persons, who have been shown to have higher rates in certain surveys) might wish to use age-specific consumption rates, which are available from some surveys. For additional information on the use of fish consumption rates, see EPA's 2000 Human Health Methodology (USEPA 2000b). Again, EPA recommends that states and tribes use only uncooked weight intake values and freshwater or estuarine species data.

3.2.1.2.3 Use national surveys

If applicable consumption rates are not available from local, state, or regional surveys, EPA's third preference is that states and authorized tribes select intake rate assumptions for different population groups from national food consumption surveys. EPA has analyzed two such national surveys, the 1994–1996 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII). These surveys, conducted by the U.S. Department of Agriculture (USDA), include food consumption information from a probability sample of the population of all 50 states. Respondents to the survey provided 2 days of dietary recall data. A separate EPA report provides a detailed description of the combined 1994–1996 and 1998 CSFII surveys, the statistical methodology, and the results and uncertainties of the EPA analyses (USEPA 2002b). The estimated fish consumption rates

in the CSFII report are presented by fish habitat (i.e., freshwater or estuarine, marine, and all habitats) for the following population groups: (1) all individuals, (2) individuals age 18 and over, (3) women ages 15–44, and (4) children age 14 and under. Three kinds of estimated fish consumption rates are provided: (1) per capita rates (rates based on consumers and nonconsumers of fish from the survey period), (2) by consumers-only rates (rates based on respondents that reported consuming finfish or shellfish during the 2-day reporting period), and (3) per capita consumption by body weight (per capita rates reported as mg/kg-day). For purposes of revising the fish consumption rate in the methylmercury criterion, EPA recommends using the rates for freshwater and estuarine fish and shellfish.

The CSFII surveys (USDA/ARS 1998, 2000) have advantages and limitations for estimating per capita fish consumption. The primary advantage of the CSFII surveys is that USDA designed and conducted them to support unbiased estimation of food consumption across the population in the United States and the District of Columbia. One limitation of the CSFII surveys is that individual food consumption data were collected for only 2 days—a brief period that does not necessarily depict "usual intake." Usual dietary intake is defined as "the long-run average of daily intakes by an individual." Upper percentile estimates might differ for short-term and long-term data because short-term food consumption data tend to be inherently more variable. It is important to note, however, that variability due to duration of the survey does not result in bias of estimates of overall mean consumption levels. Also, the multistage survey design does not support interval estimates for many of the subpopulations because of sparse representation in the sample. Subpopulations with sparse representation include American Indians on reservations and certain ethnic groups. Although these persons were participants in the survey, they were not present in sufficient numbers to support fish consumption estimates. The survey does support interval estimates for the U.S. population and some large subpopulations (USEPA 2002b).

3.2.1.2.4 Use EPA default fish intake rates

EPA's fourth preference is that states and authorized tribes use as fish intake assumptions, default rates on the basis of the 1994–1996 CSFII data for the U.S. population, which EPA believes are representative of freshwater and estuarine fish and shellfish intake for different population groups. The 1994–1996 CSFII data for U.S. fish consumption among both consumers and nonconsumers of fish is delineated below in table 3.

Because the combined 1994–1996 CSFII survey is national in scope, EPA uses the results from it to estimate fish intake for deriving national criteria. EPA applies a default rate of 17.5 grams/day for the general adult population. EPA selected an intake rate that is protective of a majority of the population (the 90th percentile of consumers and nonconsumers, according to the 1994–1996 CSFII survey data) (USEPA 2000b). EPA also recommends a default rate of an average of 17.5 grams/day for sport fishers.

Table 3. Estimates of freshwater and estuarine combined finfish and shellfish consumption from the combined 1994–1996 and 1998 CSFII surveys (U.S. population)

	Mean	Median	90th percentile	95th percentile	99th percentile
All ages	6.30	N/a	11.65	41.08	123.94
Age 18 and over	7.50	0.00*	17.53	49.59	142.41
Women ages 15-44	5.78	N/a	6.31	32.37	109.79
Children age 14 and under	2.64	0.00	0.00	13.10	73.70

Note: All values expressed as grams per day for uncooked fish.

* The median value of 0 grams/day might reflect the portion of persons in the population that never eat fish, as well as the limited reporting period (2 days) during which intake was measured.

Similarly, EPA believes the 99th percentile of 142.4 grams/day is within the range of consumption estimates for subsistence fishers, according to the studies reviewed, and that it represents an average rate for subsistence fishers. EPA knows that some local and regional studies indicate greater consumption among American Indian, Pacific Asian American, and other subsistence consumers and recommends the use of those studies in appropriate cases, as indicated by the first and second preferences. Again, states and authorized tribes have the flexibility to choose intake rates higher than the average values for these population groups. If a state or authorized tribe has not identified a separate well-defined population of exposed consumers and believes that the national data from the 1994–1996 CSFII are representative, the state or tribe may choose these recommended rates.

EPA has made these risk management decisions after evaluating numerous fish intake surveys. These values represent the uncooked weight intake of freshwater and estuarine finfish and shellfish. As with the other preferences, EPA requests that states and authorized tribes routinely consider whether a substantial population of sport fishers or subsistence fishers exists in the area when establishing water quality criteria rather than automatically using data for the general population.

The CSFII surveys also provide data on marine species, but EPA considered only freshwater and estuarine fish intake values for determining default fish consumption rates because EPA considered exposure from marine species of fish in calculating an RSC for dietary intake.[13] States and authorized tribes should ensure that when evaluating overall exposure to a contaminant, marine fish intake is not double-counted with the other dietary intake estimate used. Coastal states and authorized tribes that believe accounting for total fish consumption (fresh or estuarine *and* marine species) is more appropriate for protecting the population of concern may do so, provided that the marine intake component is not double-counted with the RSC estimate (USEPA 2000b).

[13] See the discussion of the RSC in sections 3.1.2.3 and 3.2.1.1.

3.2.2 How do water quality standards variances apply?

Where a discharger or waterbody cannot meet a water quality standard, a state or authorized tribe may adopt a temporary water quality standard through a variance process. The variance would then, in effect, serve as a substitute standard for a point source, and the WQBEL contained in an NPDES permit would then be based on the variance. As a revision to the otherwise applicable water quality standard (designated use and criteria), water quality standards variances must be supported by one of the six justifications under 40 CFR 131.10(g) (see section 3.2.3.4 below). Variances are generally determined based on the discharger's ability to meet a WQBEL and, therefore, are considered after an evaluation of controls necessary to implement water quality standards. In addition, EPA recommends that the permitting authority require the facility seeking a variance to develop and implement a mercury minimization plan (MMP) to both reduce mercury loading and to determine the highest level of water quality achievable to inform future permit decisions (see section 7.5.2.4 for more discussion of MMPs).

Variances typically apply for a limited period but may be reviewed at the time of the state triennial review of water quality standards, and require the same procedural steps that are required of a change in the standards. Where the term of a variance extends beyond three years, as for example in an NPDES permit, the variance must still be reassessed as part of the state's three year triennial review to confirm that the underlying attainability analysis remains relevant and accurate. A variance must continue to protect "existing uses" (defined in 40 CFR 131.3(e) as uses actually attained in the waterbody on or after November 28, 1975). Typically, variances apply to specific pollutants and facilities, which would mean that a water quality standards variance for mercury would apply to only the new methylmercury criterion in a stated waterbody and specifically to the discharger requesting the variance. The state or authorized tribe, however, may provide justification for more than one discharger or for an entire waterbody or segment to receive a variance (as discussed in section 3.2.2.3 of this document). See section 3.2.3 for a discussion of the requirement to conduct a use attainability analysis for changes to water quality standards, including the prohibition on removing existing uses.

3.2.2.1 When is a variance appropriate?

Some regulated point sources discharging mercury might apply for variances for their discharges into impaired waters where the largest source of mercury is atmospheric deposition. In other cases, limits to technology or naturally elevated levels of methylmercury in a waterbody could preclude attainment of standards. To address these types of issues, the following scenarios are examples of demonstrations that could satisfy the requirements under 40 CFR 131.10(g). The demonstrations are more thoroughly explained below and in the *Water Quality Standards Handbook* (USEPA 1994).

- *Economic or social impacts* (131.10(g)(6)). Demonstrate that, in the short term, the costs of constructing controls necessary to meet the methylmercury criterion (beyond those required by sections 301(b)(1)(A) and (B) and 306 of the CWA) would result in substantial and widespread economic and social impact.

- *Human-caused conditions that cannot be remedied* (131.10(g)(3)). Demonstrate that, in the short term, none of the present technologies for improving the quality of

an effluent are capable of bringing methylmercury levels in the discharge down to a level as stringent as necessary to meet the criterion (i.e., there is no technological remedy or it is technologically infeasible).

- *Natural conditions that preclude attainment* (131.10(g)(1)). Demonstrate that local conditions of an aquatic system result in high methylmercury levels. For example, elevated methylmercury concentrations might occur naturally in a system because of a short-term condition.

During the period the variance applies, any permit issued must be consistent with applicable water quality standards (40 CFR 122.44(d)(1)(vii)), which in this case would be the temporary standard approved in the variance. The permit would need to be modified to derive from and comply with the underlying standard if the variance is not re-issued.

3.2.2.2 What should a state or tribe consider before granting a variance?[14]

In general, the temporary revised standard established by a variance should be set at a level representing the highest attainable water quality (like all water quality standards). Variances may not interfere with existing uses, and variances should ensure progress toward ultimate attainment of the designated use for the waterbody. Regarding procedural considerations, the same requirements apply for a variance as for a new or revised standard (e.g., public review and comment, EPA approval or disapproval) because a variance is a change to the water quality standards. In addition, the following describes more specific issues that states and authorized tribes should take into account when considering granting a variance.

- *Variance protocols.* If a state or authorized tribe anticipates receiving a number of variance requests for mercury discharges, it could consider establishing a mercury variance protocol, with EPA's participation and agreement. The protocol would govern the development and processing of variance requests. It would specify the information needed and the criteria the state would use in considering whether to adopt the variance. Although the state or tribe would need to submit each variance to EPA for approval (40 CFR 131.20), EPA's advance agreement to the protocol could streamline EPA's review of any variances developed in accordance with the protocol. Public notice requirements for variances could be satisfied through the process of issuing the NPDES permit that incorporates limits based on such temporary standards, as long as the variance is identified and all the necessary information pertaining to the variance is included.

- *Time frames.* A variance is typically a time-limited change in the water quality standards. Although EPA part 131 regulations do not specify a time limit for variances, EPA's triennial review regulations at 40 CFR 131.20 require that variances, as part of water quality standards, are reexamined every three years to

[14] Federal or state regulations also govern the granting of a variance. For example, regulations promulgated under 40 CFR part 132, appendix F, procedure 2, specify the conditions for granting variances in the Great Lakes and prohibit the granting of variances to new dischargers or recommending Great Lakes dischargers.

determine if new information has become available and modified as appropriate. Variances that extend longer than three years are traditionally revisited in the context of a triennial review. Once a variance has expired, to justify the continuation of the variance, the state must demonstrate that meeting the standard is still unattainable based on one of the factors at 131.10(g). The state should also ensure that the permittee has made reasonable progress to control mercury in the discharge during the period of the previously approved variance (i.e. has adopted a mercury minimization plan.)

As with any other revision to the water quality standards, the permit and permit conditions implementing the variance do not automatically change back to the previous permit conditions if the variance expires, unless that is a condition of a variance and permit. Although water quality standards can change with every triennial review, states and authorized tribes are not obliged to reopen and modify permits immediately to reflect those changes, but may do so where the permit contains a reopener condition to address such revised water quality standards. In the Great Lakes, however, permits with limits based on variances must include a provision enabling the permitting authority to reopen and modify the permit based on triennial revisions to water quality standards. (40 CFR part 132, appendix F, procedure 2, section F.4). Any new or reissued permit must implement the water quality standards applicable at time of permit issuance. 40 CFR 122.44(d)(1).

- *Antidegradation.* Permits with effluent limits based on a variance for methylmercury must conform, as do all permits, to the state or authorized tribe's antidegradation policy.

- *Mercury Minimization Plans (MMPs).* EPA recommends that states and authorized tribes require dischargers receiving a variance to adopt and implement an MMP as described in section 7.5.2.4. By reducing mercury sources up front, as opposed to traditional reliance on treatment at the end of a pipe, diligent implementation of MMPs might mitigate any adverse effects of a variance by improving the water quality. As noted above, MMPs also serve to inform the evaluation of controls needed to grant a variance and to determine the highest attainable water quality

3.2.2.3 What is involved in granting a variance on a larger scale?

Traditionally, variances are specific to a pollutant and a facility. However, for situations where a number of NPDES dischargers are located in the same area or watershed and the circumstances for granting a variance are the same, states and authorized tribes may consider administering a multiple-discharger variance for a group of dischargers collectively. Such a group variance can be based on various scales and may depend largely on the rationale for adopting a variance for methylmercury. Possible applications of a group variance may include facilities with similar discharge processes, a watershed basis, particularly for states that issue NPDES permits on a watershed basis, or a broader geographic basis, analogous to a general NPDES permit.

For example, Ohio adopted a statewide mercury variance applicable to point source dischargers in the state that meet specified criteria. In addition, Michigan has authorized multiple discharger variances for mercury with permit requirements, including development and implementation of an MMP.

It is important to note that, despite the coverage of a multiple-source variance, an individual discharger must still demonstrate that the underlying criterion is not attainable with the technology-based controls identified by CWA sections 301(b) and 306 and with cost-effective and reasonable best management practices (BMPs) for nonpoint sources (40 CFR 131.10(h)(2)).

3.2.3 How are use attainability analyses conducted?

3.2.3.1 What is a use attainability analysis?

A use attainability analysis (UAA) is defined in 40 CFR 131.3(g) as a structured scientific assessment of the factors affecting the attainment of a use, which may include physical, chemical, biological, and economic factors, that must be conducted whenever a state wishes to remove a designated use specified in section 101(a)(2) of the CWA, or to adopt subcategories of uses specified in section 101(a)(2) of the CWA, which require less stringent criteria (see 40 CFR 131.3 and 40 CFR 131.10(g)).

Where a UAA indicates that the current use is unattainable, the state or tribe will need to identify and assign the "highest attainable use," which should reflect the factors and constraints on the attainability of a use that were evaluated as part of the UAA process. Once the state or tribe has determined the highest attainable use, it should propose adopting this designated use in place of the designated use deemed unattainable. For example, to the extent allowed by state or tribal law, the state or tribe could refine its designated use from "fish consumption" to "mercury-limited fish consumption." That way the waterbody would still be expected to meet other pollutant criteria designed to protect fish consumption.

3.2.3.2 What is EPA's interpretation of CWA section 101(a)?

CWA section 101(a) (2) establishes as a national goal "water quality [that] provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water," wherever attainable. These goals are commonly referred to as the "fishable/swimmable" goals of the CWA. EPA interprets these goals as providing for the protection of aquatic communities and human health related to the consumption of fish and shellfish. In other words, EPA views "fishable" to mean that fish and shellfish can thrive in a waterbody and, when caught, can also be safely eaten by humans. This interpretation also satisfies the CWA section 303(c)(2)(A) requirement that water quality standards protect public health. Including human consumption of fish and shellfish as the appropriate interpretation of the definition of section 101(a)(2) uses is not new. For example, in the National Toxics Rule, all waters designated for even minimal aquatic life protection (and therefore a potential fish and shellfish consumption exposure route) are protected for human health (57 FR 60859, December 22, 1992).

3.2.3.3 When is a UAA needed for a "fishable" use?

Under 40 CFR 131.10(j) of the Water Quality Standards Regulation, states and authorized tribes are required to conduct a UAA whenever the state or authorized tribe designates or has designated uses that do not include the "fishable/swimmable" use specified in CWA section 101 (a)(2); or the state or authorized tribe wishes to remove a

designated use that is specified in CWA section 101(a)(2) or adopt subcategories of the uses specified in that section that require less stringent criteria.

An important caveat to the process of removing a designated use is that states and authorized tribes may not remove an "existing use" as defined by the Water Quality Standards Regulation. An existing use is defined in 40 CFR 131.3(c) as any use that has been actually attained on or after November 28, 1975, when the CWA regulations regarding use designation were originally established. In practical terms, waters widely used for recreational fishing would not be good candidates for removing a "fishable" use, especially if the associated water quality supports, or has until recently supported, the fishable use, on the basis, in part, of the "existing use" provisions of EPA's regulations.

In addition, EPA considers designated uses attainable, at a minimum, if the use can be achieved (1) through effluent limitations under CWA sections 301(b)(1)(A) and (B) and 306 and (2) through implementation of cost-effective and reasonable BMPs for nonpoint sources. The federal regulations at 40 CFR 131.10(g) further establish the basis for finding that attaining the designated use is not feasible, as long as the designated use is not an existing use. EPA emphasizes that when adopting uses and appropriate criteria, states and authorized tribes must ensure that such standards provide for the attainment and maintenance of the downstream uses (40 CFR part 131.10(b)). States and tribes are not required to conduct UAAs when designating uses that include those specified in CWA section 101(a) (2), although they may conduct these or similar analyses when determining the appropriate subcategories of uses.

3.2.3.4 What conditions justify changing a designated use?

EPA's regulations at 40 CFR 131.10(g) list the following six reasons for states or authorized tribes to use to support removal of a designated use or adoption of a subcategory of use that carries less stringent criteria:

- Naturally occurring pollutant concentrations prevent the attainment of the use.
- Natural, ephemeral, intermittent, or low-flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met.
- Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.
- Dams, diversions, or other types of hydrologic modifications prevent the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in attainment of the use.
- Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, prevent attainment of aquatic protection uses.

- Controls more stringent than those required by CWA sections 301(b) and 306 would result in substantial and widespread economic and social impact.

In addition to citing one or more of these factors to support removal of a use, states and authorized tribes use the same six factors to guide analysis and decision-making with respect to establishing an attainable use.

In all cases, states and authorized tribes must obtain scientifically sound data and information to make a proper assessment. It is also recommended that they conduct pollutant source surveys to define the specific dominant source of mercury in the waterbody. Sources may include point source loadings, air deposition, mining waste or runoff, legacy levels (e.g., mercury resulting from historical releases), and geologic "background levels." This is similar to source assessments under the TDML program. Existing documents provide guidance on obtaining data and conducting analyses for the other components of a UAA. These documents are at http://www.epa.gov/waterscience/standards/uaa/info.htm. The *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses* (USEPA 1983) covers the physical and chemical components of UAAs. Technical support for assessing economic and social impacts is offered through the *Interim Economic Guidance for Water Quality Standards Workbook* (USEPA 1995b).

EPA recognizes that there may be naturally occurring concentrations of methylmercury which may exceed the national recommended 304(a) criterion. However, EPA policy, whereby criterion may be set at ambient conditions if contaminant levels are due only to non-anthropogenic sources, applies only to aquatic life uses. The policy does not apply to human health uses. The policy states that for human health uses, where the natural background concentration is documented, this new information should result in, at a minimum, a re-evaluation of the human health use designation (USEPA 1997e).

4 Monitoring and Assessment

Water quality monitoring and assessment are essential elements in implementing the CWA at the local, state, and national levels. In implementing the water quality-based approach, the most obvious uses of monitoring information are in determining attainment of water quality standards and in developing TMDLs and permits. In the case of mercury, analyzing for mercury and methylmercury in water and fish is particularly important for states and tribes that choose to develop BAFs and methylmercury-to-mercury translators. This chapter provides guidance on analytical methods, field sampling, and assessment considerations for mercury. Additional information on developing site-specific BAFs and translators is provided in section 3.1.3 of this guidance.

4.1 What are the analytical methods for detecting and measuring mercury and methylmercury concentrations in fish and water?

Over the past two decades, EPA and other organizations have developed several analytical methods for determining mercury and methylmercury concentrations in fish and water. In 2001 EPA conducted a literature review to assess the availability of different analytical methods and to determine which of the analytical methods would be most useful for implementing the new methylmercury criterion. After the review, EPA concluded that nearly all current research on low-level concentrations of mercury and methylmercury is being performed using techniques that are based on procedures developed by Bloom and Crecelius (1983) and refined by Bloom and Fitzgerald (1988), Bloom (1989), Mason and Fitzgerald (1990), and Horvat et al. (1993).

To assist states and authorized tribes in selecting an analytical method to use, this chapter describes selected analytical methods available (sections 4.1.1 and 4.1.2), and identifies five specific methods that EPA recommends for use in implementing this guidance (section 4.1.3). In addition, appendix C of this document presents a list of available methods in more detail. Table C1 of the appendix summarizes 4 methods to analyze mercury and methylmercury in fish tissue, and table C2 summarizes 18 methods for the analysis of mercury and methylmercury in water and other nontissue matrices. Each table identifies the forms and species of mercury targeted by each method, estimated or known sensitivity, the techniques employed in the method, and any known studies or literature references that use the techniques employed in the method.

The CWA establishes an EPA approval process for certain methods used in the NPDES program and for section 401 certifications. As described in section 4.1.2 below, EPA has approved two of the above methods for analysis of mercury in water under 40 CFR part 136: method 1631, revision E and method 245.7. EPA's regulations generally require that these methods be used whenever such analyses are required for the NPDES program and for CWA section 401 certifications issued by states and authorized tribes (40 CFR 136.1). Sections 7.4 and 7.5.1.1 of this guidance provide additional information on appropriate analytical methods for measuring mercury in water for NPDES permitting purposes.

There are no regulatory requirements for the use of particular methods in setting water quality standards, evaluating the attainment of standards, or developing TMDLs,

although any methods used need to be scientifically defensible. Although this chapter provides recommendations for methods that can be used for these purposes, states and tribes are not precluded from using other methods, including those in appendix C.

4.1.1 Analytical Methods for Methylmercury

For measuring methylmercury in water, EPA method 1630 (USEPA 2001d), developed by EPA's Office of Water, reflects the techniques developed by Bloom and Crecelius (1983) and refined by Bloom and Fitzgerald (1988), Bloom (1989), Mason and Fitzgerald (1990), and Horvat (1993). This method has a quantitation level of 0.06 ng/L.

Draft modifications to method 1630, described in table C1 (see appendix C) and in Horvat et al. (1993), allow for measurement of methylmercury in fish tissue as low as 0.001 to 0.002 mg/kg, well below the water quality criterion for methylmercury in tissue (0.3 mg/kg). EPA recommends using these techniques when direct measurements of methylmercury in fish tissue are desired.

Three additional methods for measuring methylmercury in water are listed in table C2 (see appendix C). These methods are UW-Madison's standard operating procedure, or SOP (Hurley et al. 1996), used by the Great Lakes National Program Office for its Lake Michigan Mass Balance Study; USGS Wisconsin-Mercury Lab SOPs 004 (DeWild et al. 2002), used by USGS and EPA in the Aquatic Cycling of Mercury in the Everglades study; and a recently released USGS method (DeWild et al. 2002). All these procedures are based on the same techniques and have detection limits of 0.01 ng/L, 0.05 ng/L and 0.04 ng/L, respectively.

Because the four methods are nearly identical test procedures, they are expected to produce very similar results with sensitivity as low as 0.01 to 0.06 ng/L in water. These levels are well below the expected range of water column concentrations associated with the methylmercury fish tissue criterion.

4.1.2 Analytical Methods for Mercury

For measuring low level mercury in water, EPA method 1631, revision E (USEPA 2002c), developed by EPA's Office of Water, reflects the techniques developed by researchers mentioned previously. It has a quantitation level of 0.5 ng/L. EPA made this revision to clarify method requirements, increase method flexibility, and address frequently asked questions. The revision includes recommendations for using the clean techniques contained in EPA's *Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels* (USEPA 1996a). The benefits of using method 1631 are that it has been fully validated, numerous laboratories are routinely using the method, and it is sensitive enough to measure at the water concentrations expected to be associated with the criterion. This method was approved in 2002 under 40 CFR part 136 for NPDES permitting and other purposes under the CWA (67 FR 65876).

In addition, EPA method 245.7 (USEPA 2005e), which has a quantitation level of 5.0 ng/L, was approved under part 136 in 2007 (72 FR 11200). Developed by EPA's Office of Water, method 245.7 is similar to EPA method 1631E because both methods require use of a cold-vapor atomic fluorescence spectrometry (CVAFS) detector to measure low levels of mercury. Method 245.7 has been validated in two EPA

laboratories, one university laboratory, and an interlaboratory validation study. Results from these studies indicate that the method is capable of producing reliable measurements of mercury at some toxic criteria levels (40 CFR 136).

Appendix A to method 1631 (64 FR 10596) details the researcher's techniques for determining total and dissolved mercury in tissue, sludge, and sediments. The appendix was developed for processing fish tissue samples to be analyzed for mercury using the previously validated and approved method 1631 analytical procedures. The procedures are expected to be capable of measuring mercury in the range of 0.002 to 5.0 mg/kg.

EPA recognizes that some users might find Method 1631 (appendix A) costly or difficult to implement. Appendix C summarizes three other methods available for analyzing mercury in fish tissue that are less costly and less difficult to implement, but they have not undergone the same extensive interlaboratory validation studies as Method 1631 (appendix A). Two are listed in table C1 (Methods 245.6 and 7474). The third—Method 7473 for analyzing mercury in water, listed in table C2—has been adapted by some users for analyzing mercury in fish tissue; this approach has been used to measure mercury in fish tissue to support state fish consumption advisories.

Because researchers have found that nearly all mercury in fish tissue is in the form of methylmercury (USEPA 2000c), EPA also suggests that analysis of tissue for mercury, as a surrogate for methylmercury, might be a useful means for implementing the methylmercury criterion. If mercury concentrations in tissue exceed the criterion, further investigation of the methylmercury component might be desired.

4.1.3 Summary of Recommended Analytical Methods

In summary, on the basis of the available information, EPA believes that the most appropriate methods for measuring low levels of mercury concentrations in the water column are method 1631, revision E (mercury in water by CVAFS) and method 245.7 (mercury in water by CVAFS). Likewise, EPA believes that the most appropriate method for measuring methylmercury concentrations in the water column is method 1630 (methylmercury in water by CVAFS), and the most appropriate methods for measuring mercury concentrations in fish tissue are appendix A to method 1631 (mercury in tissue by CVAFS) and modifications to method 1630 for handling tissues. EPA recommends these procedures for the following reasons:

- EPA developed methods 1631 and 1630 to support implementation of water quality criteria for mercury and methylmercury, respectively. Both are already in the appropriate EPA format and include all standardized quality control elements needed to demonstrate that results are reliable enough to support CWA implementation.

- EPA developed method 245.7 specifically to address state needs for measuring mercury at ambient water quality criteria levels, when such measurements are necessary to protect designated uses. In addition, it has been validated in two EPA laboratories, one university laboratory, and an interlaboratory validation study.

- EPA developed appendix A to method 1631 to support its National Study of Chemical Residues in Lake Fish Tissue. Appendix A provides information on

preparing a fish tissue sample for analysis using method 1631. The method was validated by Brooks Rand (USEPA 1998b) and was used by Battelle Marine Sciences to analyze more than a thousand tissue samples collected during EPA's national study (USEPA 2000d). Successful use of these techniques also has been widely reported in the literature. This history, combined with the fact that appendix A supplements the already well-characterized and approved method 1631, makes this method a good candidate for use with the new fish tissue criterion.

- Method 1630 already has been used in several studies, including EPA's Cook Inlet Contaminant Study (USEPA 2001e) and the Savannah River TMDL study (USEPA 2001f). The techniques described in the method and in the recommended method modifications also have been successfully applied in numerous studies described in the published literature. Furthermore, the procedures in method 1630 are nearly identical to those given in the USGS method and in the University of Wisconsin SOP (Hurley et al., 1996), listed in table C2. The University of Wisconsin SOP was used in EPA's Lake Michigan Mass Balance Study (USEPA 2001g).

Table 4 summarizes the recommendations discussed above.

Table 4. Recommended analytical methods for detecting and measuring low levels of methylmercury and mercury in fish tissue and water

Recommended for analysis of:	Methylmercury… (see section 4.1.1)	Mercury… (see section 4.1.2)
...in fish tissue (for additional available methods, see appendix C, table C1)	Method 1630 with draft modifications for tissue	Method 1631, draft Appendix A
…in water (for additional available methods, see appendix C, table C2)	Method 1630	Method 1631, revision E* Method 245.7*

*Approved under 40 CFR part 136. See sections 7.4 and 7.5.1.1 for further information on appropriate methods for NPDES permitting purposes.

4.2 What is the recommended guidance on field sampling plans for collecting fish for determining attainment of the water quality standard?

EPA has published guidance providing information on sampling strategies for a fish contaminant monitoring program in volume 1, *Fish Sampling and Analysis*, of a document series, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000c). This guidance provides scientifically sound recommendations for obtaining a representative sample for issuing fish consumption advisories, and can be applied for obtaining a representative sample for determining attainment. The guidance also includes recommendations for quality control and quality assurance considerations. In all cases, states and authorized tribes should develop data quality objectives for determining the type, quantity, and quality of data to be collected (USEPA 2000e).

4.2.1 What fish species should be monitored?

EPA's fish sampling guidance (USEPA 2000c) provides recommendations for selecting finfish and shellfish species for monitoring to assess human consumption concerns. According to the guidance, the most important criterion for selecting fish is that the species are commonly eaten in the study area and have commercial, recreational, or subsistence fishing value. States and tribes also should ensure that the species monitored reflect the fish species consumed by culturally and economically diverse communities. Fish creel data (from data gathered by surveying recreational fishers) from state fisheries departments are a justifiable basis for estimating types and amounts of fish consumed from a given waterbody. States and authorized tribes should ensure that the creel data are of sufficient quality and are representative of the local population of people that eat fish.

The fish sampling guidance also identifies recommended target species for inland fresh waters and for Great Lakes waters. Walleye and largemouth bass have been identified as freshwater fish that accumulate high levels of methylmercury. Reptiles, such as turtle species and alligators, are recommended as target species for mercury if they are part of the local diet. Larger reptiles can also bioaccumulate environmental contaminants in their tissues from exposure to contaminated sediments or consumption of contaminated prey.

The fish sampling guidance further recommends that the size range of the sampled target fish ideally should include the larger fish individuals harvested at each sampling site because larger (older) fish within a population are usually the most contaminated with methylmercury (Phillips 1980, Voiland et al. 1991). In addition, the methylmercury concentrations in migratory species are likely to reflect exposures both inside and outside the study area, and the state or authorized tribe should take this into account when determining whether to sample these species. For migratory species, EPA's fish sampling guidance recommends that neither spawning populations nor undersized juvenile stages be sampled in fish contaminant monitoring programs (USEPA 2000c). States and authorized tribes should consider the life history of migratory species and the consumption patterns of the local population when including migratory species in their fish sampling protocols. Sampling of target finfish species during their spawning period should be avoided because contaminant tissue concentrations might decrease at that time.

If states and authorized tribes do not have local information about the types of fish that people eat, the following two options provide an alternative for identifying which fish to sample:

- *Match assumed or known consumption pattern to sampled species.* If the state has some knowledge of the fish species consumed by the general population or by individuals in another target population, a monitoring sample could be composited to reflect this knowledge. For example, a state might decide that 75 percent of the fish consumed are trophic level 4 species, 20 percent are trophic level 3 species, and 5 percent are trophic level 2 species. A composite sample (see section 4.2.2) would reflect the determined trophic level breakout.

- *Use trophic level 4 fish only.* Predator species (e.g., trout, walleye, largemouth bass, and smallmouth bass) are good indicators for mercury and other persistent pollutants that are biomagnified through several trophic levels of the food web. Increasing mercury concentrations correlate with an increase in fish age, with some

variability, so that consumption of larger (older) individuals correlates with greater risks to human health. Increasing mercury concentrations also correlate with higher trophic levels, and thus consumption of higher-trophic-level species would provide greater risks to human health. Therefore, targeting trophic level 4 species should serve as a conservative approach (depending on the species most frequently consumed by recreational fishers) for addressing waterbodies with highly varying concentrations of methylmercury.

4.2.2 What sample types best represent exposure?

EPA recommends using composite samples of fish fillets from the types of fish that people in the local area eat because methylmercury is found primarily in fish muscle tissue (USEPA 2002c). Using skinless fillets is a more appropriate approach for addressing mercury exposures for members of the general population and most recreational fishers because fish consumers typically eat the fillets without skin. Because mercury is differentially concentrated in muscle tissue, leaving the skin on the fish fillet actually results in a lower mercury concentration per gram of skin-on fillet than per gram of skinless fillet (USEPA 2000c). Analysis of skinless fillets might also be more appropriate for some target species, such as catfish and other scaleless finfish species. Some fish consumers, however, do eat fish with the skin on. In areas where the local population eats fish with the skin or eats other parts of fish, the state or authorized tribe should consider including these parts of fish in the sample.

Composite samples are homogeneous mixtures of samples from two or more individual organisms of the same species collected at a site and analyzed as a single sample. Because the costs of performing individual chemical analyses are usually higher than the costs of sample collection and preparation, composite samples are most cost-effective for estimating average tissue concentrations in target species populations. In compositing samples, EPA recommends that composites be of the same species and of similar size so that the smallest individual in a composite is no less than 75 percent of the total length (size) of the largest individual (USEPA 2000c). Composite samples can also overcome the need to determine how nondetections will be factored into any arithmetical averaging because the composite represents a physical averaging of the samples. However, depending on the objectives of a study, compositing might be a disadvantage because individual concentration values for individual organisms are lost. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories,* volume 1, at sections 6.1.1.6 and 6.1.2.6, provides additional guidance for sampling recommendations.

4.2.3 What is the recommended study design for site selection?

Ideally, states and authorized tribes should collect samples over a geographic area that represents the average exposure to those who eat fish from the waterbody. However, if there are smaller areas where people are known to concentrate fishing, those areas should be used as the sampling area. Fish sampled in locations with mercury point sources should be included in the average concentration if fishing occurs in those areas but not included if the areas are not used for fishing.

Once the state or tribe identifies the geographic area, EPA recommends that they use a probabilistic sampling design to select individual sites or sampling locations. Use of a

probabilistic design can address the spatial variability of methylmercury levels in fish. This approach allows statistically valid inferences to be drawn about tissue levels in the area as a whole. EPA's *Guidance on Choosing a Sampling Design for Environmental Data Collection, for Use in Developing a Quality Assurance Project Plan* (USEPA 2002d) contains information about probabilistic site selection.

4.2.4 How often should fish samples be collected?

EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories,* volume 1 (USEPA 2000c), at section 6.1.1.5, provides recommendations for how frequently to sample fish tissue. If program resources are sufficient, this guidance recommends biennial sampling of fish in waterbodies where recreational or subsistence harvesting is commonly practiced. If biennial screening is not possible, waterbodies should be screened at least once every five years. Also, the state or authorized tribe should sample during the period when the target species is most frequently harvested or caught.

In fresh waters, the guidance recommends that the most desirable sampling period is from late summer to early fall (August to October). Water levels are typically lower during that time, simplifying collection procedures. Also, the fish lipid content is generally higher, allowing the data to also provide information for other contaminant levels. The guidance does not recommend the late summer to early fall sampling period if it does not coincide with the legal harvest season of the target species or if the target species spawns during that period. In estuarine and coastal waters, the guidance recommends that the most appropriate sampling time is during the period when most fish are caught and consumed (usually summer for recreational and subsistence fishers).

EPA recommends that states and authorized tribes sample consistently in a season to eliminate seasonal variability as a confounding factor when analyzing fish monitoring data. Moreover, focused seasonality studies could be used both to assess the impact of seasonal variability on fish concentrations and to normalize concentrations to a standard season(s). Several studies have measured seasonality in the mercury concentrations in fish fillet muscle in estuaries and reservoirs (Kehrig et al. 1998; Park and Curtis 1997; Szefer et al. 2003). In these studies, concentrations were generally higher in cold seasons than in warm seasons by as much as two to three times. Slotten et al. (1995) showed that the uptake of methylmercury in zooplankton and fish increased dramatically during the fall mixing of Davis Creek Reservoir, a California reservoir contaminated by mercury mining activities.

No studies of seasonality of mercury concentrations in fish were found for rivers or natural lakes. On the basis of literature-reported fish mercury depuration rates, EPA does not expect seasonal fluctuations in fish mercury levels. Though reported mercury elimination half-lives cover a wide range of rates, from a few days to several years, the central tendency is 100–200 days (Burrows and Krenkel 1973; Giblin and Massaro 1973; Huckabee et al. 1979 [literature review]; McKim et al. 1976; Rodgers and Beamish 1982). Such slow depuration rates are expected to dampen strongly any fluctuations in methylmercury concentrations in fish. Instead, seasonal variations in fish tissue are likely linked to seasonal nutrition variability that affects fish body conditions but not mercury body burden.

4.2.5 How many samples should be collected?

EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, v*olume 1 (USEPA 2000c), at section 6.1.2.7.2, provides information to help determine the number of composite samples needed for comparing fish tissue information to a target value. The guidance does not recommend a single set of sample size requirements (e.g., number of replicate composite samples per site and number of individuals per composite sample) for all fish contaminant monitoring studies, but rather presents a more general approach that is both scientifically defensible and cost-effective. The guidance provides the means for determining an optimal sampling design that identifies the minimum number of composite samples and of individuals per composite necessary to detect a minimum difference between a target (in this case, the water quality criterion) and the mean concentration of composite samples at a site. Under optimal field and laboratory conditions, at least two composite samples are needed at each site to estimate the variance. To minimize the risk of a destroyed or contaminated composite sample's preventing the site-specific statistical analysis, at least three replicate composite samples should be collected at each site.

4.2.6 What form of mercury should be analyzed?

Because of the higher cost of methylmercury analysis (two to three times greater than that for mercury analysis), one approach for the states and authorized tribes could be to first measure mercury in fish tissue. States and tribes may find that more labs have the capability for mercury analysis and that the analysis time may be quicker.

When measuring only mercury, the state or authorized tribe might make the conservative assumption that all mercury in fish tissue is methylmercury. Appendix A summarizes eight studies of the relative proportion of the mercury concentration in North American freshwater fish that is in the form of methylmercury. In six of the eight studies, methylmercury, on average, accounted for more than 90 percent of the mercury concentration in fish tissue. In the remaining two studies, methylmercury, on average, accounted for 80 to 90 percent of the mercury concentration in trophic level 3 and 4 fish. If the measured mercury level exceeds the methylmercury criterion, states and tribes may wish to repeat the sampling (if sufficient tissue is not left) and analyze for methylmercury.

4.2.7 Other sampling considerations

EPA recommends that states and tribes routinely collect both weight and length data when assessing the potential influence of fish nutritional state on mercury concentration, and potentially for normalizing fish concentrations to a standard body condition. Greenfield et al. (2001), Cizdziel et al. (2002, 2003), and Hinners (2004) reported a negative correlation between fish body condition (a ratio of weight to cubed length) and fish tissue mercury concentration. Regardless of the exact mechanism, body condition offers a useful method to explain variability in fish mercury.

4.3 How should waterbody impairment be assessed for listing decisions?

Section 303(d)(1) of the CWA and EPA's implementing regulations require states and authorized tribes to identify and establish priority ranking for waters that do not, or are not expected to, achieve or maintain water quality standards. In accordance with this ranking, a TMDL for such waters must then be established. For purposes of determining impairment of a waterbody and whether to include it on section 303(d) lists, or in category 5 of the Integrated Report under sections 303(d) and 305(b)[15], states and authorized tribes must consider all existing and readily available data and information (see 40 CFR 130.7).

States and authorized tribes determine attainment of water quality standards by comparing ambient concentrations to the numeric and narrative AWQC (40 CFR 130.7 (b)(3)). Where a fish tissue criterion has been adopted, states and tribes should consider observed concentrations in fish tissue in comparison to the criterion. Where a water column translation of the fish tissue criterion has been developed and is adopted as part of the state's or tribe's water quality standards, states and tribes should consider ambient water concentrations in comparison to the translation.

For assessment of concentrations in fish tissue, resources may typically be unavailable to collect an adequate number of replicate composite samples to support rigorous statistical testing, especially where it is desirable to evaluate each individual target species separately. In these situations, states should make direct comparisons between composite sample concentrations and the criterion, as each composite effectively represents the average concentration observed in several fish.

Statistical tests for comparing the average concentration from multiple replicate composite samples to the criterion may be conducted where a sufficient number of replicates have been collected. EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories,* volume 1 (USEPA 2000c), at section 6.1.2.7.2, recommends using the t-test to determine whether the mean concentration of mercury in composite fish tissue samples exceeds the screening value. This test involves a statistical comparison of the mean of all fish tissue data to the criterion. States and authorized tribes can evaluate whether the t-test statistic of the mean exceeds the water quality standards. This procedure could also be used to determine impairment, provided it is consistent with a state's water quality standards. States and authorized tribes might also want to consider the guidance in appendixes C and D of the *Consolidated Assessment and Listing Methodology*: *Toward a Compendium of Best Practices* (USEPA 2002e). Ultimately, the method that states and authorized tribes choose depends on how they express their water quality standards and apply their water quality assessment methodology.

4.3.1 How should nondetections be addressed?

When computing the mean of mercury in fish tissue, a state or authorized tribe might encounter a data set that includes analyzed values below the detection level. EPA does

[15] See EPA's guidance for Integrated Reports described at http://www.epa.gov/owow/tmdl/2006IRG/.

not expect this to occur frequently for two reasons. First, if the samples are physically composited (see section 4.2.2.), the composite itself provides the average, and there is no need to mathematically compute an average. Second, the newer analytical methods 1630 and 1631 can quantify mercury at 0.002 mg/kg, which should be lower than the observed mercury in most fish tissue samples being analyzed.

If, however, a state or authorized tribe is mathematically computing an average of a data set that includes several values below the detection level, the water quality standards and/or assessment methodology should discuss how it will evaluate these values. The convention recommended in EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories,* volume 1, at section 9.1.2, is to use one-half of the method detection limit for nondetects in calculating mean values (USEPA 2000c). The guidance also recommends that measurements that fall between the method detection limit and the method quantitation limit be assigned a value of the detection limit plus one-half the difference between the detection limit and the quantitation limit. EPA notes, however, that these conventions provide a biased estimate of the average concentration (Gilbert 1987) and, where the computed average is close to the criterion, might suggest an impairment when one does not exist or, conversely, suggest no impairment when one does exist.

States or authorized tribes can calculate the average of a data set that includes values below the detection level using other statistical methods (e.g., sample median and trimmed means) (Gilbert 1987). EPA has published a review of several methods and analyzed the potential bias each can introduce into the calculation of the mean (USEPA 2001h).

One approach that a state or authorized tribe could take is to conduct a sensitivity analysis to ascertain the consequence of what value is used to quantify samples below the detection level. In a sensitivity analysis, the state or authorized tribe would compute the mean concentration by first using the value of the detection level to quantify samples below the detection level and then using a zero value for samples below the detection level. If both calculated means are above or below the criterion, it is clear that the choice of how to quantify samples below the detection level does not affect the decision. However, if one calculated mean is below the criterion and the other is above, it is clear that the choice of how to quantify samples below the detection level does affect the decision, and a more sophisticated approach such as the ones in *Robust Estimation of Mean and Variance Using Environmental Data Sets with Below Detection Limit Observations* (USEPA 2001h) should be used.

All methods have advantages and disadvantages. A state or authorized tribe should understand the consequences of which method it uses, especially if the choice makes a difference as to whether a waterbody is considered impaired or not. Furthermore, a state or authorized tribe should be clear about which approach it used. Again, the selected methodology must be consistent with the state's water quality standards and their published assessment method.

4.3.2 How should data be averaged across trophic levels?

If target populations consume fish from different trophic levels, the state or authorized tribe should consider factoring the consumption by trophic level when computing the average methylmercury concentration in fish tissue. To take this approach, the state or authorized tribe would need some knowledge of the fish species consumed by the general population so that the state or authorized tribe could perform the calculation using only data for fish species that people commonly eat. (For guidance on gathering this information, see section 3.2.1.2.) States and authorized tribes can choose to apportion all the fish consumption, either a value reflecting the local area or the 17.5 grams fish/day national value for freshwater and estuarine fish if a local value is not available, to the highest trophic level consumed for their population or modify it using local or regional consumption patterns. Fish creel data from state fisheries departments are one reasonable basis for estimating types and amounts of fish consumed from a given waterbody. The state or authorized tribe must decide which approach to use.

As an example of how to use consumption information to calculate a weighted average fish tissue concentration, see table 5 and equation 4.

Table 5. Example data for calculating a weighted average fish tissue value

Species	Trophic level	Number of samples	Geometric mean methylmercury concentration (mg/kg)
Cutthroat trout	3	30	0.07
Kokanee	3	30	0.12
Yellow perch	3	30	0.19
Smallmouth bass	4	95	0.45
Pumpkinseed	3	30	0.13
Brown bullhead	3	13	0.39
Signal crayfish	2	45	0.07

These concentrations are used to compute a weighted average of tissue methylmercury concentrations for comparison to the 0.3 mg/kg criterion. All fish measured are classified as trophic level 3 except signal crayfish, which are trophic level 2, and smallmouth bass, which are trophic level 4. The mean methylmercury concentration in trophic level 3 fish in this example is 0.15 mg/kg. This is calculated by weighting the geometric mean methylmercury concentration in each trophic level 3 species by the number of samples of each of the trophic level 3 species, and then averaging the weighted geometric means. Had the concentrations been averaged without weighting for the number of samples, the average concentration would have been 0.18 mg/kg and would have given more weight to the methylmercury concentrations in brown bullhead than to the concentrations in the other species. (Note that this averaging approach does not consider that the trophic level 3 fish in this sample are of different sizes, or that some fish might be consumed more or less frequently than is represented by the number of samples.) Equation 4 shows how the total (all trophic levels) weighted concentration is calculated using the 0.15 mg/kg value as representative of trophic level 3 fish and the default consumption for each trophic level:

$$C_{avg} = \frac{3.8 * C_2 + 8.0 * C_3 + 5.7 * C_4}{(3.8 + 8.0 + 5.7)} = 0.23 \text{ mg/kg} \qquad \text{(Equation 4)}$$

Where:

C_2 = average mercury concentration for trophic level 2
C_3 = average mercury concentration for trophic level 3
C_4 = average mercury concentration for trophic level 4

This calculation is based on apportioning the 17.5 grams/day national default consumption rate for freshwater and estuarine fish and shellfish by trophic level (5.7 grams/day of trophic level 4 fish, 8.0 grams/day of trophic level 3 fish, and 3.8 grams/day of trophic level 2 fish[16]). As noted throughout this document, however, the consumption pattern of the target population should be used if available.

If fish tissue concentration data from a trophic level are missing, one would drop the consumption factor for that trophic level from both the numerator and denominator. For example, if there were no tissue concentration data for trophic level 2 fish in the previous example, equation 5 shows the revised calculation:

$$C_{avg} = \frac{8.0 * C_3 + 5.7 * C_4}{(8.0 + 5.7)} = 0.27 \text{ mg/kg} \qquad \text{(Equation 5)}$$

This revised calculation preserves the relative contribution of each trophic level to consumption patterns. This approach (i.e., dropping a trophic level from Equation 4), however, should not be used if there are no fish tissue data for trophic level 4 fish. Since level 4 fish are the type of fish that people most often consume, dropping trophic level 4 from Equation 4 may result in underprotection if trophic level 4 fish are actually consumed at the site. Instead, the state or authorized tribe should collect information to determine the consumption rate for fish in trophic level 4. If the state or authorized tribe finds that no trophic level 4 fish are eaten, the state or tribe may drop trophic level 4 from Equation 4.

If the state or authorized tribe has developed a site-specific fish consumption rate for the criterion, the state or authorized tribe should incorporate this site-specific rate into equation 4. In this case, the state or authorized tribe would replace the values of 5.7 grams/day of trophic level 4 fish, 8.0 grams/day of trophic level 3 fish, and 3.8 grams/day of trophic level 2 fish with the values that the state or authorized tribe developed.

As an alternative approach, states or authorized tribes might wish to translate fish tissue sample data to a standard size, length, or species of fish that is more commonly consumed or is representative of the risk considerations of the state. Regression models

[16] The values for each trophic level are the same as those discussed in section 3.2.1.2; they can be found in *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (USEPA 2000b).

have been developed for this purpose (Rae 1997; Wente 2003). An inherent assumption is that concentrations will differ between samples of two different species/lengths/sample cuts in a fixed equilibrium distribution relationship among all fish. If this relationship is known and at least one tissue sample concentration is measured from a species/length/sample cut that is accurately described by this relationship, fish consumption risk analyses could be performed for any species/lengths/sample cuts described by the relationship at this site.

Such regression models may include independent variables that account for species, aquatic environment (e.g., lotic vs. lentic, or other waterbody characteristics), sample cut (e.g., whole fish, skin-on fillet, skinless fillet), specific characteristics (e.g., age and retention time) of reservoirs, temporal trends, and fish length. The response variable is fish mercury concentration, which is typically assumed to be lognormally distributed. In a graphic sense, the model shows the covariance of each combination of nominal scale variables (e.g., whole fish, lentic waterbody) with fish length, with the slope representing the concentration/length ratio. Regression slopes can vary from lake to lake, resulting in models that inappropriately retain some fish size covariation (Soneston 2003).

EPA used the USGS National Descriptive Model for Mercury in Fish Tissue in various analyses (USEPA 2005a). This model is a statistical model related to covariance, and it allows the prediction of methylmercury concentrations in different species, cuts, and lengths of fish for sampling events, even when those species, lengths, or cuts of fish were not sampled during those sampling events. The model can also prove useful to states and authorized tribes in averaging fish tissue across trophic levels.

4.3.3 How should older data be assessed?

For purposes of determining waterbody impairment and inclusion on section 303(d) lists or category 5 of the Integrated Report, states and authorized tribes must consider all existing and readily available water quality-related data and information (40 CFR 130.7). Ideally, a state or authorized tribe would have collected fish tissue information within the past five years, as recommended in section 4.2.4. Such recent information might not always be available, however, and the available data often includes mercury samples collected and analyzed several years in the past. When the state or authorized tribe evaluates this information, it should take into account the reliability of this information and its compliance with applicable data collection or quality assurance/quality control program requirements.

4.3.4 How should fish consumption advisories be used to determine impairment?

On October 24, 2000, EPA issued guidance on the use of fish advisories in CWA section 303(d) listing and 305(b) reporting decisions (USEPA 2000j). This guidance notes EPA's general interpretation that fish consumption advisories on the basis of waterbody-specific information can demonstrate impairment of CWA section 101(a) "fishable" uses. Although the CWA does not explicitly direct the use of fish consumption advisories to determine attainment of water quality standards, states and authorized tribes must consider all existing and readily available data and information to identify impaired waterbodies on their section 303(d) lists. For purposes of determining waterbody

impairment and inclusion on a section 303(d) list or in an Integrated Report, EPA considers a fish consumption advisory and the supporting data existing and readily available data and information.

When listing waters under CWA sections 303(d) or in the Integrated Reporting format on the basis of a fish advisory for a migratory fish species, the state or authorized tribe should include the waters the migratory fish are known to inhabit because those are the waters where the fish potentially would be exposed to mercury. In addition, a state or authorized tribe has the discretion to include any other water having a fish consumption advisory as impaired on its section 303(d) list if the state or authorized tribe believes inclusion is appropriate.

A state or authorized tribe should include on its section 303(d) list or in its Integrated Report, at a minimum, those waters for which waterbody-specific data that were the basis of a fish or shellfish consumption advisory demonstrate nonattainment of water quality standards. EPA believes that a fish or shellfish advisory demonstrates nonattainment when the advisory is based on tissue data, the data are from the specific waterbody in question, and the risk assessment parameters of the advisory or classification are cumulatively equal to or less protective than those in the water quality standards.[17]

For example, consider a state or authorized tribe that bases its water quality criterion on eating two fish meals a month. If the state or authorized tribe finds fish tissue information showing that the level of mercury is at a level where it decides to advise people not to eat more than one fish meal a month and all other risk assessment factors are the same, the advisory also may serve to demonstrate a water quality standard exceedance and that the waterbody should be placed on the 303(d) list or in the Integrated Report. In contrast, if this same state or authorized tribe finds the level of mercury in fish in another waterbody is at a level at which it would advise people to eat no more than three meals a month, and all other risk assessment factors are the same, the advisory is not necessarily the same as an impairment and the waterbody might not need to be listed.

[17] The October 2000 EPA guidance assumes that the fish tissue monitoring that supports the advisory is sufficiently robust to provide a representative sample of mercury in fish tissue. EPA's fish tissue guidance (USEPA 2000c) provides recommendations on how public health officials can collect sufficient information about contaminants in fish.

5 Other Water Quality Standards Issues

5.1 How does this criterion relate to the criteria published as part of the Great Lakes Initiative?

The 2001 recommended methylmercury fish tissue criterion and EPA's recommendations for its implementation do not supersede the requirements applicable to the Great Lakes at 40 CFR part 132. The Great Lakes regulatory requirements, known as the Great Lakes Initiative, or GLI, apply to all the streams, rivers, lakes and other bodies of water within the U.S. portion of the Great Lakes drainage basin. For those waters, a state or authorized tribe must adopt requirements (including water quality criteria) that are consistent with (as protective as) regulations EPA promulgated on March 23, 1995. See 60 FR 15366 and 40 CFR 132.1(b) and 132.4.

Under these regulations, if a state or authorized tribe adopts a fish tissue residue methylmercury criterion for the protection of human health, EPA, in its review of the new state or tribal criterion, must determine whether it is as protective as the mercury water column criterion for human health protection promulgated at 40 CFR 132.6, table 3, and whether all implementation procedures are as protective as the implementation procedure. See 40 CFR 132.5(g).

As described below, it is unlikely that adoption of EPA's 2001 recommended methylmercury fish tissue-based criterion of 0.3 mg/kg to protect human health would result in TMDLs or NPDES permit limits addressing mercury impairments in the Great Lakes basin less stringent than those that would be required under the existing GLI regulations. The reasons for this include the following:

- The GLI requires all states and authorized tribes to adopt the GLI wildlife water column criterion. The GLI wildlife criterion has a significantly more stringent methylmercury fish tissue basis than either the 2001 criterion or the GLI human health criteria and would therefore likely be the controlling basis for any TMDLs or NPDES permit limits addressing mercury pollution.

- Even if that were not the case, the 2001 criterion is more stringent than the methylmercury fish tissue basis for the GLI human health water column criteria for mercury.

Furthermore, using the 2001 fish tissue criterion would not necessarily result in lower transaction costs than the GLI. The GLI implementation procedures (e.g., the mixing zone prohibition, 40 CFR part 132, appendix F, procedure 3) require the use of water column criteria, so the 2001 methylmercury fish tissue criterion would need to be converted to a water column criterion following the GLI site-specific modification procedures before it could be approved by EPA and implemented using other GLI implementation procedures.

The human health criterion for mercury established by the GLI is 3.1 ng/L[18]. This water column criterion for mercury is equivalent to a methylmercury fish tissue residue value of 0.35 mg/kg using the Great Lakes-specific BAFs for mercury—27,900 L/kg for trophic level 3 and 140,000 L/kg for trophic level 4—as well as other Great Lakes-specific information (USEPA 1995c). Because EPA's 2001 methylmercury criterion (0.30 mg/kg) is more stringent than the GLI fish tissue residue value, the 2001 criterion would result in more stringent water column concentrations than the GLI human health criteria unless other, site-specific factors were significantly less stringent. This could occur, for example, if a state or authorized tribe applied the GLI site-specific modification procedures and found that the current, local BAF is significantly lower than the one used to develop the GLI criterion. In that case, the state or tribe could use the lower, local BAF and EPA's recommended fish tissue-based criterion to recalculate the water column criterion using the GLI site-specific modification procedures and submit it to EPA for review and approval. If the site-specific water column criterion was approved by EPA, the state or authorized tribe could use it and the GLI implementation procedures to develop TMDLs and NPDES permits.

Finally, as indicated above, if a state or authorized tribe were to adopt the 2001 human health criterion in the Great Lakes basin, this action most likely would not result in a change to TMDLs or NPDES permits. The GLI also includes a 1.3 ng/L criterion for the protection of wildlife, and in most instances, this more stringent criterion will drive the calculation of TMDLs or NPDES permit limits.

5.2 What is the applicable flow for a water column-based criterion?

If a state or authorized tribe adopts new or revised methylmercury criteria based on a water column value rather than a fish tissue value, it should consider the dilution flow specified in the state's or tribe's water quality standards when applying the new mercury criterion. Where a state's or authorized tribe's water quality standards do not specify the appropriate flow for use with the mercury criterion, EPA recommends using a harmonic mean flow. EPA used this flow for application of the human health criteria for mercury in the Great Lakes (40 CFR part 132). EPA also used this flow for application to the human health criteria in the National Toxics Rule (40 CFR 131.36) and the California Toxics Rule, or CTR (40 CFR 131.38). The Agency considers this flow to better reflect the exposure of fish to mercury. The technical means for calculating a harmonic mean is described in section 4.6.2.2.a of the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991).

[18] EPA promulgated the GLI human health criteria of 1.8 ng/L in 40 CFR part 132, table 3, in March 1995, based on an RfD of 0.06 µg/kg/d. In May 1995 EPA revised the RfD to the current 0.1 µg/kg/d, which would result in GLI criteria of 3.1 ng/L. In October 1996 EPA issued guidance indicating that the 3.1 ng/L criteria were considered as protective as the promulgated 1.8 ng/L.

5.3 How are mixing zones used for mercury?

5.3.1 What is a mixing zone?

A mixing zone is the area beyond a point source outfall (e.g., a pipe) in which concentrations of a pollutant from a wastewater discharge mix with receiving waters. Under 40 CFR 131.13, states and authorized tribes may, at their discretion, include mixing zones in their water quality standards. Within a mixing zone, the water may be allowed to exceed the concentration-based water quality criterion for a given pollutant. The theory of allowing mixing zones is based on the belief that by mixing with the receiving waters within the zone, the concentration of the pollutant being discharged will become sufficiently diluted to meet applicable water quality criteria beyond the borders of that zone and fully protect the designated use of the waterbody as a whole. More information on mixing zones is available in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991) and the *Water Quality Standards Handbook* (USEPA 1994). States and authorized tribes often authorize mixing zone provisions and methodologies for calculating mixing zones for later application to NPDES point source discharge points.

5.3.2 How does a mixing zone apply for the fish tissue-based methylmercury criterion?

The question of mixing zones is not relevant when applying the fish tissue-based criterion, which refers to the level of mercury found in fish flesh. The criterion is fish tissue-based, not water column-based. The criterion reflects the exposure of the fish to mercury in the water column and food over the life of the fish, and thus it reflects an integration of the exposure over time and over spatially varying water column concentrations. The total load of mercury in the waterbody, taking into account the methylation rate and bioaccumulation of mercury in fish, affects the level of methylmercury in the fish tissue.

Some states and authorized tribes, however, might choose to adopt a water column criterion based on the fish tissue criterion and thus have a criterion for which a mixing zone might apply. In this situation, a state or authorized tribe should follow its existing procedures for determining appropriate mixing zones. EPA advises caution in the use of mixing zones for mercury. While fish tissue contamination tends to be a far field problem affecting entire waterbodies, rather than a narrow scale problem confined to mixing zones, EPA's guidance recommends restricting or eliminating mixing zones for bioaccumulative pollutants such as mercury so that they do not encroach on areas often used for fish harvesting (particularly for stationary species such as shellfish). Restriction or elimination might also be used to compensate for uncertainties regarding the ability of aquatic life or the aquatic system to tolerate excursions above the criteria, uncertainties inherent in estimating bioaccumulation, or uncertainties in the assimilative capacity of the waterbody. See the *Water Quality Standards Handbook*, section 5.1.3 (USEPA 1994).

5.3.3 Does the guidance for the fish tissue-based criterion change the Great Lakes Initiative approach to mixing zones for bioaccumulative pollutants?

To reduce the adverse effects from bioaccumulative chemicals of concern (BCCs) in the Great Lakes, on November 13, 2000, EPA promulgated an amendment to the Final Water Quality Guidance for the Great Lakes System (40 CFR part 132, appendix F, procedure 3). The regulation requires prohibition of mixing zones for bioaccumulative pollutants from existing discharges in the Great Lakes to the greatest extent technically and economically feasible. Specifically, existing discharges of BCCs are not eligible for a mixing zone after November 10, 2010 (although under certain circumstances mixing zones may be authorized). For new BCC discharges, the rule essentially prohibits mixing zones of bioaccumulatives immediately upon commencing discharge. This means that NPDES permit limitations for mercury discharged to the Great Lakes system must not exceed the water quality criterion. This also limits the flexibility that states and authorized tribes would otherwise have to adjust point source controls on the basis of nonpoint source contributions.

EPA reiterates that the new methylmercury criterion, and EPA's recommendations on its implementation, does not supersede the requirements applicable to the Great Lakes at 40 CFR part 132. The criteria for the Great Lakes are water column-based, and therefore they can be applied as an effluent requirement at the end of a pipe. EPA continues to view the prohibition of a mixing zone for mercury and other bioaccumulative pollutants for the Great Lakes as appropriately protective for water column-based water quality criteria applied to these waters.

If a state or authorized tribe adopts the new fish tissue-based criterion for a Great Lake or tributary to the Great Lake, the state or tribe would do this using the site-specific modification procedures of part 132 (see section 5.1 of this document). The state or tribe would have determined a site-specific BAF in this process and therefore would have the means for calculating a water column-based criterion. Under the part 132 regulations, EPA in its review of the new state or tribal implementation procedures would determine whether they are as protective as the Great Lakes procedures for human health protection (40 CFR 132.5(g)(3)). Specifically, EPA would determine whether the implementation procedures are as protective as applying the table 3 (in 40 CFR part 132) criterion for protection of human health without a mixing zone, consistent with the prohibition on mixing zones for BCCs (40 CFR 132, appendix F.3.c.). In addition, if the state's or tribe's implementation procedures involve converting the fish tissue-based criterion into an equivalent water column-based number, the mixing zone prohibition requirements of 40 CFR part 132 still apply.

5.4 How are fish consumption advisories and water quality standards harmonized?

5.4.1 What is the role of state and tribal Fish Advisory Programs?

States and authorized tribes have the primary responsibility of estimating the human health risks from the consumption of chemically contaminated, noncommercially caught finfish and shellfish (e.g., where water quality standards are not attained). They do this by

issuing consumption advisories for the general population, including recreational and subsistence fishers, and for sensitive subpopulations (such as pregnant women, nursing mothers and their infants, and children). These advisories are nonregulatory and inform the public that high concentrations of chemical contaminants, such as mercury, have been found in local fish. The advisories recommend either limiting or avoiding consumption of certain fish from specific waterbodies or, in some cases, from specific waterbody types (e.g., all lakes). In the case of mercury, many states and authorized tribes have calculated a consumption limit to determine the maximum number of fish meals per unit of time that the target population can safely eat from a defined area.

5.4.2 How are consumption limits for consumption advisories determined?

EPA has published guidance for states and authorized tribes to use in deriving their recommended fish consumption limits, titled *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*, volumes 1 and 2 (USEPA 2000c, 2000f). This guidance describes the two main equations necessary to derive meal consumption limits on the basis of the methylmercury RfD. Basically, the first equation is used to calculate the daily consumption limits of grams of edible fish (in g/day); a second equation is used to convert daily consumption limits to meal consumption limits over a specified period of time. Variables used to calculate the advisory consumption limits include fish meal size and frequency, consumer body weight, contaminant concentration in the fish tissue, the time-averaging period selected, and the reference dose for methylmercury health endpoints.

In the absence of site-specific fish consumption data, EPA recommends using a fish consumption rate of 17.5 grams/day of fish (uncooked) eaten from the local water as a screening level. This consumption rate equates to approximately two 8-ounce meals per month. Using this consumption rate, and assuming a 70-kg body weight (the same assumption used to derive the methylmercury criterion), the concentration of methylmercury in locally caught fish that would result in exposures that do not exceed the RfD (0.0001 mg/kg-day) is about 0.4 mg/kg and lower ([0.001 mg/kg-day x 70 kg bw]/0.0175 kg fish/day). This means that you can safely consume approximately two 8-ounce meals per month of locally-caught fish, where concentrations in such fish are 0.4 mg/kg or lower, and where there is no additional exposure (i.e., consumption of store bought or marine-caught fish).

Advisory limits can differ from one state or tribe to another. This inconsistency is due to a host of reasons, some of which speak to the flexibility states and authorized tribes have to use different assumptions (chemical concentrations, exposure scenarios and assumptions) to determine the necessity for issuing an advisory. The nonregulatory nature of fish advisories allows such agencies to choose the risk level deemed appropriate to more accurately reflect local fishing habits or to safely protect certain subpopulations (e.g., subsistence fishers).

5.4.3 How does the criterion differ from the advisory level?

Although EPA derived its recommended screening value for a fish advisory limit for mercury and human health methylmercury criterion from virtually identical

methodologies, it is important to clarify the distinctions between the two values. They are consistently derived, but because each value differs in purpose and scope, they diverge at the risk management level. Fish advisories are intended to inform the public about how much consumers should limit their intake of individual fish species from certain waterbodies. Alternatively, the Agency uses its methylmercury criterion, like other CWA section 304(a) criteria, as a basis for both nonregulatory and regulatory decisions. The criterion can serve as guidance to states and authorized tribes for use in establishing water quality standards, which, in turn, serve as a benchmark for attainment, compliance, and enforcement purposes.

The main risk management difference between EPA's recommended methylmercury water quality criterion and the fish advisory default screening value for mercury is that the criterion includes an RSC[19] and the screening value does not. In deriving the criterion, EPA assumed an RSC value of 2.7×10^{-5} mg/kg-day to account for exposure from marine fish and shellfish. The guidance for setting fish consumption limits also discusses using an RSC to account for exposures other than those from noncommercially caught fish, but the guidance may be applied without using an RSC. The RSC guidance in the 2000 Human Health Methodology (USEPA 2000b) provides more detail and specific quantitative procedures to account for other exposure pathways. EPA's advisory guidance recommends that states and authorized tribes consider using an RSC to account for exposure from other sources of pollutants (such as mercury) when deriving a fish consumption limit and setting a fish advisory for mercury.

5.4.4 What if there is a difference between assessing criterion attainment and issuance of a fish consumption advisory?

In many states and authorized tribes, numeric water quality criteria and fish and shellfish consumption limits differ because of inherent differences in the technical and risk assumptions used to develop them. As discussed in section 4.2, EPA considers a fish consumption advisory to demonstrate nonattainment of water quality standards when the advisory is based on tissue data, the data are from the specific waterbody in question, and the risk assessment parameters of the advisory or classification are cumulatively equal to or less protective than those in the water quality standards. Two situations in which the presence of an advisory might not imply an exceedance of the water quality standard (USEPA 2005f) are as follows:

- *Statewide or regional advisory.* States have issued statewide or regional warnings regarding fish tissue contaminated with mercury, on the basis of data from a subset of waterbodies, as a precautionary measure. In these cases, fish consumption advisories might not demonstrate that a CWA section 101(a) "fishable" use is not being attained in an individual waterbody and might not be appropriate for determining attainment based on exceedance of water quality criteria.

- *Local advisory.* States have issued local advisories using a higher fish consumption value than that which they use in establishing water quality criteria for protection of human health. Again, in this case the fish consumption advisories might not

[19] See discussion on the RSC in section 3.1.2.3 and 3.2.1.1.

demonstrate that a section 101(a) "fishable" use is not being attained in an individual waterbody and might not be as appropriate as comparison with water quality criteria as a basis for determining attainment.

For example, consider a state or authorized tribe that adopts EPA's methylmercury criterion of 0.3 mg/kg, which is based on eating approximately two 8-ounce fish meals a month. If the state or authorized tribe finds that a waterbody has fish with a mercury level of 0.2 mg/kg, this water would not be exceeding the water quality criterion. Yet, this mercury concentration is sufficient for the state or authorized tribe to issue a fish consumption advisory recommending that people eat no more than four 8-ounce meals a month. In this case, because the fish consumption advisory uses a higher fish consumption value than that used to develop the water quality criterion (and the fish tissue concentration does not exceed the criterion), consistent with EPA's 2000 guidance, the waterbody is not necessarily impaired (USEPA 2005f).

In the case where a local advisory is based on a higher fish consumption value which is considered representative of local consumption, the state or authorized tribe should consider whether it should adopt a site-specific criterion for the waterbody. A local advisory generally reflects actual contaminant monitoring data and may reflect local fish consumption patterns, and it might identify more representative fish species. The information gathered in developing the advisory might provide valid grounds for revising the level of a numeric water quality criterion to match that of the advisory.

5.4.5 Should existing advisories be revised to reflect the new criterion?

Although EPA's screening value for fish advisory studies and the recommended 304(a) criterion for mercury are based on similar methodologies and are intended to protect people who consume mercury-contaminated fish, they do not necessarily have to be the same value. As explained above, each limit is predicated on different risk-management decisions and thus incorporates different assumptions. However, recognizing that differences in consumption advisories and waterbody impairment for the methylmercury criterion can be confusing to the public, states may wish to consider explaining the differences in the information that these two types of listings provide. Likewise, there is merit in adopting a site-specific methylmercury criterion on the basis of a local fish advisory, if that advisory is supported by sufficient fish tissue and fish consumption data that are representative and of acceptable quality. Alternatively, states may wish to consider issuing a fish consumption advisory, where appropriate, if a waterbody is considered impaired based on the methylmercury 304(a) criterion and no such consumption warning exists.

5.4.6 What federal agencies issue advisories?

The Food and Drug Administration's (FDA's) mission is to protect the public health with respect to levels of chemical contaminants in all foods, including fish and shellfish, sold in interstate commerce. To address the levels of contamination in foods, FDA has developed both action levels and tolerances. An action level is an administrative guideline that defines the extent of contamination at which FDA may regard food as adulterated and represents the limit at or above which FDA may take legal action to

remove products from the marketplace. It is important to emphasize that FDA's jurisdiction in setting action levels is limited to contaminants in food shipped and marketed in interstate commerce; it does not include food that is caught locally by recreational or subsistence fishers. FDA also issues fish consumption advice on fish and shellfish sold in commerce in cases where contaminants have been detected at levels that may pose public health concerns for some consumers.

As described in section 5.4.2, EPA provides guidance to states, tribes, local governments and others on scientifically sound, cost-effective methods for developing and managing noncommercial fish consumption advisories on local waters. See EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000c, 2000f). In addition, EPA has issued advice under CWA section 104(b)(6) to supplement state and/or tribal advice on local waters.

In March 2004, EPA and FDA issued a joint national fish advisory about mercury in fish and shellfish. The purpose of the advisory is to inform women who may become pregnant, pregnant women, nursing mothers, and parents of young children how to get the positive health benefits from eating fish and be confident that they have reduced their exposure to the harmful effects of mercury. The 2004 advisory lists fish sold in interstate commerce that are known to be high in mercury as well as fish that that are low in mercury to help consumers choose the most appropriate fish. The advisory also contains recommendations about eating fish harvested from local waters where no advice has been provided by state or tribal authorities. Information regarding the national advisory is at http://www.epa.gov/waterscience/fish/.

5.4.7 How is the criterion related to FDA action levels?

The current FDA action level for mercury in fish is 1 mg/kg. Generally, an action level is different from a fish advisory limit—and even more different from a CWA section 304(a) criterion. FDA action levels are intended for members of the general population who consume fish and shellfish typically purchased in supermarkets or fish markets that sell products harvested from a wide geographic area. The underlying assumptions used in the FDA methodology were never intended, as local fish advisories are, to be protective of recreational, tribal, ethnic, and subsistence fishers who typically consume fish and shellfish from the same local waterbodies repeatedly over many years. EPA and FDA have agreed that the use of FDA action levels for the purposes of making local advisory determinations is inappropriate. Furthermore, it is EPA's belief that FDA action levels and tolerances should not be used as a basis for establishing a state's or tribe's methylmercury criterion.

5.5 What public participation is recommended for implementing the methylmercury criterion?

By applicable regulations, water quality standards, TMDL, and NPDES permit decisions require public notice and the opportunity for the public to comment on tentative decisions. Some public interest groups might have an interest in decisions related to mercury, especially in areas where local citizens rely heavily on locally caught fish as a food source. EPA recommends that organizations with an interest in environmental justice issues be included in the public notice.

6 TMDLs

6.1 What is a TMDL?

CWA section 303(d)(1) and EPA's implementing regulations require states and authorized tribes to identify and establish priority rankings for waters that do not, or are not expected to, achieve or maintain water quality standards with existing or anticipated required controls. This list is known as the state's or tribe's list of "impaired" waterbodies or 303(d) list. States and authorized tribes then must establish TMDLs for the impaired waterbodies.

A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL also allocates the pollutant loads among the contributing sources, both point and nonpoint. The TMDL calculation must include a margin of safety to take into account any uncertainty in the TMDL calculation and must account for seasonal variation in water quality. The current statutory and regulatory framework governing TMDLs includes CWA section 303(d) and the TMDL regulations published in 1985 at 40 CFR 130.2 and 130.7 and amended in 1992 (see 50 FR 1774 (Jan. 11, 1985); 57 FR 33040 (July 24, 1992)).

As of the 2008 303(d) listing cycle, 43 states and Puerto Rico reported at least one waterbody as impaired due to mercury, and more than 8,800 specific waterbodies were listed as impaired due to mercury, either solely or in combination with other pollutants. As mentioned previously in section 2.4, with the implementation of the new methylmercury fish tissue criterion, monitoring of previously unmonitored waterbodies, and use of more sensitive analytical methods, EPA expects that the number of waterbodies listed as impaired due to mercury might increase.

6.2 How have states and tribes approached mercury TMDLs?

Developing TMDLs for waters impaired by mercury raises a number of technical and policy issues. For example, air deposition is the predominant source of mercury to many waterbodies, especially in the eastern United States. The mercury deposited from air comes from local, regional, and international sources, and identifying how each of these sources contributes to the mercury load in the waterbody is challenging. In other waterbodies, significant loadings might come from other sources, such as past metal-mining activity or geologic sources. Frequently, states and authorized tribes do not have the authority to address all the sources that contribute mercury to their waterbodies and rely on efforts conducted under a variety of programs, such as regulations under the CAA, pollution prevention programs, and international efforts to reduce releases and emissions from mercury sources. States and EPA have found that, in many cases, it is important to coordinate closely with programs other than those under the CWA to address these mercury sources.

Given these challenges, EPA is working with states, tribes, and stakeholders to determine how best to use TMDLs and the 303(d) listing process to provide a basis for reducing mercury releases to water, including consideration of air deposition, to meet applicable

water quality standards and CWA goals. In areas where large numbers of waterbodies are impaired due to mercury derived from air deposition, some states have begun to explore ways to address mercury impairments efficiently, such as through development of TMDLs on various geographic scales. As of April 2010, mercury TMDLs have been approved for more than 6,700 waterbodies, including a "statewide" mercury TMDL in Minnesota and a multi-state mercury TMDL for the Northeast states (see below).

On March 8, 2007, EPA issued a memorandum describing a voluntary approach for listing waters impaired by atmospheric mercury under CWA section 303(d) and managing the development of mercury TMDLs. (USEPA 2007) (http://www.epa.gov/owow/tmdl/mercury5m/Mercury5m.pdf). EPA recommends this approach for states that have in place a comprehensive statewide mercury reduction program with elements recommended by EPA. These states may separate their waters impaired by mercury predominantly from atmospheric sources in a subcategory of their impaired waters list ("5m") and defer the development of TMDLs for those waters. A state using the 5m subcategory may continue to defer the development of mercury TMDLs where the state demonstrates continuing progress in reducing in-state mercury sources. Recommended elements of a mercury reduction program include identification of air and multimedia sources within a state and programs to address those sources; mercury reduction goals and target dates; multimedia monitoring; public reporting on the state's mercury reduction efforts; and multistate coordination. The 5m subcategory is intended to recognize states with comprehensive mercury programs and to allow states to focus on early implementation actions.

Because the 5m subcategory is focused primarily on waterbodies impaired by mercury from air deposition, EPA recommends that the 5m subcategory include waters where the proportion of mercury from air deposition is high compared to other mercury sources. In the 5m memorandum, EPA recommends that states describe how such waterbodies were identified. Such information will help determine whether the 5m approach is appropriate. EPA also believes that, as the relative contribution to a waterbody from sources other than air deposition increases, such as water point sources, it may be more appropriate to use the TMDL process to characterize and address those sources sooner, rather than deferring TMDL development. As stated in the 5m memorandum, states have the option to continue developing mercury TMDLs sooner, whether or not they place waterbodies in subcategory 5m.

On September 29, 2008, EPA issued a document titled *Elements of Mercury TMDLs Where Mercury Loadings Are Predominantly from Air Deposition*, to assist states, EPA regional staff, and other stakeholders in identifying approaches for the development of mercury TMDLs (USEPA 2008a). Compiled in a checklist format, approaches described in the document are drawn largely from approaches and best practices used in approved mercury TMDLs. The checklist summarizes considerations in addressing the required and recommended TMDL elements described in the *Guidelines for Reviewing TMDLs under Existing Regulations Issued in 1992* (USEPA 2002f) when developing mercury TMDLs on geographic scales ranging from waterbody-specific to multi-state.

While the checklist is based on existing guidance for reviewing TMDLs, this guidance document supplements the checklist by providing additional information and case studies on approaches that have been used in approved mercury TMDLs to date, and examples of

technical tools available to assist in mercury TMDL development. Technical tools available to assist in the development of mercury TMDLs include screening-level analyses of mercury loadings and sources using the Mercury Maps tool and more complex water and air models. Many of these tools are discussed in the sections below.

EPA recommends that states continue to develop TMDLs for mercury-impaired waters where appropriate, taking into account the considerations and approaches described in this guidance. States may also consider using the 5m subcategory for waters impaired by mercury predominantly from air deposition if the state has a comprehensive mercury reduction program as described in the 5m memorandum.

6.2.1 What geographic scales have been used for mercury TMDLs?

Many mercury TMDLs approved to date were developed on a waterbody-specific basis. They include some of the first approved mercury TMDLs, such as those developed for waterbodies in middle and south Georgia. Other examples include TMDLs developed for waterbodies in Louisiana, such as the Ouachita River, the Narraguinnup and McPhee reservoirs in Colorado, and Pena Blanca and Arivaca lakes in Arizona. Various aspects of these TMDLs are described further in appendix D.

In areas of the country where many waterbodies are listed as impaired due to mercury primarily from atmospheric sources, some states have begun to explore the development of mercury TMDLs on a watershed scale or on the basis of a large geographic area, such as a state or region. One example of a regional or grouped approach is the mercury TMDL for the Coastal Bays and Gulf Waters of Louisiana, approved in June 2005. The TMDL covers six segments of coastal Louisiana. Because of the large geographic extent of mercury in the coastal waters and the similar extent of mercury contributions from air deposition, the TMDL was developed on a watershed basis rather than waterbody by waterbody. The TMDL used air deposition modeling results from the Regional Modeling System for Aerosols and Deposition (REMSAD) to estimate wet and dry deposition of mercury for the six segments. The air deposition modeling results, in turn, were used to model runoff or nonpoint source mercury loadings. As described in the following section, mercury loadings can include direct deposition to waterbodies and deposition to the watershed that is subsequently transported to the waterbody via runoff and erosion. Additional information on this TMDL can be found on EPA's TMDL webpage at http://iaspub.epa.gov/tmdl/waters_list.tmdl_report?p_tmdl_id=11642.

A "statewide" mercury TMDL developed by Minnesota was approved by EPA on March 27, 2007. The TMDL report covers 998 mercury impairments and is the first approved mercury TMDL covering such a large number of waterbodies and large geographic area. (Note: Although called statewide, the TMDL does not cover all mercury-impaired waterbodies in the state.) Minnesota used a statewide approach because the predominant mercury source in those waterbodies—air deposition—is relatively uniform across the state. The final TMDL report includes two TMDLs—one for the northeast region of the state and the other for the southwest region of the state. Waterbodies were grouped into the two regions on the basis of differences in fish tissue concentrations, with higher fish mercury concentrations in the northeast region compared to the southwest region. The difference in mercury concentrations is thought to be due to the effect of land use and other factors on the methylation of mercury. For example, the

northeast region is dominated by wetlands, where mercury tends to be methylated more readily; the southwest is dominated by cultivated lands. A summary of the Minnesota mercury TMDL approach is provided in appendix D, and the allocation approach is described further below. The final TMDL and EPA decision document are at http://www.pca.state.mn.us/water/tmdl/tmdl-ercuryplan.html#approval.

On December 20, 2007, EPA approved the Northeast Regional Mercury TMDL covering waterbodies in Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont. In using a regional approach, the TMDL document provides aggregate wasteload allocations and load allocations for the region. The regional approach was based on an analysis of data showing similar levels of mercury in fish throughout waterbodies in the region, and the states' finding that air deposition is the predominant mercury source. The TMDL document focuses on waters impaired by mercury primarily from atmospheric sources; it excludes coastal and marine waters and a few areas of high localized deposition and high fish mercury levels. The number of individual waterbodies covered by the regional TMDL document amounts to over 5,300 (the specific number of waterbodies covered by the TMDL document vary from state to state and are cited in EPA's approval documents). The TMDL target is EPA's recommended fish tissue criterion of 0.3 ppm methylmercury for each of the states except for Connecticut and Maine, where the targets are 0.1 ppm and 0.2 ppm, respectively. The TMDL allocates approximately 2.0 percent of the loading capacity to point sources and 98 percent to nonpoint sources (predominantly atmospheric deposition). The TMDL assumes that most of the reductions would need to come from atmospheric sources. The Northeast Regional Mercury TMDL are at http://www.epa.gov/region1/eco/tmdl/assets/pdfs/ne/Northeast-Regional-Mercury-TMDL.pdf, and the EPA approval documents for each of the states are at http://www.epa.gov/region1/eco/tmdl/approved.html.

6.2.2 What are the considerations in developing mercury TMDLs?

A TMDL must identify the applicable water quality standards for each listed segment and identify the loading capacity of a water (40 CFR 130.2). In addition, a TMDL must allocate the pollutant loads among the sources, both point and nonpoint (40 CFR 130.2(i)). EPA guidance further notes that a TMDL should identify the pollutant sources, both point and nonpoint, including the location of the sources and quantity of the loading. Where feasible, states are encouraged to consider waterbodies affecting disadvantaged communities and tribal issuses in setting priorities for TMDL development. Some of the considerations in developing a mercury TMDL and approaches used in approved mercury TMDLs are described in more detail in the text below.

6.2.2.1 What are potential mercury sources to waterbodies?

An important step in TMDL development is an evaluation of the loadings from various sources. The potential sources of mercury to waterbodies include the following: (1) direct discharges of mercury from water point sources, including industrial dischargers and wastewater treatment plants; (2) atmospheric deposition, including direct deposition to the waterbody surface and deposition to the watershed, which subsequently is transported to the waterbody via runoff and erosion, including via stormwater; (3) runoff, ground water flow, acid mine drainage, and erosion from mining sites or mining wastes, and

other waste disposal sites such as landfills and land application units; (4) sediments, which might have mercury contamination or hot spots resulting from past discharges; and (5) "naturally occurring" mercury in soils and geologic materials. Sediments containing mercury from past discharges might continue to contribute mercury to the overlying waterbody. Further discussion of each of these types of sources follows.

Point sources. Point source discharges of mercury include POTWs, electric utilities, and other industrial facilities. Sources of data on point source discharges of mercury include the Permit Compliance System, as well as a study of domestic mercury sources by the Association of Metropolitan Sewerage Agencies (AMSA 2000), now called the National Association of Clean Water Agencies (NACWA). Without accurate discharge data, a sample of a representative portion of dischargers has been used in mercury TMDLs to estimate the mercury discharges from point sources. In addition, some point source dischargers, such as chlor-alkali plants and POTWs, might have permits requiring monitoring for mercury, although most dischargers, especially smaller dischargers, are not likely to have such monitoring requirements. NPDES-permitted stormwater sources might also include mercury discharges, which in turn might include mercury originating from atmospheric deposition.

Atmospheric deposition. Deposition of mercury from the air can be a significant source of mercury in many waterbodies. Some waterbodies have been identified as receiving as much as 99 percent of their total loading from atmospheric deposition, either directly or indirectly via runoff and erosion. (See Ochlockonee, Georgia, TMDL in appendix D.) The mercury in atmospheric deposition originates from anthropogenic sources, including U.S. and international sources, as well as natural sources. Examples of specific anthropogenic sources that emit mercury to the air include medical and municipal waste incinerators, electric utilities, chlor-alkali plants, and active metals mining, among others.

Mercury is emitted to the air in several chemical forms or species. Common measurements of mercury in air differentiate between reactive gaseous mercury (RGM), elemental mercury (Hg^0), and particulate mercury (Hg_p). Some chemical forms of mercury emissions to air deposit relatively close to their sources, while others are transported over longer distances and even globally. The mix of chemical forms or species emitted from a given source determines what fraction of the mercury from that source is depositing locally and what proportion is transported over longer distances, making the task of identifying sources of deposition to a waterbody challenging. At any given location, the mercury deposited from air can originate from several sources. Figure 3 depicts the current understanding of deposition from U.S. and international sources. It shows that in many parts of the United States, the source of deposited mercury is not a U.S. source.

Of the approved mercury TMDLs involving atmospheric loadings, most have characterized the contributions from air deposition in terms of total or aggregate loadings. Atmospheric mercury loadings include both direct deposition to the waterbody surface and indirect deposition to the watershed. Indirect deposition is that which is deposited to the watershed and then transported to the waterbody via runoff and erosion. Atmospheric mercury loadings include both wet and dry deposition of mercury.

It is important to use the most current information about deposition because U.S. mercury emissions into the air have decreased over time. Older data on deposition might not reflect current deposition conditions. For example, figure 4 depicts a summary of U.S. mercury air emissions between 1990 and 2005 and shows a 58 percent overall decrease.

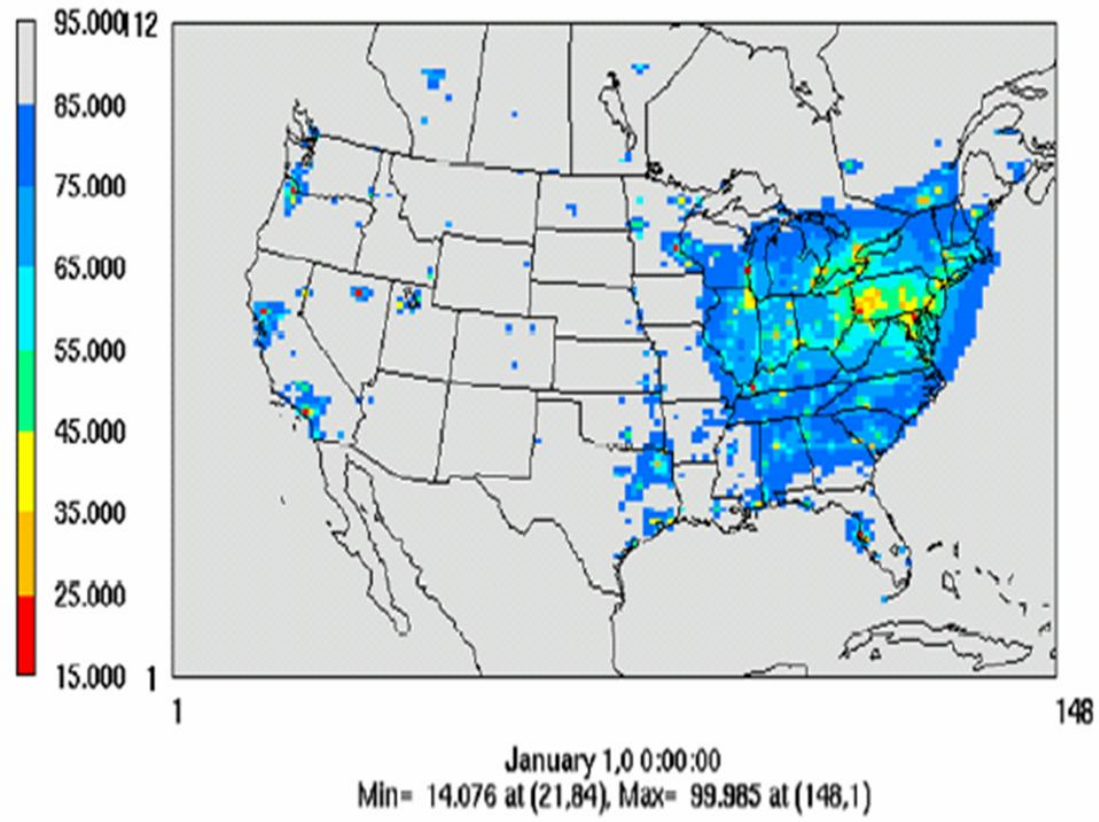
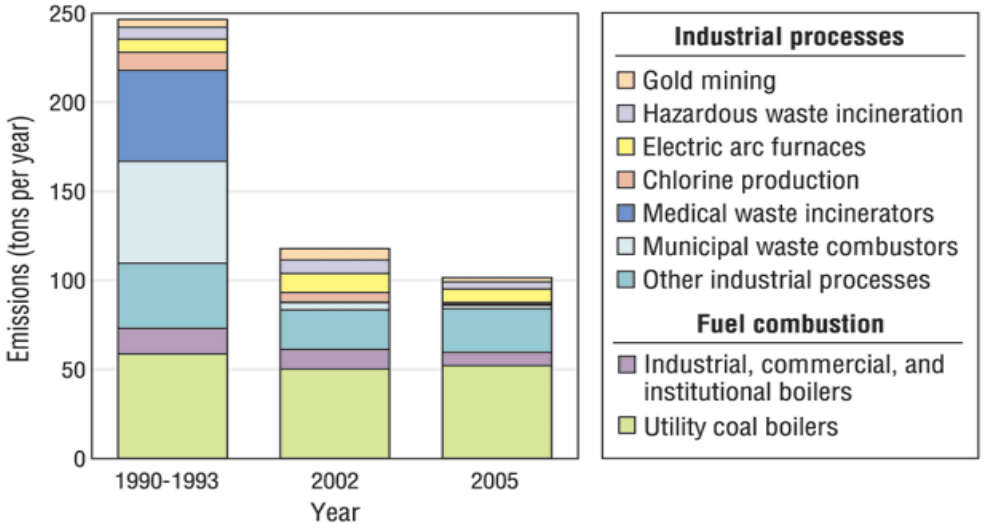


Figure 3. Percentage of total mercury deposition attributable to global sources (USEPA 2005a).

Exhibit 2-39. Mercury emissions in the U.S. by source category, 1990-1993, 2002, and 2005[a,b]



[a]1990-1993 is considered the baseline period for mercury emissions. The baseline period spans multiple years due to the availability of emissions data for various source categories. The data presented for the baseline period are annual emissions (tons per year) and are therefore comparable to the 2002 and 2005 data.

[b]Mercury emissions from mobile sources are not depicted because they have been estimated only for inventory years 2002 (0.8 tons) and 2005 (1.1 tons), not for the baseline period.

Data source: *U.S. EPA, 2009*

Figure 4. Trends in mercury air emissions between 1990 and 2005 (USEPA 2008b).

Additional decreases in mercury air emissions may have occurred since 2005 as the result of EPA's regulatory efforts under the CAA. At the same time, however, global emissions might have increased.

The 2005 National Emissions Inventory (NEI) is EPA's latest comprehensive national emission inventory. It contains emission measurements and estimates for 7 criteria pollutants and 188 hazardous air pollutants (HAPs). The NEI contains emissions for all major contributors to air pollution, including point sources (large industrial sources such as electric utilities and petroleum refineries), mobile sources (both onroad sources such as cars and trucks and nonroad engines such as those in construction equipment and agricultural equipment), and nonpoint sources (small stationary sources such as residential fuel use and various types of fires). The NEI includes emission estimates for the entire United States. For point sources, the NEI inventories emissions for each individual process at an industrial facility. For mobile and nonpoint sources, the NEI contains county-level emission estimates. The NEI is developed using the latest data and best estimation methods, including data from Continuous Emissions Monitors; data collected from all 50 states, as well as many local and tribal air agencies; and data generated using EPA's latest models such as the MOBILE and NONROAD models. More information on the 2005 NEI is at http://www.epa.gov/ttn/chief/net/2005inventory.html.

Some approved mercury TMDLs have identified the types or categories of sources likely to contribute to mercury deposition in a waterbody. An example of this type of source analysis is included in the Savannah River mercury TMDLs issued February 28, 2001, and a series of mercury TMDLs issued February 28, 2002, for a number of watersheds in middle and south Georgia (see http://gaepd.org/Documents/TMDL_page.html). These TMDLs included an analysis of the categories of air sources contributing deposition to the waterbodies and the reductions in loadings expected from controls in place when the TMDL was approved. To estimate the total contributions from air deposition, data from the Mercury Deposition Network (MDN) were used. Modelers also used the existing Regional Langrangian Model of Air Pollution (RELMAP) deposition results developed for the 1997 Mercury Report to Congress to estimate the relative contributions from local sources within a 100-kilometer airshed.

EPA has evaluated water and air deposition modeling tools as part of two mercury TMDL pilot projects in Wisconsin and Florida. In particular, the pilots examined approaches for combining the results of air deposition and water quality modeling, which in turn might be used in a TMDL context. In the Florida pilot, air modelers used a combination of modeling tools to predict the amount of mercury deposition to the study area from local sources in southern Florida. Using the Mercury Cycling Model, aquatic modelers then used results from the atmospheric modeling and other data to examine how mercury levels in fish might respond to reductions in deposition. The Florida pilot report is complete (see ftp://ftp.dep.state.fl.us/pub/labs/assessment/mercury/tmdlreport03.pdf) (Atkeson et al. 2002).

In the Wisconsin pilot project, EPA evaluated modeling tools such as the Regional Modeling System for Aerosols and Deposition (REMSAD) for identifying the sources or categories of sources contributing mercury deposition to a waterbody, as well as how to use the deposition results as input to aquatic models, similar to the approach used in the Florida pilot. REMSAD is a three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations (ICF International 2006). REMSAD simulates both wet and dry deposition of mercury. (See appendix E for further information on REMSAD.) In the Wisconsin pilot, the results of the air deposition modeling were used as input to the Mercury Cycling Model to examine how mercury levels in fish might respond to potential changes in deposition.

Other TMDLs in which the results of REMSAD modeling were used include the mercury TMDL for the Coastal Bays and Gulf Waters of Louisiana approved in 2005. The results of earlier air modeling for the *Mercury Study Report to Congress* were used in the mercury TMDLs for middle and south Georgia approved in 2002 (see Ochlockonee TMDL in appendix D). EPA plans to provide each state or authorized tribe with modeled estimates of mercury deposition from sources within the state or on the tribal land and contributions from sources outside the state or tribe. The modeling results will help EPA and the states and authorized tribes develop TMDLs and determine the appropriate strategies for addressing mercury deposition from sources within their jurisdictions.

Additional tools available for determining mercury deposition loadings include the Community Multi-Scale Air Quality (CMAQ) model. The CMAQ modeling system is a comprehensive, three-dimensional, grid-based Eulerian air quality model designed to

estimate pollutant concentrations and depositions over large spatial scales (Dennis et al. 1996; Byun and Ching 1999; Byun and Schere 2006). The CMAQ model is a publicly available, peer-reviewed, state-of-the-science model with a number of science attributes that are critical for simulating the oxidant precursors and nonlinear chemical relationships associated with mercury formation. Version 4.3 of CMAQ (Bullock and Brehme 2002; Byun and Schere 2006) reflects updates to earlier versions in a number of areas to improve the underlying science and address comments from peer review. Further information on the CMAQ model is provided in appendix E.

As with any analysis based on limited data, uncertainty is inherent in the estimates of all analytical outputs of modeling. Model uncertainty results from the fact that models and their mathematical expressions are simplifications of reality used to approximate real-world conditions, processes, and their relationships. Models do not include all parameters or equations necessary to express real-world conditions because of the inherent complexity of the natural environment and the lack of sufficient data to describe the natural environment. Consequently, models are based on numerous assumptions and simplifications and reflect an incomplete understanding of natural processes. As a result, there will be some uncertainty when using models to quantify the sources of air-deposited mercury.

Other tools available to help states characterize mercury deposition include existing national monitoring networks and modeling tools, such as the MDN. Examples of these tools are provided in appendix F. Published results of national modeling studies could also be available to help estimate atmospheric deposition loadings. Further information on tools and approaches for characterizing atmospheric deposition to waterbodies can be found in the Frequently Asked Questions about Atmospheric Deposition section of EPA's Web site at http://www.epa.gov/oar/oaqps/gr8water/handbook/.

An analysis of deposition should take into account both direct deposition to the waterbody, as well as mercury deposited within the watershed (indirect deposition). In addition, fires, flooding, and other landscape disturbances could re-mobilize mercury previously deposited within the watershed and cause an increase in mercury transported to the waterbody. Studies are underway to examine the extent to which mercury deposited to a watershed is transported to a waterbody. For example, the Mercury Experiment to Assess Atmospheric Loading in Canada and the United States (METAALICUS) project is a mercury loading experiment to examine the timing and magnitude of the relationship between mercury loading to ecosystems and mercury concentrations in fish (Harris et al. 2006). Using stable mercury isotopes, researchers are examining the fate of mercury deposited to uplands, wetlands, and directly to lakes. It is being carried out at the Experimental Lakes Area (ELA) in northwestern Ontario by U.S. and Canadian researchers. A discussion of factors affecting mercury transport and bioavailability is included in chapter 2 of this guidance.

As part of a source evaluation, EPA encourages states to conduct a careful analysis to verify and quantify the contributions of air deposition as compared to other sources. Such information is important for determining the appropriate management approaches. For example, an analysis of the contribution from air sources is the basis for determining whether it may be appropriate to defer TMDLs under the 5m approach, or whether it is more appropriate to develop TMDLs to address significant local sources.

Although not required for a TMDL, states may wish to examine the contributions to the watershed from local air sources within the state as compared to out-of-state sources. Such information provides a basis for determining the appropriate allocations. In turn, such source information can help to develop a meaningful TMDL implementation plan and identify the extent to which state and local programs may be appropriate for addressing the mercury sources.

Metals mining activity. Loadings from metals mining activities might reflect both historical and recent mining activity within the watershed. Mining areas of interest are those involving "placer" deposits, in which mercury itself is present in the ore, or those deposits for which mercury is used to extract other metals such as gold. For example, sulfide replacement deposits are often associated with mercury. Locations at mining sites that might serve as sources of mercury include direct seeps, as well as leachate from tailings or spoil piles. In the Clear Lake TMDL (see appendix E), ground water from an abandoned mining site was reported to contain mercury that is readily methylated. In Clear Lake, acid mine drainage was found to contain high sulfate concentrations, which might enhance methylation by sulfate-reducing bacteria. Sources of data on potential mercury deposits associated with mining activity include USGS, the U.S. Bureau of Mines (for a list of major deposits of gold and silver), the State Inactive Mine Inventory, and the EPA Superfund program. Examples of TMDLs involving mercury associated with mining are provided in appendix E.

Sediments. A TMDL analysis should account for any mercury present in sediments as a result of current and past mercury loadings. Mercury in sediments may be the result of past metals mining activity as described above, past industrial activity, and historical air deposition. Data on levels of mercury in sediments are important in determining which sources are most significant, the most appropriate approach for addressing the sources and how long it will take to achieve water quality standards. For example, development of appropriate allocations, and in turn development of management strategies, may need to address both current sources of deposition as well as legacy sources. An examination of past industrial practices in the watershed could include whether sediments might serve as a reservoir for mercury. Various national databases, such as the National Sediments Database (USEPA 2002g) and data collected by USGS might help to identify isolated locations of elevated mercury in sediments. EPA has also developed a detailed guide on sediment source analysis in the first edition of *Protocol for Developing Sediment TMDLs*: http://www.epa.gov/owow/tmdl/sediment/pdf/sediment.pdf.

In the absence of sediment data for a waterbody, site-specific monitoring might be needed to confirm the levels of mercury in sediments to use as input to water quality models. In the sediment TMDL for Bellingham Bay, Washington, site-specific sediment analyses for mercury and other pollutants were conducted, including sediment sampling and toxicity analyses. Two kinds of modeling were also conducted:

- Modeling of contaminant transport and mixing to determine whether loadings from a location were contributing to water quality standards violations
- Screening modeling to identify other potential sources of sediment contamination (see the TMDL at http://www.epa.gov/waters/tmdldocs/1991_Bellingham%20Bay%20TMDL.pdf)

Other examples of TMDLs involving an analysis of mercury contributions from sediments include the TMDLs for Pena Blanca, Arizona, and the Cache Creek watershed in California (see appendix D). As described in the section on allocations, the Cache Creek watershed TMDL also accounts for methylmercury production in sediments.

Natural or background levels of mercury in soils. Soils and sediments can include mercury of geologic origin or mercury produced by the weathering of geologic materials, together with mercury of anthropogenic origin (mercury emitted over time from human sources and then deposited on soils). Mercury in soils can also re-emit or become re-suspended and subsequently redeposit to soils. Local studies have been used in some TMDLs to estimate the geologic contributions of mercury to waterbodies. For example, a TMDL developed for the Ouachita watershed in Arkansas relied on a study of mercury concentrations in the rocks of the Ouachita Mountains (FTN 2002). The mercury concentration estimated to be of geologic origin was then subtracted from the total concentration of mercury measured in soils to estimate the nongeologic concentration of mercury in soils.

6.2.2.2 What modeling tools are available to link mercury sources and water quality?

When developing a TMDL, states and authorized tribes should characterize the association between the concentration of methylmercury in fish tissue and the identified sources of mercury in a watershed. The association is defined as the cause-and-effect relationship between the selected targets, in this case the fish tissue-based criterion and the sources. The association provides the basis for estimating the total assimilative capacity of the waterbody and any needed load reductions. TMDLs for mercury typically link models of atmospheric deposition, watershed loading, and mercury cycling with bioaccumulation. For example, a watershed model (e.g., Grid Based Watershed Mercury Model, GBMM) might be linked with a receiving water mercury model (e.g., Water Quality Analysis Simulation Program, WASP) and a bioaccumulation model (e.g., Bioaccumulation and Aquatic Simulator, BASS). These models are described further in appendix E. Linking models together can enable a translation between the endpoint for the TMDL (expressed as a fish tissue concentration of methylmercury) and the mercury loads to the water without having explicit water column criteria or translations. The analysis determines the loading capacity as a mercury loading rate consistent with meeting the endpoint fish tissue concentration. This section describes some of the modeling tools available for use in mercury TMDLs.

When selecting a model or models for developing a mercury TMDL, states and authorized tribes should first consider whether the models will effectively simulate the management action(s) under consideration. If a percent reduction in mercury load to the waterbody is the sole action considered, a simple model might suffice; to answer more complex questions, a more complex or detailed model might be needed. Some questions decision makers should address include:

- How much do specific mercury loads need to be reduced to meet the criterion?
- What are the relative sources of the mercury load to the segment?

- Are mercury loads to the waterbody from sediments and watershed runoff and concentrations in fish at equilibrium with respect to current deposition levels? If not, how much will an equilibrium assumption affect the accuracy of predicted future fish concentrations?
- Could other pollution-control activities reduce mercury loads to the waterbody or affect the mercury bioaccumulation rate?
- After regulatory controls are implemented, how long will it take for fish tissue levels to meet the criterion?

Depending on the types of questions states and authorized tribes ask and the management approaches they consider, appropriate models could range from a very simple steady state model to a comprehensive dynamic simulation model, as described below. In addition, models are often used in TMDL analyses but are not required. For more information on the specific models described here, see http://www.epa.gov/athens and http://www.epa.gov/crem.

6.2.2.2.1 Steady state models and the proportionality approach

Steady state modeling describes the dynamic equilibrium between environmental media established in response to constant loads over the long term. Consequently, complex mercury cycling processes can be compressed into simple equations. One such approach, assumes that a ratio of current to future fish tissue concentration equals the ratio of current to future mercury loads to the waterbody. This approach, often referred to as the proportionality approach and explained in detail in the Mercury Maps report (USEPA 2001b), assumes that where air deposition is the sole significant source, factors affecting methylation remain unchanged. As a result, the ratio of current to future fish tissue concentrations can be assumed to equal the ratio of current to future air deposition loads in this situation. Mercury Maps, and the situations in which the proportionality assumption may or may not apply, are described further in appendix E.

A number of mercury TMDLs where air deposition is the predominant mercury source have been developed using an assumption of proportionality between mercury deposition and fish tissue methylmercury concentration. Specifically, such TMDLs have reasoned that a reduction in deposition will result in a proportional reduction in mercury concentrations in fish over time. Such an approach applies to situations where air deposition is the only significant mercury source and relies on steady-state conditions. This approach may also be used to estimate the reductions needed to meet a fish tissue target without necessarily calculating a water column target.

Mercury TMDLs which applied a proportional relationship between reductions in deposition and reductions in fish tissue methylmercury concentration include TMDLs for waterbodies in Louisiana, such as the Ouachita Basin (FTN 2002), the Mermentau and Vermillion-Teche River Basins (USEPA 2001i, 2001j) and the Coastal Bays and Gulf Waters of Louisiana (Parsons 2005). Using the Everglades Mercury Cycling Model, the pilot mercury TMDL study in the Florida Everglades also reported a linear relationship between mercury deposition and the concentrations of mercury in largemouth bass (Atkeson et al. 2002).

More recently, the Minnesota statewide mercury TMDL applied the proportionality approach. As described in section 6.2.1 above, waterbodies within the state were grouped into two regions, and a TMDL developed for each region. Minnesota calculated a reduction factor for each region, or the percent reduction in total mercury load needed in each region to achieve the fish tissue target of 0.2 mg/kg for the 90th percentile of the standard-length fish (MPCA 2007). Using the proportionality assumption, Minnesota applied the regional reduction factor (51 percent for the southwest region and 65 percent for the northeast region) to the total source loadings to determine the load reduction goal. The Minnesota TMDL explains in further detail the basis for using the proportionality approach.

Mass balance models are somewhat more complex implementations of the steady state approach. In place of a simple ratio, such models describe fluxes of mercury in and out of the model domain (e.g., impaired segment) and, optionally, balance fluxes (e.g., methylation and demethylation) within the model domain. The advantage provided by this approach is that individual fate processes can also be simulated. For example, if soil erosion and sediment runoff are modeled, decreased mercury soil erosion load can be related to decreased fish tissue concentrations (AZDEQ 1999). Where all other aspects of a watershed and waterbody remain unchanged, steady state models can produce as accurate an estimate of the necessary load reductions as a dynamic model, generally with less-intensive data collection and analysis. In addition, such simple approaches might be less prone to calculation error and are much easier for the public to understand.

6.2.2.2.2 Continuous-simulation and dynamic models

Continuous-simulation and dynamic models take into account time-varying effects such as variable pollutant inputs, precipitation, hydrologic responses, seasonal ecosystem changes, and effects on fish tissue concentrations. For mercury, they might also include a variety of physical and chemical fate and transport processes such as oxidation, demethylation, volatilization, sedimentation, resuspension, and adsorption and desorption. Dynamic models can be important in establishing cause-and-effect relationships. They assemble available scientific knowledge on mercury fate and transport into a single picture. Such models have been used to demonstrate how mercury moves from air emission to deposition to watershed runoff to subsequent bioaccumulation in fish at observed levels in remote waterbodies (USEPA 1997c).

Dynamic models could be used to describe waterbodies in dis-equilibrium (e.g., a recent surface water impoundment with elevated methylation rates). The Everglades Mercury TMDL pilot project (USEPA 2000g) simulated the amount of time necessary to attain equilibrium in response to reduced mercury loads using the Everglades Mercury Cycling Model. The model results predicted that sediments would continue to supply as much as 5 percent of the mercury load 100 years after air deposition reductions occurred. The Dynamic Mercury Cycling Model (D-MCM) was used in the mercury TMDLs for McPhee and Narraguinnep reservoirs in Colorado and the TMDLs for Arivaca and Pena Blanca lakes in Arizona (see appendix D) (Tetra Tech 2001).

The SERAFM model incorporates more recent advances in scientific understanding and implements an updated set of the IEM-2M solids and mercury fate algorithms described in the 1997 *Mercury Study Report to Congress* (USEPA 1997c).

Dynamic models can also describe how fish tissue concentrations are expected to respond to environmental variability, such as seasonal or year-to-year changes in meteorology. Thus, they can be used to better interpret how samples collected in a specific season of a specific year would be expected to vary relative to other seasons or years with mercury loads being constant.

6.2.2.2.3 Spatially detailed models

Spatially detailed models, such as that used in the Savannah River mercury TMDL (USEPA 2001j), can demonstrate how mercury fish tissue concentrations are expected to vary with distance downstream of the impaired segment(s). For the Savannah River, EPA used the Water Quality Analysis Simulation Program (WASP) model. WASP is a dynamic, mass balance framework for modeling contaminant fate and transport in surface water systems. The model helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions. Another model that has been used for mercury TMDLs is the EPA Region 4 Watershed Characterization System (WCS). WCS is a geographic information system (GIS)-based modeling system for calculating soil particle transport and pollutant fate in watersheds (Greenfield et al. 2002).

As with the steady state mass balance model, including additional processes can allow a modeler to determine the impact of different environmental regulatory or management controls on mercury fish tissue concentrations. For example, where mercury transport to a waterbody occurs predominantly through soil erosion, erosion control might be identified as a useful nonpoint source control on mercury to waterbodies (Balogh et al. 1998). As another example, controls on acid deposition and, thus, changes in lake pH and their effect on fish tissue mercury concentrations can also be modeled (Gilmour and Henry 1991, Hrabik and Watras 2002). Finally, spatially detailed landscape models hypothetically could be used to reflect the local effects of wetlands and their impacts on mercury methylation rates.

6.2.2.2.4 Regression models

In general, a regression model is a statistical model describing how a parameter, such as mercury levels in fish, is related to one or more variables. Regression models provide only approximations of real trends.

One example of a regression model for mercury is the regression-based model under development for New England. The model, known as MERGANSER (Mercury Geospatial Assessments for the New England Region), is being developed by EPA and several partners. The partners include USGS, the Biodiversity Research Institute, the State of Vermont, the Clean Air Association of the Northeast States, and the New England Interstate Water Pollution Control Commission. The model will integrate recent atmospheric mercury-deposition models with many databases on mercury sources, mercury levels in fish and bird tissue, and ecosystem features that might be associated with the risk of mercury contamination in biota and, ultimately, humans.

The intent of the project is to identify, by using regression modeling, explanatory variables that contribute to elevated mercury levels in fish and wildlife in New England. The model can then be applied in a predictive mode to lakes throughout New England

that have no mercury fish tissue or loon blood data. Specifically, the model will (1) identify watershed and other factors associated with high mercury levels in fish and wildlife; (2) identify likely sources of mercury; (3) provide estimates of mercury levels in fish and wildlife at any lake or stream in New England; (4) provide estimates of mercury reductions needed from air deposition to meet water-quality criteria; and (5) identify optimal locations for long-term monitoring. Modeling will be done within a GIS environment so that the spatial distribution of data is retained and results can be displayed watershed by watershed. Maps from MERGANSER will show the areas in New England that are susceptible to high mercury levels in biota and that are, therefore, areas where human health impacts (through fish consumption) and ecological impacts (bird tissue mercury levels) are potentially occurring. In addition, the model can be used to produce maps that identify mercury sources and show the relative magnitude of mercury loading from those sources.

6.2.2.2.5 Model selection

When selecting a model, a state or authorized tribe should be aware of the assumptions inherent in each type of model and consider the potential effects of those assumptions on relationships between loadings and fish tissue levels or water quality. The first consideration for model assumptions is methylation. Several factors, including pH, redox, potential sulfate concentrations, temperature, dissolved organic carbon (DOC) concentrations, salinity, and microbial populations, influence the speciation of mercury (Ullrich et al. 2001). If these factors fluctuate seasonally around an average condition, a waterbody could be at a dynamic equilibrium and the steady state assumption would still apply over the long term. If these factors change over time such that they might have a significant impact on fish tissue concentrations, the equilibrium assumptions inherent in steady state modeling might not hold, and a dynamic model like the D-MCM (EPRI 1999) should be used. In using this model, the state or authorized tribe should consider the amount of environmental media concentration data needed to initialize the model to represent its non-equilibrium state.

The second consideration for model assumptions is the BAF. As discussed in section 3.1.3.1, the BAF assumes a constant proportionality between fish tissue methylmercury concentrations, water column methylmercury concentrations, and water column mercury concentrations. Mercury in a waterbody might not be at a steady state because of ongoing reductions in mercury emissions, changes in water chemistry that affect methylation, changes in aquatic ecosystem makeup, or changes in fish biomass. If these factors change with time, the equilibrium assumptions inherent in steady state modeling might not hold, and a dynamic model should be used.

The third consideration for model assumptions is the relative importance of the mercury in aquatic sediments to the concentrations in fish tissue. Depending on previous loadings to the watershed, the deposition pattern of solids, and the chemistry in the aquatic sediments, the mercury in sediments can significantly influence the mercury concentrations in fish tissue. Sediments are repositories, and the loading that caused sediment mercury could be a legacy source. If so, a simplified steady state approach cannot simulate changes in mercury concentrations in fish tissue due to external loading reductions, and a dynamic model should be used.

6.2.2.2.6 Model limitations

To effectively estimate fish methylmercury concentrations in an ecosystem, it is important to understand that the behavior of mercury in aquatic ecosystems is a complex function of the chemistry, biology, and physical dynamics of different ecosystems. The majority (95 to 97 percent) of the mercury that enters lakes, rivers, and estuaries from direct atmospheric deposition is in an inorganic form (Lin and Pehkonen 1999). Microbes convert a small fraction of the pool of inorganic mercury in the water and sediments of these ecosystems into methylmercury. Methylmercury is the only form of mercury that biomagnifies in organisms (Bloom 1992). Ecosystem-specific factors that affect both the bioavailability of inorganic mercury to methylating microbes (e.g., sulfate, DOC) and the activity of the microbes themselves (e.g., temperature, organic carbon, redox status) determine the rate of methylmercury production and subsequent accumulation in fish (Benoit et al. 2003). The extent of methylmercury bioaccumulation is also affected by the number of trophic levels in the food web (e.g., piscivorous fish populations) because methylmercury biomagnifies as large piscivorous fish eat smaller organisms (Watras and Bloom 1992; Wren and MacCrimmon 1986). These and other factors can result in considerable variability in fish methylmercury levels among ecosystems at the regional and local scales.

The lack of complete knowledge about key mercury process variables, such as the functional form of equations used to quantify methylation rate constants, is a major contributor to overall uncertainty in models that cannot be quantified at this time.

6.2.2.3 What are the allocation approaches in mercury TMDLs?

A requirement for an approvable TMDL is that the state or authorized tribe allocate the pollutant load necessary to achieve water quality standards among point and nonpoint sources. EPA's regulations, however, leave the decision regarding how to allocate loadings to the state or authorized tribe developing the TMDL. States and authorized tribes have discretion in selecting a method or system for allocating pollutant loads among sources, provided that the allocations will result in attainment of water quality standards represented by the loading capacity (40 CFR 130.2). States and authorized tribes could reasonably consider the relative contribution of each source as one factor in developing allocations. Other factors might include cost-effectiveness, technical and programmatic feasibility, previous experience with the approach being considered, likelihood of implementation, and past commitments to load reductions. These same considerations apply to mercury TMDLs.

A number of pollutant loading and allocation scenarios have occurred in mercury TMDLs, each with a different mix of point and nonpoint sources. The scenarios have ranged from situations where mercury loadings are predominantly from air deposition, with small loadings from point sources or other sources, to situations where mercury loadings are predominantly from past mining activity. In addition, allocation approaches in mercury TMDLs have included allocations to individual sources as well as allocations to sectors and regions where appropriate. Examples of scenarios involving different source mixes and allocation approaches in approved mercury TMDLs are provided below.

Mercury loadings predominantly from air deposition, with very small loadings from point sources or other sources

Contributions from air deposition, such as direct deposition to the waterbody and deposition to the watershed transported to the waterbody by runoff and erosion, are typically included as part of the load allocation. As discussed in EPA guidance on reviewing TMDLs, allocations for nonpoint sources may range from reasonably accurate estimates to gross allotments (USEPA 2002f). TMDLs where air deposition is the predominant mercury source have usually allocated only a small portion of the reductions to the point sources or wasteload allocation, as described in the examples below. Many mercury TMDLs have included an allocation to air deposition as a whole; in some mercury TMDLs, the contributions from air deposition are further allocated to within-state and out-of-state sources, and contributions from anthropogenic and natural contributions are distinguished.

The Savannah River mercury TMDL is one of the first examples of an approach to allocating loadings where the predominant mercury source is atmospheric deposition. Many of the TMDLs developed to date are for situations where air deposition is the predominant mercury source. The Savannah River mercury TMDL indicated that NPDES point sources contribute 1 percent of the mercury loadings, while atmospheric deposition contributes 99 percent of the loadings. The TMDL identified only one point source on the Georgia side of the river that has a permit to discharge mercury to the Savannah River. It identified 28 point sources in Georgia that might have the potential to discharge larger amounts of mercury in their effluent according to the nature of the discharge or the mercury levels that have been found in their effluents above the water quality standard level.

The Savannah River mercury TMDL assigned 99 percent of the load reductions to the air sources and 1 percent of the reductions to point sources. The TMDL provides specific wasteload allocations for these 28 sources on the basis of meeting the water quality criterion at the end of a pipe or, alternatively, implementing a pollutant minimization program. In addition, the TMDL identifies about 50 other point sources expected, on the basis of their size and nature, to discharge mercury at levels below the water quality standard or not add mercury in concentrations above the concentrations in their intake water. Individual wasteload allocations are given to these point sources on the basis of their holding their effluents at current levels. The wasteload allocations for these point sources are expressed in the TMDL as a sum or aggregate allocation.

Note: After the Savannah River mercury TMDL was issued, Georgia adopted a new interpretation of its narrative water quality criteria that used EPA's new recommended fish tissue criterion for methylmercury. On the basis of the new interpretation, Georgia determined, and EPA agreed, that the Savannah River was meeting water quality standards for mercury. EPA therefore withdrew the TMDL. EPA believes, however, that the decisions, policies, and interpretations set forth in the TMDL are still valid and provide an example of a possible approach to mercury TMDLs. The Savannah River mercury TMDL is at http://www.gaepd.org/Files_PDF/techguide/wpb/TMDL/Savannah/EPA_Savannah_River_Watershed_Hg_TMDL.pdf.

The series of mercury TMDLs issued February 28, 2002, for watersheds in middle and south Georgia, such as the Ochlockonee watershed, also illustrate the first scenario. In

these basins, point source loadings contribute very little to the mercury loadings (the cumulative loading of mercury from all point sources is less than 1 percent of the total estimated current loading), with the vast majority of loading to the basins as air deposition.

The Ochlockonee mercury TMDL assigns most of the load reductions to the air sources, with a load allocation of 1.16 kg/yr and a wasteload allocation of 0.06 kg/yr. Although point sources collectively contribute a very minute share of the mercury load, the Ochlockonee and other mercury TMDLs for middle and south Georgia include wasteload allocations for the point sources. The TMDLs include wasteload allocations for each facility identified as a significant discharger of mercury, with the remainder of the allocation assigned collectively to the remaining point sources, considering that these smaller point sources would reduce their mercury loadings using appropriate, cost-effective minimization measures. The TMDL was written so that all NPDES-permitted facilities would achieve the wasteload allocation through discharging mercury at concentrations below the applicable water quality standard or through implementing a pollutant minimization program. A summary of the Ochlockonee mercury TMDL is provided in appendix D and is at http://gaepd.org/Files_PDF/techguide/wpb/TMDL/Ochlockonee/EPA_Ochlockonee_River_Hg_TMDL.pdf.

The Minnesota "statewide" mercury TMDL document takes a regional approach to allocations, providing a single wasteload allocation and a single load allocation that applies to each region rather than to individual waterbodies. The TMDL document indicates that such a regional allocation serves as a regional "cap." The predominant source is atmospheric deposition, with a small contribution (about 1.2 percent of the total source load for both regions combined) from point sources. The wasteload allocation is set at 1 percent of the TMDL or the 1990 baseline load, whichever is lower, with the remainder allocated to nonpoint sources. Point sources, including NPDES-permitted stormwater sources, municipal treatment facilities, and industrial dischargers that impact the waterbodies covered by the TMDL, are subject to the wasteload allocation. For the load allocation, the Minnesota TMDL estimates the contributions to air deposition from within-state and out-of state sources, as well as from global sources and anthropogenic sources. A summary of the Minnesota mercury TMDL is included in appendix D. The TMDL and related documents can be found at http://www.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html.

Mercury loadings predominantly from past mining activity, with small or no contributions from atmospheric deposition and/or NPDES point source contributions

One example of a TMDL for this scenario is the Cache Creek Watershed TMDL. Cache Creek is a tributary to the Sacramento-San Joaquin Delta in California. Sources of mercury entering the Cache Creek watershed include leaching from waste rock and tailings from historical mercury and gold mines, erosion of naturally mercury-enriched soils, geothermal springs, and atmospheric deposition. There are multiple inactive mercury and gold mines in the Cache Creek watershed and no NPDES-permitted discharges. Methylmercury is also produced *in situ* in the streambed of Cache Creek. The TMDL analysis provides load allocations for Cache Creek, as well as each of the tributaries. For each waterbody, load reductions are provided for both methylmercury and total mercury. Allocations are expressed as a percentage of the existing methylmercury

loads. Estimated atmospheric contributions of mercury, from direct deposition and runoff after deposition, are very small compared to loads of mercury from mine sites or erosion of the stream bed and banks, and thus no allocations are made to air deposition. Reducing the methylmercury loads will require a multifaceted approach that includes controlling inorganic mercury loads and limiting the entry of inorganic mercury into sites with high rates of methylmercury production. The Cache Creek watershed mercury TMDL and the allocation approach are summarized further in appendix D.

Mercury loadings from a combination of different sources, including atmospheric deposition, past mining, and point sources

The Mercury TMDL for the Willamette Basin, Oregon, identifies atmospheric deposition (direct plus indirect deposition: 47.7 percent) and erosion of mercury-containing soils (47.8 percent) as the top sources, along with small contributions from legacy mining (0.6 percent) and NPDES-permitted point sources (3.9 percent). The point source loadings consist of 2.7 percent from POTWs and 1.2 percent from industrial discharges. The TMDL assigns interim allocations to each of the source categories or sectors, rather than individual sources, based on the considerable uncertainty in the loading estimates and other factors. The TMDL specifies an across-the-board reduction of 27 percent in each source. After the 27 percent reduction to each source, the allocations for the Willamette mainstem are approximately similar to their relative contribution to the total loadings: 44.7 kg/yr for air deposition, 44.8 kg/yr for erosion, 0.6 kg/yr for legacy mine discharges, 2.6 kg/yr for POTWs, 1.1 kg/yr for industrial discharges, and 0.8 kg/yr for reserved capacity. Allocations are also provided for other waterbodies in the basin. The TMDL is at http://www.deq.state.or.us/wq/tmdls/docs/willamettebasin/willamette/chpt3mercury.pdf.

Mercury loadings from point sources predominate or are not insignificant compared to other sources

A small number of approved TMDLs have been developed for situations where mercury is primarily or exclusively from point sources, including TMDLs for waterbodies in Colorado. Examples of such TMDLs can be found at http://iaspub.epa.gov/tmdl_waters10/attains_impaired_waters.control?p_state=CO&p_pollutant_id=693.

6.2.2.4 What kinds of monitoring provisions have been associated with approved TMDLs?

Monitoring provisions in approved TMDLs have included point source effluent and influent monitoring, as well as water column, fish tissue, sediment, and air deposition monitoring. Examples of mercury TMDLs with post-TMDL monitoring are the middle and south Georgia mercury TMDLs approved in 2002. For facilities with the potential to discharge significant amounts of mercury on the basis of their large flow volume or other factors, the TMDL provides the permitting authority with two options for the wasteload allocation:

- Implement the criteria-end-of-pipe (i.e., apply the TMDL water quality target to a discharger's effluent at the outfall point).
- Monitor for mercury in the facilities' influent and effluent using more sensitive analytical techniques (e.g., EPA method 1631) and implement cost-effective mercury minimization if mercury is present in effluent at concentrations greater

than source water concentrations and if the discharge exceeds the water quality target.

Other facilities expected to discharge at levels below the water quality target will be expected to verify through monitoring whether or not they are significant dischargers of mercury. Other follow-up activities include further characterization of the air sources and additional ambient monitoring of mercury concentrations in water, sediment, and fish.

The mercury TMDL for the coastal bays and gulf waters of Louisiana (approved July 2005) includes similar monitoring provisions for point source dischargers with flows above a specified discharge volume. The TMDL also indicates that Louisiana will conduct water, fish tissue, and air deposition monitoring and that the state will develop a statewide mercury risk reduction program, including an assessment of all mercury sources. (See the TMDL and supporting documents at http://iaspub.epa.gov/tmdl/waters_list.tmdl_report?p_tmdl_id=11642.)

TMDLs involving past mining activity have also included follow-up monitoring; examples include three of the TMDLs described in appendix D (Clear Lake, California; Arivaca Lake, Arizona; and Cache Creek, California). The mercury TMDL for Arivaca Lake lists several follow-up actions and monitoring activities, such as additional watershed investigations to identify other potential mine-related mercury sources, including sediment sampling; evaluation of livestock BMPs to reduce erosion of soils containing mercury and follow-up monitoring; and fish tissue monitoring to evaluate progress toward the TMDL target (see the TMDL at http://www.epa.gov/waters/tmdldocs/17.pdf). The Clear Lake, California, mercury TMDL also identifies the need for follow-up monitoring of fish tissue and sediment (see appendix D, and the TMDL at http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/clear_lake_hg/cl_final_tmdl.pdf. The Cache Creek TMDL indicates that monitoring will be conducted to determine whether mercury loads have been reduced and to measure progress toward the TMDL target, as well as to better characterize areas of methylmercury production and mercury loadings from tributaries. Monitoring will include fish tissue, sediment, and water monitoring.

EPA recommends that states and authorized tribes periodically review TMDLs during implementation to ensure that progress is being made toward achieving water quality standards. Such “adaptive implementation” provides the flexibility to refine and improve a TMDL as data on the success of implementation activities are collected. States may refine information on the contributions from sources such as runoff from abandoned mining sites, sediment loading of mercury-laden sediments, and air deposition as data and modeling tools improve. States should consider the application of adaptive implementation in determining load allocations for these sources. Although a monitoring plan is not required in a TMDL, EPA guidance documents recommend using a monitoring plan to track the effectiveness of a TMDL; see *Guidance for Water Quality-Based Decisions: the TMDL Process* (EPA 440/4-91-001). Post-TMDL monitoring is an important tool for evaluating implementation success and, if necessary, refining the TMDL. Follow-up monitoring may include monitoring of water quality, fish tissue, air deposition, and sediments.

7 National Pollutant Discharge Elimination System (NPDES) Implementation Procedures

7.1 What are the general considerations in NPDES permitting?

Section 301(a) of the CWA prohibits the discharge of any pollutant, including mercury, from a point source into waters of the United States except in compliance with certain enumerated provisions of the CWA, among them section 402. CWA section 402 establishes the NPDES program, under which EPA or states and tribes authorized to administer the program issue permits that allow the discharge of pollutants into waters of the United States, notwithstanding the general prohibition established by section 301(a). These permits must contain (1) technology-based effluent limitations, which represent the degree of control that can be achieved by point sources using various levels of pollution control technology (see CWA sections 301, 304, and 306) and (2) more stringent limitations, commonly known as water quality-based effluent limitations (WQBELs), when necessary to ensure that the receiving waters achieve applicable water quality standards (see CWA section 301(b)(1)(C)).[20]

Most WQBELs are expressed as numeric limits on the amounts of specified pollutants that may be discharged. However, WQBELs may also be expressed in narrative form such as best management practices (BMPs) or pollutant minimization measures (e.g., practices or procedures that a facility follows to reduce pollutants to waters of the United States) when it is infeasible to calculate a numeric limit (see 40 CFR 122.44(k)(3)). In addition, BMPs may be imposed in the form of NPDES permit conditions to supplement numeric effluent limitations when the permitting authority determines that such requirements are necessary to carry out the purposes and intent of the CWA (see CWA section 402(a)(1)(B) and 40 CFR 122.44(k)(4)).

As noted above, NPDES permits must contain WQBELs when necessary to achieve applicable water quality standards. The procedure for determining the need for WQBELs is called a "reasonable potential" analysis. Under EPA's regulations at 40 CFR 122.44(d)(1)(i), effluent limitations must control all pollutants that the permitting authority determines "are or may be discharged at a level that will cause, have the reasonable potential to cause, or contribute to an exceedance of any applicable water quality standard." Thus, if a pollutant discharge has the reasonable potential to cause or contribute to an exceedance of applicable water quality standards, the discharger's NPDES permit must contain a WQBEL for that pollutant (see 40 CFR 122.44(d)(1)(iii)–(vi)). The procedure for determining reasonable potential must consider the variability of the pollutant in the effluent, other loading sources, and dilution (when allowed by the water quality standards) (see 40 CFR 122.44(d)(1)(ii)). The procedure specifies only

[20] When developing WQBELs, the permitting authority must ensure that the level of water quality achieved by such limits derives from and complies with water quality standards (see 40 CFR 122.44(d)(1)(vii)(A)).

whether a discharge must have a WQBEL; it does not specify the actual permit limits. The NPDES regulations at 40 CFR 122.44(d)(1)(vii) specify that the level of water quality to be achieved by the WQBEL must derive from and comply with water quality standards, as required by CWA section 301(b)(1)(C) (requiring "any more stringent limitation… necessary to meet water quality standards"). This would necessarily be a permit-by-permit determination.

7.2 What is the EPA-recommended NPDES permitting approach for methylmercury?

The recommendations below assume that an approved TMDL is not available at the time of permit issuance. If EPA has approved or established a TMDL containing wasteload allocations for the discharge of mercury (and methylmercury where appropriate), the WQBEL for that discharge must be consistent with the wasteload allocation (see 40 CFR 122.44(d)(1)(vii)(B)).

EPA believes, depending on the particular facts, that a permit writer may reasonably conclude that limits on point sources consistent with this guidance are likely to be as stringent as necessary to achieve water quality standards. As described in more detail below, the permit writer should conduct a reasonable potential analysis to determine whether a discharger will cause or contribute to the exceedance of applicable water quality standards. Once such a determination is made, limits can be imposed consistent with this guidance. In circumstances where waters are not yet impaired, the permit writer should consider other factors or conditions when determining whether a facility has reasonable potential with the goal of preventing future impairments. (See Sections 7.2.2, 7.5.1.2.2 and 7.5.1.2.3).

7.2.1 Developing NPDES permit limits based on the fish tissue criterion

The first component of the recommended NPDES permitting approach for methylmercury is to determine how the methylmercury criterion is expressed in the applicable water quality standard and to determine whether a water column translation of the fish tissue criterion or site-specific data to translate are available at the time of permit issuance. This will inform the selection of the appropriate recommended implementation option. If the methylmercury criterion is expressed as a water column value, the permit writer should develop permit limits based on this criterion according to procedures described in section 5.4.4 of the *Technical Support Document for Water Quality-based Toxics Control*, or TSD (USEPA 1991). If the criterion is expressed as a fish tissue value and a water column translation of the fish tissue criterion or site-specific data to translate are available at the time of permit issuance, the permit limits based on the translated water concentration value should again be developed according to procedures described in section 5.4.4 of the TSD.

If, however, the criterion is expressed as a fish tissue value and a water column translation of the fish tissue criterion or site-specific data to translate are not available at the time of permit issuance, the permitting authority may reasonably conclude that a numeric WQBEL is infeasible to calculate. In that instance, EPA recommends that the permitting authority develop NPDES permit limits based on the criterion using the

procedures described below. Section 7.3 contains additional information about expressing and developing permit limits based on the methylmercury criterion.

7.2.2 Determining reasonable potential

The second component of the recommended NPDES permitting approach for methylmercury is to conduct a reasonable potential analysis to determine whether the discharge will cause or contribute to an exceedance of applicable water quality standards. The recommended reasonable potential analysis consists of two steps. Step one is to determine whether there is a quantifiable amount of mercury in the discharge using a sufficiently sensitive analytical method (see sections 7.4 and 7.5.1.1 for more information on sufficiently sensitive methods.) If this information is unknown, EPA recommends including a monitoring requirement in the permit to collect this information and a reopener clause to allow establishment of appropriate requirements if the permitting authority determines that the discharge has reasonable potential. If, using a sufficiently sensitive analytical method, there is not a quantifiable amount of mercury in the discharge, depending on the particular facts, the permitting authority may reasonably conclude that the discharge does not have reasonable potential and that no water quality-based limits are necessary. If there is a quantifiable amount of mercury, however, the permitting authority should move to step two of the reasonable potential analysis. Section 7.5.1.1 contains additional information on step one of the reasonable potential analysis.

Step two of the reasonable potential analysis is to determine whether the fish tissue concentration of methylmercury in the receiving water is close to or exceeds the criterion.

If the fish tissue concentration of methylmercury in the receiving water is below and not close to the criterion, depending on the particular facts, the permitting authority may reasonably conclude that the discharge does not have reasonable potential, but tier 2 antidegradation provisions should be considered. This situation is described below in the third component of the NPDES permitting approach.

If the fish tissue concentration of methylmercury in the receiving water is close to or exceeds the criterion, depending on the particular facts, the permitting authority may reasonably conclude that the discharger has reasonable potential, and a WQBEL must be included in the permit. Recommended WQBELs for this situation are described below in the fourth component of the NPDES permitting approach. Section 7.5.1.2 contains additional information on step two of the reasonable potential analysis. If information for step two is unknown, EPA recommends including in the permit a special permit condition to conduct a fish tissue survey of the receiving waterbody and a reopener clause so that reasonable potential can be determined when the fish tissue data become available. EPA further recommends that in this situation the permitting authority encourage permittees to develop and implement mercury minimization plans (MMPs) to reduce mercury loading to the waterbody.

In order to prevent future impairments, EPA recommends that a state or authorized tribe consider other factors or conditions such as rising fish tissue concentrations or the relative contribution of mercury or methylmercury from the source when determining whether a facility has reasonable potential in waters that are not yet impaired. Section

7.5.1.2.2 contains additional examples of other factors, such as downstream impacts, that should be considered in a reasonable potential analysis.

7.2.3 Implementing antidegradation

The third component of the recommended NPDES permitting approach for methylmercury is to determine whether the discharger will undertake an activity that can increase mercury loading to the waterbody. If the discharger will not undertake such an activity, no additional permit conditions are necessary. EPA recommends, however, that in this situation the facility voluntarily develop and implement an MMP to reduce the facility's mercury loading to the receiving water. If the discharger will undertake such an activity, EPA recommends that a tier 2 antidegradation analysis be conducted in accordance with the state or tribe's antidegradation policy and that permit conditions consistent with the analysis be included in the permit.

As part of conducting a tier 2 antidegradation analysis, the state or authorized tribe would evaluate the activity's potential to lower water quality, whether there are alternatives that would avoid lowering water quality, and whether lowering of water quality would be necessary to accommodate important economic or social development in the area of the discharge. EPA considers analyses of potential pollution prevention and enhanced treatment alternatives as an appropriate starting point for the antidegradation review for both industrial and municipal dischargers. See 67 FR 68971, 68979. The results of such an analysis of potential alternatives could provide the basis for developing an MMP.

EPA further recommends that the permit contain a special condition requiring the permittee to implement an MMP and conduct effluent monitoring to allow for evaluation of the effectiveness and implementation of the MMP. Section 7.5.1.2.2 contains additional information on antidegradation considerations.

7.2.4 Establishing appropriate WQBELs

The fourth component of the recommended NPDES permitting approach for methylmercury is to develop appropriate WQBEL requirements. Where a TMDL containing wasteload allocations for the discharge of mercury (and methylmercury where appropriate) has been developed, the WQBEL for that discharge must be consistent with the wasteload allocation (see 40 CFR 122.44(d)(1)(vii)(B)). Where a TMDL is not available at the time of permit issuance, to satisfy 122.44(d)(1)(vii)(A), EPA recommends the following WQBEL requirements, which are explained in greater detail in section 7.5.2.1:

- Where a water column translation of the fish tissue criterion has been developed, or where site-specific data to do so are readily available, include a numeric water quality-based limit.
- Where a water column translation or site-specific data are not available and the permit writer determines that a numeric limit is infeasible to calculate:
    - Require the permittee to implement an MMP tailored to the facility's potential to discharge mercury. Depending on the particular facts, the permitting authority may include in the MMP a trigger level, reduction goal, or

enforceable numeric level (e.g., existing effluent quality) to further manage mercury discharges.

- Require effluent monitoring using a sufficiently sensitive EPA-approved method to enable evaluation of the effectiveness and implementation of the MMP. (See sections 7.4 and 7.5.1.1 for more information on sufficiently sensitive methods.)
- Include a reopener clause to modify the permit conditions if the MMP is not found to be effective or if a water column translation of the fish tissue criterion is developed.

Since permitting authorities need to establish and maintain WQBELs as stringent as necessary to meet water quality standards, if a state or tribe has yet to complete the transition from an existing water column criterion to a fish tissue-based criterion, states may consider retaining their existing water column criteria until translators are developed. Alternatively, until a translator is available, EPA recommends that one of the approaches outlined in this document for relating a concentration of methylmercury in fish tissue to a concentration of methylmercury in ambient water be considered, especially for waters with relatively high direct water inputs of mercury. (See section 3.1.3.1.)

In modifying or reissuing permits with existing WQBELs for mercury, permit writers must also ensure compliance with CWA anti-backsliding requirements. As described elsewhere in this Guidance, CWA section 402(o)(1) prohibits the revision of WQBELs to make them less stringent than existing permit limits unless a specific exception applies under 402(o)(2) or 303(d)(4).

Exceptions under Section 402(o)(2), which would allow for the establishment of less stringent limits are:

(1) There have been material and substantial alterations or additions to the permitted facility which justify the less stringent limit.

(2) New information (other than revised regulations, guidance, or test methods) is available that was not available at the time of permit issuance, and that would have justified a less stringent limit.

(3) Good cause exists due to events beyond the permittee's control (e.g., natural disasters) and for which there is no reasonably available remedy.

(4) The permit has been modified under 301(c), 301(g), 301(h), 310(i), 301(k), 301(n), or 316(a).

CWA section 303(d)(4) provides additional exceptions to the anti-backsliding prohibition: paragraph (A), which applies to "non-attainment waters," and paragraph (B), which applies to "attainment waters".

- **Non-attainment water:** CWA section 303(d)(4)(A) allows the establishment of a less stringent effluent limitation when the receiving water does not meet applicable water quality standards (i.e., a "non-attainment water") if the permittee meets two conditions. First, the existing effluent limitation must have been based on a total maximum daily load (TMDL) or other wasteload allocation established under

CWA section 303. Second, relaxation of the effluent limitation is allowed only if the cumulative effect of all revised limitations would assure the attainment of water quality standards, or the designated use not being attained is removed in accordance with the water quality standards regulations.

- **Attainment water:** CWA section 303(d)(4)(B) applies to waters where the water quality equals or exceeds levels necessary to protect the designated use, or to otherwise meet applicable water quality standards (i.e., an "attainment water"). Under CWA section 303(d)(4)(B), a limitation based on a TMDL, wasteload allocation, other water quality standard, or any other permitting standard may only be relaxed where the action is consistent with the state's antidegradation policy.

The application of these exceptions is limited under 402(o)(3), which prohibits the relaxation of effluent limitations in all cases if a revised effluent limitation would result in a violation of applicable effluent limitation guidelines or water quality standards, including antidegradation requirements.

In establishing WQBELs for mercury, permit writers will need to ensure that the CWA anti-backsliding requirements are met. The first step of the inquiry is to determine whether the WQBEL based on the fish tissue criterion is "less stringent" than the WQBEL in the previous permit. If the new permit limit is not less stringent (e.g., if the prior numeric WQBEL is included in the MMP as an enforceable numeric level (see section 7.5.2.4 for additional information)), then the anti-backsliding prohibition should not be triggered and it should be appropriate to include the new limit in the permit. If the WQBEL based on the new fish tissue criterion is in fact less stringent than the prior WQBEL, then the permit writer must retain the existing numeric WQBEL unless there is an available exception to the anti-backsliding prohibition.

Because CWA section 402(o)(2)(B)(i) does not allow backsliding solely because regulations are revised (e.g., adoption of the fish tissue criterion), any applicable exceptions to the anti-backsliding prohibition for impaired waters would be found under section 303(d)(4)(A). In this case, permit limits based on TMDLs or other wasteload allocations established under section 303 can be made less stringent only if: a) the cumulative effect of all loadings meets the WQS or b) the designated use is removed.

Anti-backsliding requirements are further described in EPA's *NPDES Permit Writers' Manual* (USEPA 1996a) and in EPA's *Technical Support Document for Water Quality-Based Toxics Control* (USEPA 1991).

Other considerations and requirements may be necessary in developing permits. They include the following:

- Where a discharger undertakes an activity that could increase mercury loading to the receiving water, the WQBEL must be consistent with applicable antidegradation requirements (see section 7.5.1.2.2). Additional requirements may also be necessary under the CWA and EPA's NPDES regulations (see section 7.5.2.3).

- The permitting authority would need to include appropriate technology-based limits pursuant to CWA section 301(b) and 40 CFR sections 125.3 and 122.44(a)(1) (see section 7.5.2.3).

The entire recommended NPDES permitting approach is summarized in figure 5 and explained in greater detail in the following sections.

7.3 How does EPA recommend implementing the fish tissue criterion for NPDES permits?

As discussed in section 3.1, states and authorized tribes that decide to use the recommended criterion as the basis for new or revised methylmercury water quality standards have the option of adopting the criterion into their water quality standards as a fish tissue concentration, a traditional water column concentration, or both. If states or authorized tribes choose to use both approaches, they should clearly describe in their standards how each will be used for specific applications and describe applicable implementation procedures.

EPA recommends two approaches for implementing the fish tissue-based methylmercury water quality criterion in NPDES permits, depending on the form in which the state or authorized tribe expresses the criterion—as a fish tissue concentration or as a water column concentration. In addition, states and authorized tribes that adopt the recommended criterion as a fish tissue value may choose to implement it through NPDES permitting as a water column translation of the fish tissue value. Each of these approaches is summarized in figure 6 and discussed in more detail in sections 7.4 and 7.5.

The recommendations below assume that an approved TMDL is not available. If EPA has approved or established a TMDL containing a wasteload allocation for the discharge of mercury (and methylmercury where appropriate), the WQBEL for that discharge must be consistent with the wasteload allocation (see 40 CFR 122.44(d)(1)(vii)(B)).

This chapter provides EPA's guidance on how a permitting authority could implement the fish tissue criterion in NPDES permits consistent with the CWA and its implementing regulations. States and authorized tribes retain the discretion to develop and use procedures for determining reasonable potential and establishing effluent limits in NPDES permits that differ from those in the guidance. Such procedures may use other information relevant to determining reasonable potential and establishing effluent limits, where appropriate. If a state or authorized tribe develops its own such permitting procedures, EPA recommends that states and authorized tribes make the procedures public so that all stakeholders can be aware of the requirements and expectations of the permit program. In addition, the permit's fact sheet or statement of basis should also explain the basis of the permit conditions and effluent limitations and how these are consistent with the state's or authorized tribes' permitting procedures, the CWA, and applicable federal regulations.

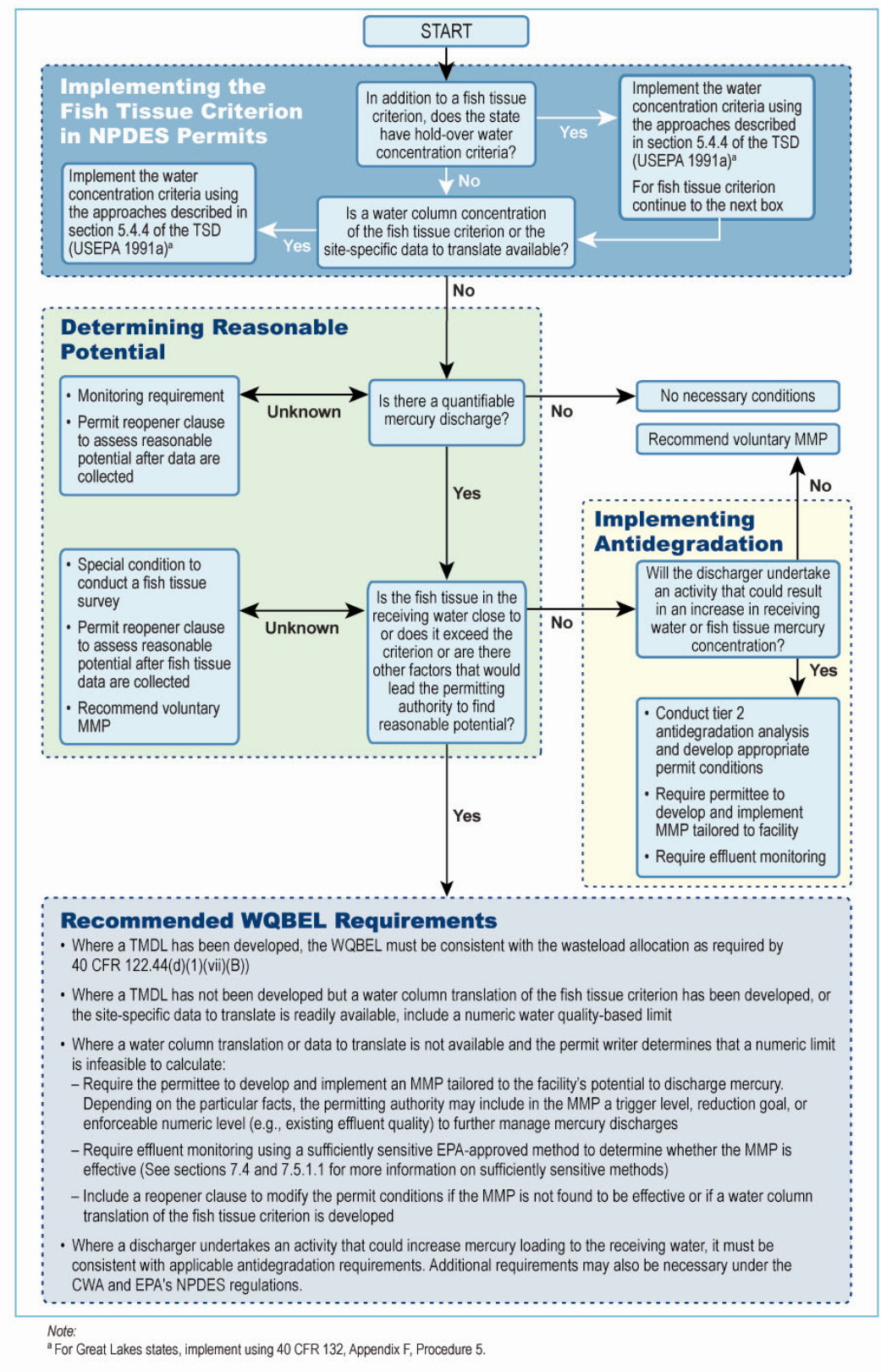


Figure 5. NPDES permitting approach for methylmercury.

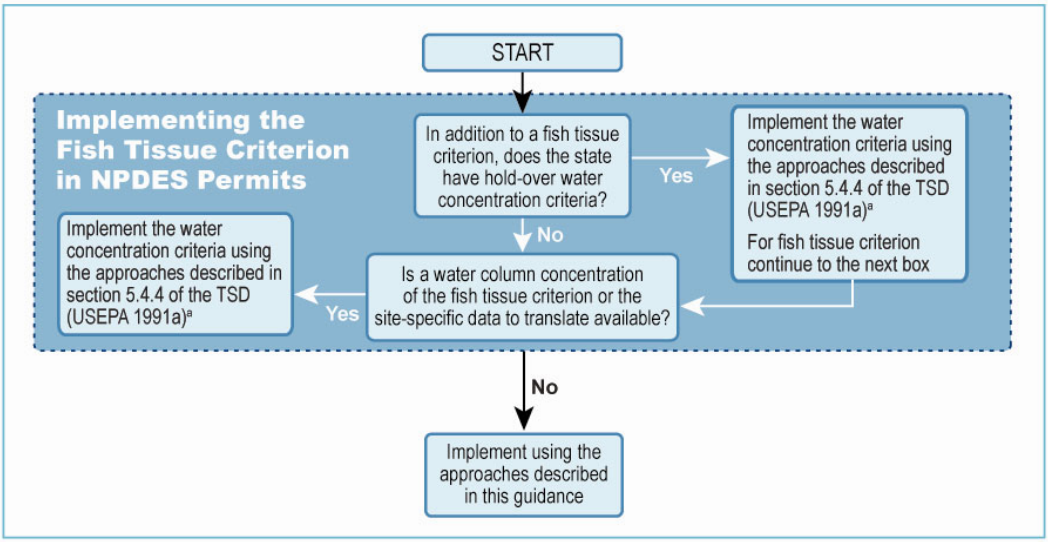


Figure 6. Implementing the fish tissue criterion in NPDES permits.

7.4 What are the procedures for developing permit limits when the criterion is adopted as a water column value or when the criterion is adopted as a fish tissue value and the permitting authority uses a water column translation of the fish tissue value?

This approach assumes that a state or authorized tribe decides to adopt a new or revised water quality criterion for methylmercury in one of the following forms:

- *Water column concentration value*. Expressing a criterion as a water column value is very common, and permitting authorities have considerable historical experience in developing permit limits based on such criteria in NPDES permits.

- *Fish tissue concentration value that is translated into a water column value*. Sections 3.1.3.1 through 3.1.3.3 of this guidance discuss the procedures for translating the fish tissue criterion into a water column value for water quality standards purposes. These procedures may also be used to translate a fish tissue criterion into a water column value for determining reasonable potential and for deriving numeric WQBELs.

In either case described above, the permitting authority should determine reasonable potential and calculate numeric WQBELs using the procedures described in section 5.4.4 of the TSD (USEPA 1991) to derive a numeric WQBEL.

This approach relies on the measurement of mercury in effluent, often at concentrations below the quantitation levels of some analytical methods. Therefore, the permitting authority should specify that the NPDES regulated discharger use a sufficiently sensitive EPA-approved method for the measurement of mercury in the discharge. An analytical method is sufficiently sensitive when (1) its method quantitation level is at or below the

level of the applicable water quality criterion or (2) its method quantitation level is above the applicable water quality criterion, but the amount of mercury in a discharge is high enough that the method detects and quantifies the level of mercury in the discharge. To illustrate the latter, if the water column criterion or water column translation of a fish tissue criterion for mercury in a particular waterbody is 2.0 parts per trillion (ppt), method 245.7 (with a quantitation level of 5.0 ppt) would be sufficiently sensitive when it reveals that the level of mercury in a discharge is 5.0 ppt or greater. In contrast, method 245.7 would not be sufficiently sensitive when it resulted in a level of nondetection for that discharge because it could not be known whether mercury existed in the discharge at a level between 2.0 and 5.0 ppt (less than the quantitation level but exceeding the water quality criterion).[21]

The selection of a sufficiently sensitive method relates method quantitation levels to the water column criterion value. If a water column criterion or a water column translation of a fish tissue criterion is not available to allow for selecting an alternate sufficiently sensitive method, EPA recommends the use of the most recent version of method 1631 to characterize discharges from all facilities for which the mercury levels are unknown or undetected. Method 1631 is relatively new, and the facilities may not have used it to analyze their effluent discharges. As a result, previous monitoring may show undetectable levels of mercury when use of method 1631 shows detectable or quantifiable amounts. Therefore, EPA recommends monitoring using the most recent version of method 1631 to help identify all facilities that contribute to mercury water quality impairment, unless another EPA-approved method can be justified as being sufficiently sensitive.

EPA's regulations require that measurements included on NPDES permit applications and on reports required to be submitted under the permit must generally be made using analytical methods approved by EPA under 40 CFR part 136. Because EPA has approved methods for analyzing mercury in water, these approved methods must be used in water analyses for NPDES permits involving mercury. See 40 CFR sections 122.21(g)(7), 122.41(j), 136.1, 136.3, and 136.6. Selection of an approved method should take into account the above discussion of method sensitivity. For metals, such as mercury, the federal regulations at 40 CFR 122.45(c) generally require effluent monitoring for the total form of the metal.

The discussion above describes analytical methods for measuring mercury in water. Refer to section 4.1 and appendix C for information on analytical methods for measuring mercury in fish tissue and for measuring methylmercury in water or fish tissue.

[21] For more information on choosing a sufficiently sensitive method, see the memorandum *Analytical Methods for Mercury in National Pollutant Discharge Elimination System (NPDES) Permits* from James A. Hanlon, Director of the Office of Wastewater Management, dated August 23, 2007, at http://www.epa.gov/npdes/pubs/mercurymemo_analyticalmethods.pdf.

7.5 What are the procedures for developing permit limits when the criterion is adopted as a fish tissue value and the permitting authority does not use a water column translation of the fish tissue value?

This approach assumes that a state or authorized tribe decides to adopt a new or revised water quality criterion for methylmercury in the form of a fish tissue concentration and that a TMDL, water column translation of the fish tissue criterion, or site-specific data to translate are not available at the time of permit issuance. As a result, the permitting authority will use a different approach than it has previously used for determining reasonable potential and expressing WQBELs. EPA recommends the approach described below, which is summarized in figure 7.

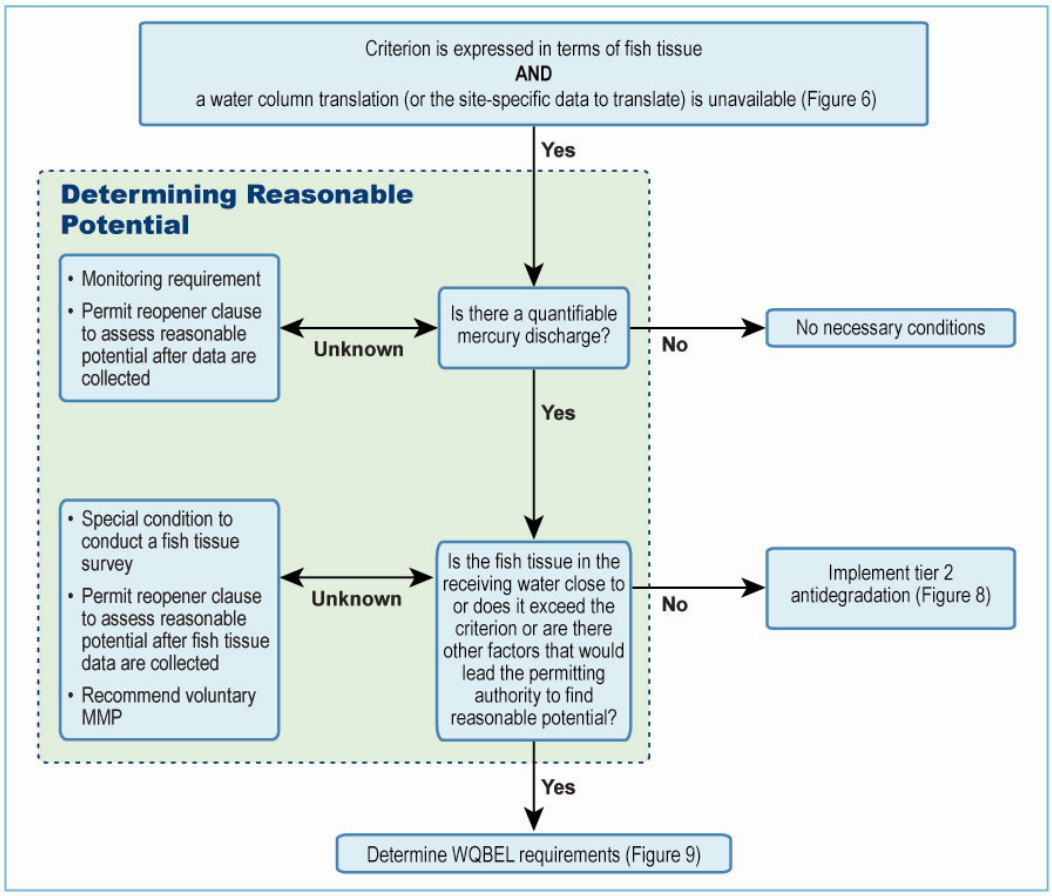


Figure 7. Determining reasonable potential.

7.5.1 How to determine the need for permit limits to control mercury (how to determine reasonable potential)

As discussed in section 3.1.2.2 of this document, EPA recommends that states and authorized tribes adopt new or revised methylmercury water quality criteria in the form of a fish tissue concentration. When a criterion is adopted into standards as a fish tissue value, states and authorized tribes may not have sufficient data to translate from a fish

tissue value to a traditional water column value using BAFs or translators. This section provides recommendations for how a permitting authority can determine reasonable potential in the absence of site-specific data to translate the fish tissue value into a water column value.

When determining reasonable potential, the permitting authority must determine whether the discharge "causes, has reasonable potential to cause, or contributes" to an exceedance of the applicable water quality criterion (see 40 CFR 122.44(d)(1)(ii)). The NPDES permit fact sheet should provide the rationale and assumptions used in determining whether WQBELs proposed in the associated draft permit are appropriate. The recommendations in this guidance could be applied on a permit-by-permit basis where appropriate to support the reasonable potential determination that satisfies 40 CFR 122.44(d)(1)(ii) with respect to a water quality criterion for methylmercury expressed as a fish tissue value in the absence of a TMDL and a water column translation of that value at the time of permit issuance.

EPA believes that, depending on the particular facts, a permitting authority could reasonably conclude that reasonable potential exists if two conditions are present: (1) the NPDES permitted discharger has mercury in its effluent at a quantifiable level and (2) the methylmercury level in fish tissue from the receiving waterbody is close to or exceeds the fish tissue water quality criterion. Under these circumstances, the effluent data indicate that the mercury load in the effluent contributes to the mercury load in the waterbody, and the fish tissue concentration indicates that the mercury load in the waterbody causes or has the potential to cause an exceedance of the water quality criterion. This approach is consistent with federal regulations pertaining to the Great Lakes Basin, which contained an approach for determining reasonable potential using fish tissue data (see 40 CFR part 132, appendix F, procedure 5.F.4). The reasonable potential approach for mercury described in this guidance has the advantage of significantly reducing environmental monitoring costs and does not involve developing a site-specific BAF for each waterbody in a state.

EPA recognizes that the mere presence of mercury at a quantifiable level in an effluent is not necessarily an indication that the mercury discharge is the sole cause of the fish contamination or even a substantial contributor of such contamination. However, mercury in an effluent discharge may contribute to the methylmercury present in fish tissue at levels close to or above the fish tissue criterion, and therefore the discharge may be found to exhibit the reasonable potential to cause or contribute to the exceedance of applicable water quality standards. EPA notes that the reasonable potential procedures as a whole are intended as conservative screening procedures to determine when a permit should contain a WQBEL to reduce the contribution to existing contamination or to prevent further possible degradation.

EPA notes that, unlike typical water quality criteria that are expressed as water column values, the fish tissue water quality criterion integrates spatial and temporal complexity and the cumulative effects of mercury loading from point and nonpoint sources that affect methylmercury bioaccumulation in aquatic systems. As discussed further in section 7.5.1.2.2, EPA believes that comparing the fish tissue concentration in steady state systems directly to the applicable fish tissue criterion appropriately accounts for the

factors specified in 40 CFR 122.44(d)(1)(ii) for a criterion expressed as a fish tissue value.

Finally, EPA further notes that because of the sensitivity of Method 1631E or other sufficiently sensitive methods (as described in section 7.4), it is reasonable to conclude that a discharge below quantitation does not have reasonable potential to exceed the criterion.

7.5.1.1 Step one of the reasonable potential analysis: Determining whether the NPDES-permitted discharger has mercury in its effluent at quantifiable levels

The first step in the reasonable potential analysis is to determine whether the discharge contains a quantifiable amount of mercury. To determine this, EPA recommends that permitting authorities require monitoring using a sufficiently sensitive analytical method approved for use by EPA under 40 CFR part 136. Section 7.4 contains additional information about sufficiently sensitive EPA-approved methods. If an alternate EPA-approved method cannot be justified as being sufficiently sensitive, EPA recommends monitoring using the most recent version of method 1631 to help identify all facilities that contribute to mercury water quality impairment. EPA recognizes that using method 1631 will likely result in a large majority of facilities showing quantifiable mercury discharges. This approach, however, is intended to allow permitting authorities to determine that facilities without quantifiable levels of mercury may not need step two of the reasonable potential analysis (determining whether the fish tissue criterion is being attained).

One of three outcomes will be reached in answering the first condition of the reasonable potential analysis:

- It is unknown whether the discharge includes a quantifiable amount of mercury.
- The discharge does not include a quantifiable amount of mercury.
- The discharge includes a quantifiable amount of mercury.

The recommended reasonable potential determination and recommended permit conditions for each of the outcomes is described in detail below.

7.5.1.1.1 What are the recommended permit conditions when it is unknown whether the discharge includes quantifiable amounts of mercury because there are limited or no effluent data to characterize the discharge of mercury?

In this situation, EPA recommends that the permitting authority include permit conditions that include the following elements:

- Effluent monitoring using a sufficiently sensitive EPA-approved analytical method to characterize the discharger's effluent for mercury (see sections 7.4 and 7.5.1.1 for information on sufficiently sensitive methods)
- A reopener clause to identify the actions that the permitting authority may take should the monitoring information indicate that a WQBEL for mercury is necessary

EPA recommends that permitting authorities require monitoring, using a sufficiently sensitive EPA-approved method, by all facilities for which the mercury levels are unknown or previously undetected (using less sensitive methods) to characterize the discharger's effluent for mercury. EPA recommends this monitoring to help identify all facilities that contribute to mercury loads in the waterbody. The permitting authority could obtain these monitoring data as part of the permit application, by requiring periodic (e.g., quarterly to annually) monitoring as part of the permit, or by invoking its authority under CWA section 308 (or equivalent state authority) to require NPDES facilities to collect information necessary for developing NPDES permit limits. The permit should include a reopener clause so that as soon as there is complete information and an indication that a more stringent limit is required, the permitting authority can establish the necessary requirements. The permitting authority may also decide to no longer require the monitoring if the information shows that the facility is not discharging mercury at quantifiable levels.

EPA recommends that when selecting the monitoring frequency, permitting authorities consider the factors in section 5.7.5 of the TSD (USEPA 1991). This section acknowledges that EPA has not recommended a specific monitoring frequency. However, the TSD recognizes that the choice of a monitoring frequency is a site-specific decision and provides the permitting authority with a number of factors to consider when making these decisions.

Until the permitting authority has sufficient data to determine whether the discharge has reasonable potential, and depending on the particular facts, the permit writer may reasonably conclude that the permit conditions described in this section are as stringent as necessary to achieve water quality standards, as required by CWA section 301(b)(1)(C).

7.5.1.1.2 What are the recommended permit conditions when the discharge does not include quantifiable amounts of mercury?

In this situation, EPA recommends that the permitting authority first review the monitoring data to determine whether they are representative of the effluent. If the permitting authority believes the monitoring data are representative of the discharge, no further permit conditions may be necessary. In contrast, if the permitting authority believes the data are not representative, the authority should consider requiring additional monitoring, as described in section 7.5.1.1.1.

7.5.1.1.3 What are the recommended actions for discharges that include quantifiable amounts of mercury?

In this case, the permitting authority should move to step two of the reasonable potential analysis and evaluate data on the concentrations of methylmercury in the fish tissue from the receiving waterbody to determine appropriate permit conditions (see section 7.5.1.2).

7.5.1.2 Step two of the reasonable potential analysis: Determining whether the fish tissue concentration of methylmercury in the receiving waterbody exceeds the fish tissue criterion

In step two of EPA's recommended fish tissue criterion reasonable potential procedure, the permitting authority has concluded that the first condition of the two-part reasonable potential analysis has been satisfied (i.e., the NPDES-permitted discharger has mercury in

its effluent at a quantifiable level). The permitting authority should then address the second condition of the reasonable potential analysis—determining whether the fish tissue from the receiving waterbody exceeds (or is close to exceeding) the fish tissue water quality criterion.

One of three outcomes will be reached in answering this question:

- The fish tissue concentration of methylmercury is unknown.
- The fish tissue concentration of methylmercury does not exceed the criterion or is not close to the criterion.
- The fish tissue concentration of methylmercury exceeds the criterion or is close to exceeding the criterion.

For discharges with quantifiable levels of mercury, the recommended reasonable potential determination and recommended permit conditions for each outcome is described in detail below.

EPA recognizes that when evaluating reasonable potential, the permitting authority should exercise discretion and careful judgment in determining whether fish tissue data are representative of current ambient conditions. EPA guidance for sampling strategies for fish tissue monitoring is provided in section 4.2 of this document.

7.5.1.2.1 What are the recommended permit conditions when a facility discharges quantifiable amounts of mercury but the fish tissue concentrations of methylmercury in the receiving waterbody are unknown?

In waterbodies for which there are insufficient fish tissue data available, a permitting authority cannot determine whether there is reasonable potential using a fish tissue approach. Therefore, in this case, EPA recommends that the permitting authority take the following actions:

- Include a special permit condition to conduct a mercury fish tissue survey for the receiving waterbody, unless such information will be available from another source in a timely manner.
- Include as a permit condition a reopener clause to identify the actions that the permitting authority may take should fish tissue monitoring information become available and indicate that a WQBEL for mercury is necessary.
- Encourage the permittee to develop and implement an MMP tailored to the facility's potential to discharge mercury.

In this instance, the permitting authority should start a process for collecting fish tissue data in the waterbodies where point source discharges of mercury exist. One approach for collecting this information is for the permitting authority to invoke its authority under CWA section 308 (state permitting authorities would use comparable state authorities) to require NPDES facilities to collect information necessary for the development of NPDES permit limits. In this case, the permitting authority could issue a section 308 letter or include special conditions in the permit to require the permittee to conduct a methylmercury fish tissue monitoring study. EPA recommends that the study design be

consistent with the recommendations on conducting ambient monitoring in section 4.2 of this guidance.

EPA also recommends that the permitting authority require only one study per waterbody. The permitting authority could do this by contacting all facilities that discharge into the waterbody and encouraging them to work jointly to conduct the study, because the outcomes of the study may affect the permit limits of those facilities. For example, the State of Idaho has developed a statewide fish tissue monitoring program for mercury that provides a standardized approach for collecting reliable data while recognizing limited resources for monitoring.

In waterbodies where the permitting authority expects to find high mercury concentrations in the water column or believes it will need a site-specific BAF to finish issuing the permits, the permitting authority should consider requiring the facility to include measurement of water column concentrations of mercury as part of the study.

EPA further recommends that the permit include a reopener clause so that as soon as there is complete information, the permitting authority can establish any additional requirements that are necessary. In this situation EPA recommends that the permitting authority encourage the permittee to develop and implement an MMP for the reasons discussed in section 7.5.1.2.2.1.

7.5.1.2.2 What are the recommended permit conditions when a facility discharges quantifiable amounts of mercury but the fish tissue concentrations of methylmercury in the receiving waterbody do not exceed and are not close to the criterion?

Once the permitting authority has determined that a facility discharges quantifiable amounts of mercury and that the concentration of methylmercury in fish tissue in the receiving waterbody does not exceed and is not close to the criterion, depending on the particular facts, the permitting authority may reasonably conclude that the discharge does not have reasonable potential to cause or contribute to an exceedance of the applicable fish tissue water quality criterion.

To assist in preventing future impairments, in some situations as outlined below, EPA recommends that states and authorized tribes also consider other factors or conditions such as a trend of rising fish tissue concentrations or the relative contribution of mercury or methylmercury from the source when determining whether a facility has reasonable potential in waters that are not yet impaired.

EPA notes that, unlike typical water quality criteria that are expressed as water column values, the fish tissue water quality criterion integrates spatial and temporal complexity as well as the cumulative effects of variable mercury loading from point and nonpoint sources that affect methylmercury bioaccumulation in aquatic systems. EPA believes that comparing the fish tissue concentration in steady state systems directly to the applicable criterion expressed as a fish tissue value appropriately accounts for the factors specified in 40 CFR 122.44(d)(1)(ii) for a criterion expressed as a fish tissue value. Existing tissue-based data are indicators of accumulation that has already occurred. Thus, where fish tissue concentrations in a watershed are expected to be constant (i.e., steady state conditions) or decreasing over time, data that indicate that the fish tissue criterion is

currently being attained may be effective indicators of current and potential continued future attainment.

However, in dynamic systems where the levels in tissue in a watershed may be expected to increase, EPA recommends that the permitting authority account for this as part of the reasonable potential determination that is designed to prevent potential future impairments.

Another factor that permitting authorities may consider is the impact of permitted discharges to downstream waters (e.g., a discharge to a river that flows into a lake where mercury is a concern). In such a circumstance, it may be appropriate to conclude that the discharge has reasonable potential on the grounds that its discharge causes or contributes to the excursion of the fish tissue criterion in the downstream water.

The presence of these other factors or conditions such as the relative contribution of mercury or methylmercury from the source, rising fish tissue concentrations, or potential excursion of the criterion downstream, could constitute a basis for concluding that an effluent limit is necessary depending on the particular facts.

As discussed in section 7.5.1.2.2.2, for discharges to waters that are not impaired, EPA recommends that states and tribes regard any activity that could result in an increase in receiving water or fish tissue mercury concentration as a significant lowering of water quality for the purposes of triggering an antidegradation review.

Implementing tier 2 antidegradation

If the facility undertakes any activity that could increase mercury loading to the receiving waterbody, an antidegradation review may be necessary. Such increases must be consistent with the applicable antidegradation policy. Federal regulations at 40 CFR 131.6 specify that tribal or state water quality standards must include an antidegradation policy, and federal regulations at 40 CFR 131.12 identify the elements of an acceptable antidegradation policy. Section 303(d)(4)(B) requires that applicable antidegradation requirements be satisfied prior to modifying NPDES permits (for example, prior to removing a WQBEL or including less stringent effluent limitations).

The federal antidegradation policy is composed of three levels of protection commonly referred to as tiers. The first tier, identified at 40 CFR 131.12(a)(1), protects the minimum level of water quality necessary to support existing uses and applies to all waters. This tier prohibits lowering water quality to the point where existing uses are impaired. The second tier, found at 40 CFR 131.12(a)(2), protects water quality where water quality is better than that needed to support "fishable/swimmable" uses of the water. Where these conditions exist, the waterbody is typically considered not impaired, and water quality must be maintained and protected unless it is demonstrated that lowering water quality is necessary to support important social and economic development and that existing uses will be fully protected. The third tier, at 40 CFR 131.12(a)(3), involves the protection of water quality in waterbodies that are of exceptional ecological, aesthetic, or recreational significance. Water quality in such waterbodies, identified and specifically designated by states or authorized tribes as Outstanding National Resource Waters, must be maintained and protected.

States and authorized tribes should determine whether the discharger will undertake an activity that can result in an increase in mercury loading to the receiving waterbody.

One of two outcomes will be reached in answering this question:

- The discharger will not undertake an activity that can increase mercury loading to the waterbody.
- The discharger will undertake an activity that can increase mercury loading to the waterbody.

As part of conducting a tier 2 antidegradation analysis, the permitting authority would evaluate the activity's potential to lower water quality, whether there are alternatives that would avoid lowering water quality, and whether lowering of water quality would be necessary to accommodate important economic or social development in the area of the discharge. EPA considers analyses of potential pollution prevention and enhanced treatment alternatives as an appropriate starting point for the antidegradation review for both industrial and municipal dischargers. See 67 FR 68971, 68979. The results of such an analysis of potential alternatives could provide the basis for developing an MMP.

EPA's recommendations for implementing antidegradation provisions and addressing increases in mercury loads are summarized in figure 8 and explained in sections 7.5.1.2.2.1 and 7.5.1.2.2.2. EPA recognizes, however, that states and tribes have the flexibility to interpret their antidegradation policies differently. For example, some states use limits established at existing effluent quality to implement their antidegradation provisions.

7.5.1.2.2.1 What are the recommended permit conditions when a facility discharges quantifiable amounts of mercury into a waterbody in which the fish tissue concentration of methylmercury does not exceed the criterion and the facility will not undertake an activity that could increase mercury loading to the waterbody?

If the facility discharges a quantifiable amount of mercury and the fish tissue concentration of methylmercury in the receiving water does not exceed the criterion, depending on the particular facts, the permitting authority may reasonably conclude that the discharge does not have reasonable potential to cause or contribute to an exceedance of the applicable fish tissue water quality criterion. In such situations, however, EPA recommends that the permitting authority encourage the facility to develop and implement an MMP.

An MMP helps ensure that the discharge will continue to have no reasonable potential to cause or contribute to an exceedance of applicable water quality standards. The recommendation to develop a voluntary MMP is also based on the extent of potential mercury impairment across the country and the scientific complexities of and uncertainties associated with assessing mercury loadings and evaluating their effects.

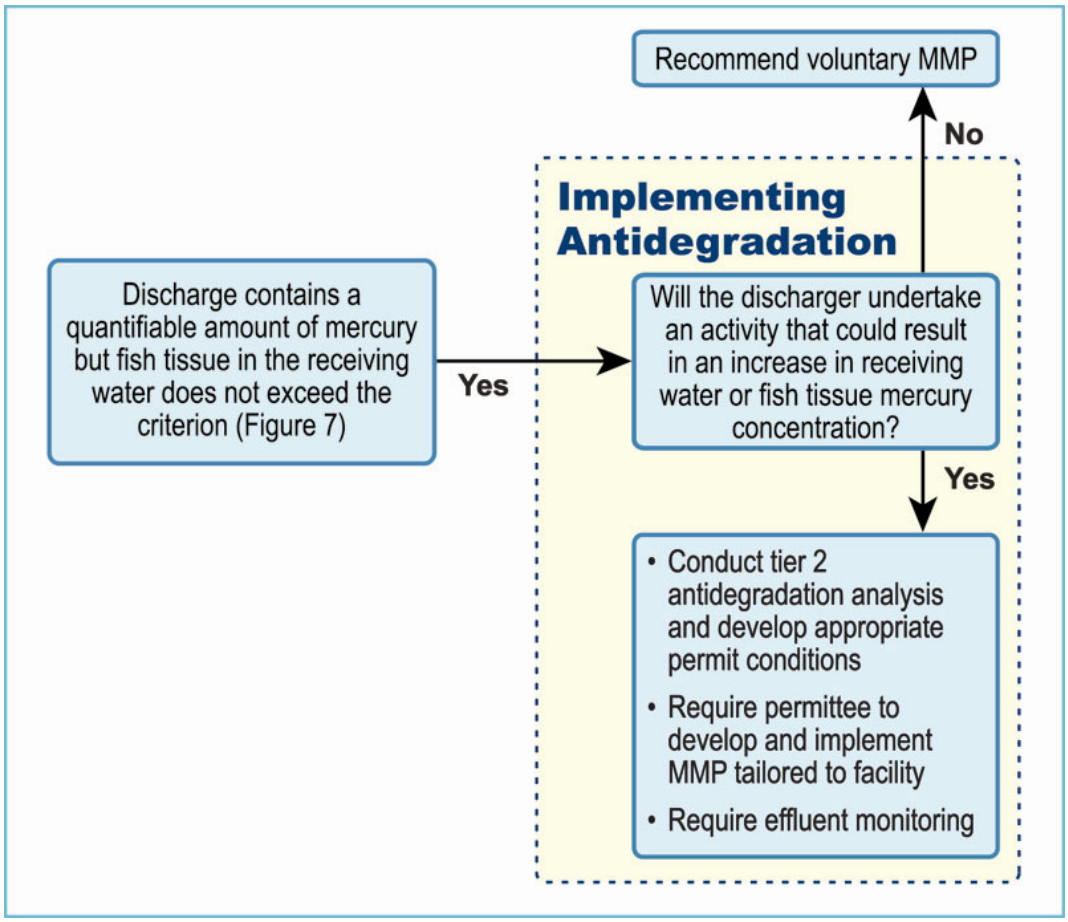


Figure 8. Implementing tier 2 antidegradation.

If future monitoring data demonstrate that a discharge does have reasonable potential, development of a MMP could assist the permit writer in establishing appropriate permit conditions. Furthermore, EPA believes that simply developing an MMP might provide dischargers of mercury with sufficient information to economically reduce the discharge of mercury into our Nation's waters by voluntarily implementing the mercury minimization measures identified in the plan. Section 7.5.2.1 provides additional information on MMPs.

7.5.1.2.2.2 What are the recommended permit conditions when a facility discharges quantifiable amounts of mercury into a waterbody in which the fish tissue concentration of methylmercury does not exceed the criterion but the facility will undertake an activity that could result in an increase in receiving water or fish tissue mercury concentration?

In this situation, the receiving water does not currently exceed the fish tissue criterion. EPA believes that increases in mercury loading to a waterbody should be allowed at levels determined appropriate by an antidegradation analysis and that such dischargers should be required to implement MMPs under the authority of CWA section 402(a)(1)(B) and 40 CFR 122.44(k)(4).

EPA recommends the following WQBEL requirements:

- Include permit conditions consistent with antidegradation requirements.
- Require the permittee to implement an MMP tailored to the facility's potential to discharge mercury. Depending on the particular facts, the permitting authority may include in the MMP a trigger level, reduction goal, or enforceable numeric level to further manage mercury discharges.
- Require the permittee to monitor its effluent using a sufficiently sensitive EPA-approved method (see sections 7.4 and 7.5.1.1 for information on sufficiently sensitive methods).

Other considerations and requirements might be necessary in developing permits:

- The permitting authority would need to include appropriate technology-based limits pursuant to CWA section 301(b) and 40 CFR sections 125.3 and 122.44(a)(1) .
- For modified or reissued permits with existing effluent limits for mercury, any less stringent effluent limit must be consistent with anti-backsliding requirements (see section 7.2.4).

Activities that would lower water quality in a high-quality water must be consistent with the applicable antidegradation provisions of a state's or authorized tribe's water quality standards. Consistent with EPA's antidegradation regulations for water quality standards, state and tribal antidegradation regulations are to provide that the quality of waters at levels better than the levels necessary to support "fishable/swimmable" uses of the water may be lowered only if the state or authorized tribe determines that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located (see 40 CFR 131.12(a)(2)). EPA recommends that states and authorized tribes regard any activity that could result in an increase in receiving water or fish tissue mercury concentration as a significant lowering of water quality for the purposes of triggering a tier 2 antidegradation review. If the state's or authorized tribe's antidegradation analysis determines that the proposed lowering of water quality should not be allowed, the permitting authority would not authorize or allow any such discharge to occur. If the state's or authorized tribe's antidegradation analysis determines that a lowering of water quality is allowable, the level to which the discharger is ultimately allowed to lower water quality (on the basis of the applicable antidegradation requirements) would then be subject to a reasonable potential analysis. Also, EPA's antidegradation regulations for water quality standards require state and tribal antidegradation regulations to protect the minimum level of water quality necessary to support existing uses by prohibiting lowering of water quality to the point where existing uses are impaired (see 40 CFR 131.12(a)(1)).[22] For new and increased discharges, states have the flexibility to interpret their antidegradation policies differently. For example, some states use limits established at existing effluent quality.

[22] This part of the antidegradation analysis is similar to the reasonable potential determination and WQBEL development process that a permitting authority conducts for an existing discharger.

EPA expects that fluctuations in mercury loadings arising from normal industrial production fluctuations, or loading fluctuations that are not results of change in existing POTW service areas, would generally not trigger a tier 2 antidegradation analysis. EPA expects that increases in mercury loadings from a POTW arising from adding a new subdivision or an unsewered neighborhood to a sewer service area would generally trigger a tier 2 antidegradation review. If an antidegradation review is triggered, the review should consider the source of the increased mercury loading, the potential for source reduction through either treatment, pretreatment or pollution prevention, and the expected benefits likely to accrue to the affected community as a result of the activities that result in increased mercury loadings. EPA recommends that states and tribes tailor the level of detail and documentation for antidegradation demonstrations to the specific circumstances. For example, in some instances, as with diffuse domestic sources of mercury, available treatment and pollution prevention alternatives may be limited or lacking, leaving only the importance of social and/or economic development as the primary focus of the review.

EPA recognizes that an increase in the discharge of mercury might be due to mercury present in stormwater or input process water that does not originate with and is not under the reasonable control of a facility. While an MMP, to the extent that there are available BMPs to minimize mercury discharges, might still be appropriate in such circumstances, EPA would not generally expect that such discharges would trigger the need for an antidegradation review, or numeric WQBELs.

In addition to permit conditions consistent with antidegradation requirements, EPA recommends that the permit require the dischargers to implement an MMP under the authority of CWA section 402(a)(1)(B) and 40 CFR 122.44(k)(4). The MMP should be tailored to the individual facility's potential to discharge mercury. For more information on MMPs, see section 7.5.2.1.

7.5.1.2.3 What are the recommended permit conditions when a facility discharges quantifiable amounts of mercury and the fish tissue concentrations of methylmercury in the receiving waterbody are close to or exceed the criterion?

EPA believes that, depending on the particular facts, a permitting authority may reasonably conclude that reasonable potential exists if two conditions are present: (1) the NPDES-permitted discharger has mercury in its effluent at quantifiable levels, and (2) the fish tissue concentrations of methylmercury from the receiving waterbody are close to or exceed the fish tissue water quality criterion.

Where fish tissue concentrations are below but close to the criterion, EPA recommends that a finding of reasonable potential be made since the effect of current discharges and other relevant factors may not yet be reflected in fish tissue concentrations. For example, where the tissue data are below the water quality criterion, the permitting authority may consider applying an appropriate confidence interval (e.g., 95 percent upper confidence limit on the mean) to such values and compare that value to the fish tissue criterion to the extent necessary to account for variability in fish tissue data. As an example of an

alternative to this statistical approach, the State of Idaho's implementation guidance[23] for its methylmercury fish tissue criterion of 0.3 mg/kg recommends that where the levels in fish exceed 0.24 mg/kg, the permitting authority should determine that reasonable potential exists. Where methylmercury levels in fish tissue are thought to be relatively sensitive to a water point source load of mercury or methylmercury, the permitting authority may take that into account in the reasonable potential determination.

When reasonable potential exists, it is necessary to establish an appropriately protective WQBEL in the permit. For guidance on recommended WQBELs, see section 7.5.2.1.

7.5.1.3 How to consider mercury in intake water with a reasonable potential approach

For some facilities, the only source of mercury in a discharge may be the intake water taken directly from the same body of water to which the facility discharges. An example of this is a discharge of cooling water where the source of the cooling water is upstream of the discharge. In these situations where there are no known sources or additional contributions of mercury at the facility, the permitting authority could reasonably conclude, based on the particular facts, that there is no reasonable potential to cause or contribute to an exceedance of water quality standards. Furthermore, any slight increase in concentration after discharge (due to evaporation or other water loss) should not have an effect on the bioaccumulation of methylmercury in fish tissue unless the fish are known to frequently inhabit the water in the area immediately adjacent to the discharge. In making this decision, the permitting authority should consider the monitoring data from both the intake and discharge to verify that there are no known sources of additional contributions of mercury at the facility. EPA also recommends that permitting authorities consider evaluating whether the methylmercury concentration in fish tissue significantly increases for facilities with anaerobic conditions in the discharge. This procedure represents a comprehensive approach for conducting a site-specific analysis of the potential for a discharge to cause or contribute to an excursion above a water quality standard, which can lead to a decision to not require a WQBEL. This approach is consistent with the rationale for the federal regulations pertaining to the Great Lakes Basin, which included consideration of intake pollutants in finding reasonable potential (see 40 CFR part 132, appendix F, procedure 5.D).

7.5.2 Where reasonable potential exists, how can WQBELs be derived from a fish tissue value?

As discussed in section 3.1.2.2 of this document, EPA recommends that states and authorized tribes adopt a new or revised methylmercury water quality criterion in the form of a fish tissue concentration. When the criterion is adopted into standards as a fish tissue value, some states and authorized tribes may not have sufficient data to translate from a fish tissue value to a traditional water column value using BAFs or translators. When developing WQBELs, the permitting authority must ensure that the level of water quality to be achieved by such limits derives from and complies with water quality

[23] *Implementation Guidance for the Idaho Mercury Water Quality Criteria* is available at http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/idaho_mercury_wq_guidance.pdf.

standards (see 40 CFR 122.44(d)(1)(vii)). This section provides recommendations on how a permitting authority could derive appropriate WQBELs in the absence of a TMDL and a water column translation of the fish tissue criterion at the time of permit issuance. The information discussed in this section is summarized in figure 9.

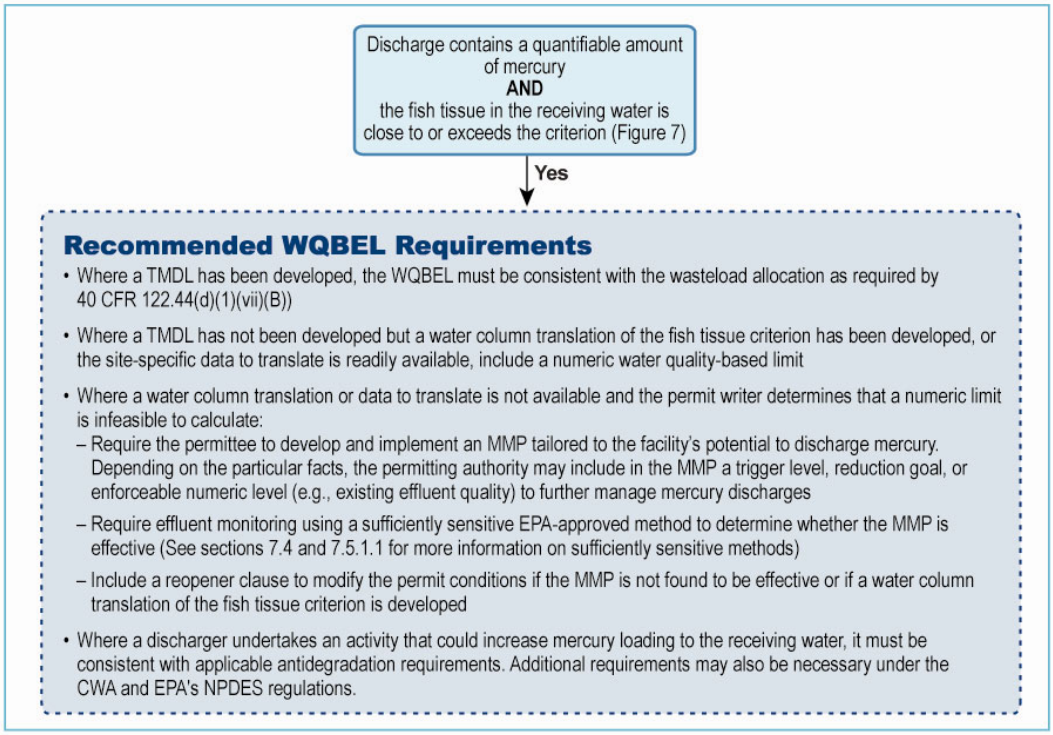


Figure 9. Determining WQBEL requirements.

7.5.2.1 What are the recommended WQBELs?

If the facility has a quantifiable amount of mercury in its discharge and the concentration of methylmercury in fish tissue in the receiving water is close to or exceeds the criterion, depending on the particular facts, the permitting authority may reasonably conclude that the discharge has reasonable potential to cause or contribute to an exceedance of the applicable fish tissue water quality criterion. In this situation, in the absence of a TMDL and a water column translation of the fish tissue criterion, it may be appropriate to conclude that it is infeasible to calculate a numeric WQBEL at the time of permit issuance and to instead express the WQBEL as narrative BMPs, as provided in 122.44(k)(3).

Where a TMDL containing wasteload allocations for the discharge of mercury (and methylmercury where appropriate) has been developed, the WQBEL for that discharge must be consistent with the wasteload allocation (see 40 CFR 122.44(d)(1)(vii)(B)). Where a TMDL is not available at the time of permit issuance, to satisfy 122.44(d)(1)(vii)(A), EPA recommends that the WQBEL consist of the following elements:

- Where a water column translation of the fish tissue criterion has been developed, or site-specific data to do so are readily available, include a numeric water quality-based limit.
- Where a water column translation or site-specific data are not available and the permit writer determines that a numeric limit is infeasible to calculate:
    - Require the permittee to implement an MMP tailored to the facility's potential to discharge mercury. Depending on the particular facts, the permitting authority may include in the MMP a trigger level, reduction goal, or enforceable numeric level to further manage mercury discharges.
    - Require effluent monitoring using a sufficiently sensitive EPA-approved method to enable evaluation of the effectiveness and implementation of the MMP. (See sections 7.4 and 7.5.1.1 for more information on sufficiently sensitive methods.)
    - Include a reopener clause to modify the permit conditions if the MMP is not found to be effective or if a water column translation of the fish tissue criterion is developed.

Other considerations and requirements may be necessary in developing permits:

- Where a discharger undertakes an activity that could increase mercury loading to the receiving water, it must be consistent with applicable antidegradation requirements. Additional requirements may also be necessary under the CWA and EPA's NPDES regulations.
- The permitting authority would need to include appropriate technology-based limits pursuant to CWA section 301(b) and 40 CFR sections 125.3 and 122.44(a)(1) .
- For modified or reissued permits with existing effluent limits for mercury, any less stringent effluent limit must be consistent with anti-backsliding requirements (see section 7.2.4).

7.5.2.2 What does EPA recommend where direct water inputs are relatively high?

This section describes EPA's recommendations where direct water inputs of mercury are relatively high. In this section, EPA discusses the recently developed "5m" listing approach for waters impaired by mercury from primarily atmospheric sources, as well as approaches for developing TMDLs, analyses of sources and loading capacity similar to what would be provided in a TMDL, or water column translations of the fish tissue criterion, to serve as the basis for permit limits.

As described in section 6.2, EPA recently developed an optional voluntary approach for deferring TMDL development for waters impaired by mercury predominantly from atmospheric sources pursuant to CWA section 303(d). Under this approach, states with comprehensive mercury reduction programs may consider waters appropriate for inclusion in a subcategory of their impaired waters lists (category 5m under the Integrated Report Guidance) and defer the development of TMDLs for those waters. EPA's 5m guidance states that in deciding on the scope of waterbodies proposed for

subcategory 5m, a contribution for states to consider would be approximately 90 to 95 percent of the loadings or higher from air deposition to the waterbody; the specific percent may vary, however. A full description of the 5m approach is at http://www.epa.gov/owow/tmdl/mercury5m/.

In watersheds where direct water inputs (mercury from point sources and nonpoint sources other than air deposition) represent a relatively high contribution of mercury, EPA recommends that states and authorized tribes specifically consider developing numeric permit limits for mercury dischargers to these waterbodies. States and authorized tribes may develop TMDLs for these waterbodies in the short term to provide important information for developing appropriate permit limits. Where a state or authorized tribe chooses not to develop a TMDL in the short term for such a waterbody, EPA recommends that the state or tribe develop an analysis of sources and loading capacity similar to what would be provided in a TMDL or a water column translation of the fish tissue criterion using the methods outlined in 3.1.3.1. Consistent with the 5m approach for establishing priorities for mercury TMDL development, in deciding whether there is a relatively high contribution from direct water inputs, a contribution for states to consider would be approximately 5 to 10 percent or more of mercury loadings from direct water inputs, taking into account that the specific percent may vary by state. At the same time, states may consider other factors, such as the complexity of the TMDL, in determining schedules for developing TMDLs.

Cumulative loads from point sources and localized nonpoint sources such as abandoned mines, contaminated sediments, and naturally occurring sources can potentially combine to cause localized mercury impairment. These situations are more complicated because the specific location and magnitude of each source could significantly affect fish tissue concentrations. In these situations, a TMDL provides the best basis for developing the appropriate permit limits.

Once EPA has approved or established a TMDL containing a wasteload allocation for the discharge of mercury (and methylmercury where appropriate), the permitting authority develops a WQBEL for a point source discharge that is consistent with the requirements and assumptions of the wasteload allocation in the TMDL (see 40 CFR 122.44(d)(1)(vii)(B)). In addition to developing a WQBEL, the permitting authority specifies monitoring requirements for the WQBEL (see 40 CFR 122.44(i) and 122.48). EPA recommends that permitting authorities require the permittee to use a sufficiently sensitive EPA-approved method for monitoring purposes.

In such watersheds where direct water inputs represent a relatively high mercury loading, EPA recommends that the permitting authority and the mercury dischargers in the watershed work together to collect the data necessary to develop a TMDL, an analysis of sources and loading capacity similar to what would be provided in a TMDL, or a water column translation of the fish tissue criterion. One approach for collecting information for a source analysis described above or a water column translation of the fish tissue criterion is for the permitting authority to invoke its authority under CWA section 308 (state permitting authorities would use comparable state authorities) to require NPDES facilities to collect information necessary for the development of NPDES permit limits. In the absence of a final TMDL, EPA recommends that a permitting authority conduct an analysis of sources and loading capacity similar to what would be provided in a TMDL.

Such an analysis that applied factors similar to those considered in a TMDL could be included in the fact sheet of the draft permit as a justification for the effluent limit being as stringent as necessary to attain the water quality standard. The permitting authority may also use a water column translation of the fish tissue criterion to derive numeric permit limits if such a translation or site-specific data to translate are available.

A water column translation of the fish tissue criterion may not always be necessary in developing a TMDL or an analysis of sources and loading capacity similar to what a TMDL would provide. For example, section 6.2.2.2.1 of this guidance provides descriptions of TMDLs that have been developed using steady state models and the proportionality approach.

Since permitting authorities need to establish and maintain WQBELs as stringent as necessary to meet water quality standards, if a state or tribe has yet to complete the transition from an existing water column criterion to a fish tissue-based criterion, states may consider retaining their existing water column criteria until translators are developed. Alternatively, until a translator is available, EPA recommends that one of the approaches outlined in this document for relating a concentration of methylmercury in fish tissue to a concentration of methylmercury in ambient water be considered (see section 3.1.3.1.)

7.5.2.3 What additional requirements may apply?

Activities that could increase mercury loadings to a receiving waterbody

Permits for sources that are seeking authorization to increase their discharge of mercury (or commence the discharge of mercury) must be consistent with applicable antidegradation requirements. See discussions of antidegradation elsewhere in this chapter, including sections 7.2.3 and 7.5.1.2.2.

The permitting authority may consider whether an offset of such discharges by other pollutant source reductions would support the development of a WQBEL that would ensure that the level of water quality to be achieved by such effluent limitation is derived from and complies with the water quality standards, as required by 40 CFR 122.44(d)(1)(vii)(A) and any other applicable NPDES regulations.

Pretreatment

A POTW is required to prohibit discharges from industrial users in amounts that result in or cause a violation of any requirement of the POTW's NPDES permit (see 40 CFR 403.2(a) and (b), 403.3(i) and 403.3(n)). A POTW that accepts mercury in its collection systems may need to ensure that its pretreatment program prevents its effluent from contributing to exceedance of the fish tissue criterion. The general pretreatment regulations (at 40 CFR part 403) require that each POTW, or combination of POTWs operated by the same water authority, with a design flow of 5.0 million gallons per day (MGD) or more develop an approved pretreatment program that protects against pass-through and interference, which may be caused by industrial discharges to the treatment facilities, by developing local limits for mercury and other pollutants or demonstrating that limits are not necessary for these pollutants. The POTW is also required to prohibit discharges from industrial users in amounts that result in or cause a violation of any requirement of the POTW's NPDES permit (see 403.2(a) and (b), 403.3(i) and 403.3(n)).

Federal categorical pretreatment standards, which are applicable to certain classes of industries, establish technology-based minimum pretreatment standards. The categorical standards, however, do not address POTW-specific problems that may arise from discharges by categorically regulated industries. In addition, many types of industries that discharge significant quantities of pollutants are not regulated by the categorical standards. Hence, there is a need for many POTWs to establish site-specific discharge limits to protect the treatment facilities, receiving water quality, and worker health and safety and to allow for the beneficial use of sludge.

Technology-based limits

When developing effluent limits for an NPDES permit, a permit writer must impose limits based on the technology available to treat mercury (technology-based limits) as a minimum level of control, as required by CWA section 301(b) and 40 CFR sections 125.3 and 122.44(a)(1). There are two general approaches for developing technology-based effluent limits for industrial facilities: national effluent limitation guidelines (ELGs) and best professional judgment (BPJ) on a case-by-case basis (in the absence of ELGs). Technology-based effluent limits for municipal facilities (POTWs) are derived from secondary treatment standards.

Anti-backsliding

Where a facility has a currently effective effluent limit for mercury and seeks a less stringent limit, the permitting authority must also comply with anti-backsliding requirements (see CWA section 402(o) and 40 CFR 122.44(l); see also CWA section 303(d)(4)). These requirements are described in EPA's *NPDES Permit Writers' Manual* (USEPA 1996b).

Permit documentation

Documentation is an important part of the permit development process. The NPDES permit fact sheet should provide an explanation of how the limit proposed in the associated draft permit is as stringent as necessary to achieve water quality standards (40 CFR 124.8 and 124.56). The recommendations in this guidance could be applied on a permit-by-permit basis, where appropriate, to support effluent limitations and other conditions that satisfy CWA section 301(b)(1)(C) and 40 CFR 122.44(d)(1) with respect to mercury.

7.5.2.4 Mercury minimization plans

EPA recommends that the permit contain a special condition requiring the permittee to implement an MMP that includes effluent monitoring using a sufficiently sensitive EPA-approved method (see sections 7.4 and 7.5.1.1 for information on sufficiently sensitive methods), with the expectation that effluent monitoring will allow for evaluation of the effectiveness and implementation of the plan. The MMP would be included in the permit in addition to a numeric WQBEL in cases where a TMDL, a water column translation of the fish tissue criterion, or other water concentration criterion is available at the time of issuance. If neither a TMDL nor a water column translation (or other water criterion) is available at the time of permit issuance, however, the MMP would be included in the permit as part of a narrative WQBEL in lieu of a numeric WQBEL. EPA believes that,

depending on the particular facts, a permit writer may reasonably conclude that such MMPs are as stringent as necessary to achieve water quality standards, for the reasons discussed below.

EPA believes that mercury reductions achieved through implementing MMPs tailored to the facility's potential to discharge mercury could result in important reductions in mercury loadings. EPA's basis for this conclusion is its study of pollutant minimization programs and their success in reducing mercury loadings to the environment. The reports *Mercury Study Report to Congress* (USEPA 1997c) and draft *Overview of P2 Approaches at POTWs* (USEPA 1999b) show that POTWs and industrial dischargers have implemented source controls, product substitution, process modification, and public education programs with great success. These minimization practices focus on sources and wastes that originate with and are under the reasonable control of a facility, not on pollutants in rainwater or source water.

As an example, POTWs can educate the public to prevent pollution by avoiding household products that contain high levels of mercury or substituting for those products ones that are mercury-free or more environmentally friendly. The most cost-effective approach for POTWs to substantially reduce mercury discharges appears to be pollution prevention and waste minimization programs that focus on high-concentration, high-volume discharges to the collection system, with considerable effort also directed at high-concentration, low-volume discharges such as those from medical and dental facilities.

Using pollutant minimization or prevention programs can also reduce the transfer from wastewater to other media through disposal of mercury-containing sludge from which mercury may subsequently reenter the environment. For example, mercury removed at a POTW through treatment is likely to reenter the environment through POTW sludges that are then incinerated or applied to land (although some is captured by air emission controls on incineration). EPA believes that a better approach for reducing mercury releases to the environment is to prevent mercury from entering the wastewater collection system at the source through product substitution, waste minimization or process modification, or removing and recycling mercury at the source (source controls) using state-of-the-art technology. These measures aimed at reducing influent loads to POTWs also reduce the use of mercury in the community, which could reduce the amount of mercury entering the environment through other media or sources. (For example, products that contain low levels of mercury may be disposed of as a nonhazardous solid waste and incinerated, releasing mercury to the air.) Where pollution prevention approaches have been implemented, substantial reductions in mercury concentrations in POTW influents, sludges, and effluents have been achieved. For a discussion of this approach, see the draft *Overview of P2 Approaches at POTWs* (USEPA 1999a). For an example of guidance on developing an MMP, see the EPA Region 5 final document *Mercury Pollutant Minimization Program Guidance*, dated November 2004 (http://www.epa.gov/region5/water/npdestek/mercury_pmp_nov_04_guidance.pdf). Many of the recommendations contained in the document are drawn from existing guidance and practice of state permitting authorities in EPA's Regional Office in Chicago. See also the City of Superior's document, *Mercury Pollutant Minimization Program Guidance Manual for Municipalities*, at http://www.ci.superior.wi.us/

index.asp?NID=129, and EPA's *Local Limits Development Guidance* (USEPA 2004) at http://www.epa.gov/npdes/pubs/final_local_limits_guidance.pdf.

Finally, as explained in section 2.1.1, mercury is a bioaccumulative, persistent pollutant that can cause adverse health effects. Given this fact, EPA believes that point sources that can cost-effectively reduce their mercury discharges should do so. The fact that air sources or historical contamination are likely dominant causes of impairment does not mean that point sources should not implement cost-effective, feasible pollution prevention measures to reduce their contribution of mercury to the environment, however small those contributions may be. In short, EPA believes that it is reasonable to expect NPDES permittees to implement cost-effective, feasible, and achievable measures to reduce the amount of mercury they discharge into the environment and that, depending on the particular facts, permit writers may reasonably conclude that permit limits that require such measures derive from and comply with water quality standards as required by EPA regulations at 40 CFR 122.44(d)(1)(vii)(A).

In cases where a permittee believes it may have reasonable potential, EPA recommends that the permittee provide information that the permitting authority can use in developing appropriate permit conditions and would encourage the permittee to provide a draft MMP. Alternatively, where a draft MMP is not initially submitted by the permittee, the permitting authority may request that the permittee provide a draft MMP. The permitting authority retains the final responsibility for determining reasonable potential, and for incorporating the appropriate permit conditions, including an effective MMP and its implementation, in the permit.

Developing an MMP need not be an intensive or burdensome activity. The content of an MMP should be determined on a case-by-case basis and tailored to the individual facility's potential to discharge mercury and implement reasonable controls. The MMP could be as little as one or two pages or as much as a major engineering study. Table 6 contains suggestions for the content of an MMP based on the type of facility. Of course, MMPs should vary in their level of detail and degree of stringency on the basis of site-specific factors and the degree to which the facility has the ability to reduce environmental releases of mercury. For example, if the mercury analysis performed for the permit application shows a much higher concentration than would be expected for the type of facility, further investigation would be appropriate and could lead to increased requirements. On the other hand, EPA recognizes that MMPs may not be effective in certain cases such as when an increase in the discharge of mercury may be due to the presence in stormwater or input process water that does not originate with and is not under the reasonable control of a facility.

If a permittee has several of the types of sources listed in table 6, each of these sources should be considered in developing an appropriate MMP. For example, if the service area of a POTW contains dental offices and medical facilities, the MMP should contain appropriate measures for both. The mercury minimization measures suggested in table 6 are expected to reduce mercury levels in the wastewater discharge as well as other waste streams and media. Most of the mercury discharged to POTWs, for example, ends up in biosolids that may be incinerated or disposed on the land, thus contributing to the overall mercury burden in the environment. In addition, any measures that reduce releases to the atmosphere should be encouraged.

Table 6. Suggested content for MMPs based on the type of facility

Type of facility	Suggested content
Publicly (or privately) owned treatment works serving a purely residential area. No dental or medical offices or hospitals. No industrial users.	Recommended distribution of outreach materials on fish-consumption advisories and properly disposing of mercury-containing products.
POTW whose service area contains dental offices.	Recommend or require that dental offices follow American Dental Association BMPs.[a] Collect any bulk mercury in the offices. Develop an approach for using amalgam separators.
POTW whose service area contains one or more hospitals.	Recommend or require that hospitals follow the practices recommended by the American Hospital Association.[b]
POTW whose service area contains schools or medical offices.	Recommend or require that schools and medical offices properly dispose of bulk mercury in their possession (including, for example, mercury-containing sphygmomanometers).
Industrial direct or indirect dischargers that use mercury as an intentional component of their process or recover mercury as a by-product of their process.	Generally, such a case would involve a thorough analysis of opportunities to reduce their releases of mercury.
Industrial direct or indirect dischargers that do not use mercury as an intentional component of their process and do not recover mercury as a by-product of their process.	Such facilities should investigate opportunities to reduce their incidental releases of mercury such as recycling fluorescent lamps, switches, thermostats, etc. and replacing them with low-mercury or non-mercury products.

Notes:

[a] For more information on the American Dental Association BMPs, see Best Management Practices for Amalgam Waste (September 2005) at http://www.ada.org/prof/resources/topics/topics_amalgamwaste.pdf.

[b] For more information on American Hospital Association practices, see Replacing Mercury in Healthcare Facilities—A Step-by-Step Approach at http://www.h2e-online.org/hazmat/mercguide.html.

When developing MMPs, EPA recommends beginning with any existing best management plans and spill prevention and containment control plans for that facility. Many of the activities covered by those plans can also reduce mercury sources to wastewater. After reviewing many pollutant minimization programs, EPA recommends that a plan include at least the following elements:

- Identification and evaluation of current and potential mercury sources
- For POTWs, identification of both large industrial sources and other commercial or residential sources that could contribute large mercury loads to the POTW
- Monitoring to confirm current or potential sources of mercury
- Identification of potential methods for reducing or eliminating mercury, including requiring BMPs or assigning limits to all potential sources of mercury to a collection system, material substitution, material recovery, spill control and collection, waste recycling, process modifications, housekeeping and laboratory use and disposal practices, and public education

- Implementation of appropriate minimization measures identified in the plan
- Effluent monitoring to verify the effectiveness of pollution minimization efforts

EPA believes that these minimum permit conditions may be appropriate because they help to ensure that the discharge does not cause or contribute to an exceedance of water quality standards to protect against possible localized impacts and to minimize the discharge of mercury. EPA also believes that, depending on the particular facts, a permit writer may reasonably conclude that such an MMP is as stringent as necessary to achieve water quality standards.

To further manage mercury discharges, the permitting authority should consider including an effluent trigger level or reduction goal in an MMP. Such a trigger level or goal could be set at a level that would provide a basis for evaluating whether the mercury minimization measures or BMPs specified in the MMP are working as anticipated. The level or goal could be expressed numerically or in narrative form. For example, the MMP might provide a trigger level equal to the existing effluent quality that, if exceeded, would indicate that mercury minimization measures may not be effective. Alternately, the MMP might provide goals for mercury reductions that are expected to occur as a result of the implementation of mercury minimization efforts specified in the MMP. As explained in this section and in section 7.5.2.1, an MMP includes a set of BMPs that would be part of an enforceable special condition of the permit. The MMP might specify that exceeding a trigger level or failing to achieve a mercury reduction goal would prompt actions such as reevaluation of the MMP, additional monitoring, or the implementation of additional BMPs. In this case, the failure of the permittee to undertake the additional actions identified in the MMP would be a violation of the permit special condition.

Even where it is infeasible to calculate a numeric WQBEL (for the reasons discussed in section 7.5.2.1), a permitting authority should consider including in the MMP an enforceable numeric level on the discharge of mercury. In this case, the enforceable numeric level would not constitute a stand-alone water quality-based effluent limit, but rather, a baseline for achieving mercury reductions that, combined with the other measures and practices in the MMP, would together constitute the water quality-based effluent limit. Such an enforceable numeric level could represent either existing effluent quality or a level representing some increment of the mercury reduction determined achievable as a result of the measures and practices specified in the MMP. Depending on the particular facts, the permit writer may reasonably conclude that the enforceable numeric level combined with the other measures and practices in the MMP will result in a level of mercury discharge that is controlled as stringently as necessary to meet water quality standards. Where the MMP contains an enforceable numeric level for mercury and/or methylmercury in the effluent, exceeding that value would be a violation of the permit special condition.

The permitting authorities should consider use of effluent trigger levels, effluent reduction goals, and enforceable numeric levels in any discharge permits that are based on MMPs as water quality-based effluent limits. EPA recommends that permitting authorities include such levels or goals in permits where direct water inputs are relatively high.

8 Related Programs

8.1 What are EPA and others doing as a whole to address mercury?

A wide variety of actions are under way in the United States and internationally to address mercury contamination. EPA's mercury Web site, at http://www.epa.gov/mercury, provides a broad range of information about mercury: actions by EPA and others, including international actions, effects on people and the environment, and how people can protect themselves and their families.

With respect to EPA's actions, on July 5, 2006, EPA issued a report titled *EPA's Roadmap for Mercury* ("*Roadmap*"). It is at http://www.epa.gov/mercury/roadmap.htm. EPA's *Roadmap* describes the Agency's progress to date in addressing mercury issues domestically and internationally, and it outlines EPA's major ongoing and planned actions to address risks associated with mercury. The *Roadmap* describes the Agency's most important actions to reduce both mercury releases and human exposure to mercury. Creating the *Roadmap* has enabled EPA to maximize coordination of its many diverse efforts, with the goal of improving its mercury program. In addition to providing a roadmap for EPA, the report provides important information about mercury to other federal agencies; to EPA's partners in state, tribal, and local governments; and to the public.

8.2 How does pollution prevention play a role in the methylmercury criterion?

Under the national pretreatment program, POTWs routinely control the volume and concentration of pollutants contributed by significant industrial users (SIUs)[24] to their collection system and wastewater treatment plant. However, as water quality criteria, sludge standards, and air emissions standards become more restrictive, even low levels of pollutants like mercury might cause noncompliance with these standards. Therefore, POTWs must expand pollutant control efforts or install treatment technologies to remove the problem pollutants.

In many cases, large-scale treatment technology is either not yet available or not economically feasible for controlling mercury at POTWs. Instead, POTWs are choosing to develop and implement pollution prevention (P2) strategies to reduce the amount of mercury received by the wastewater treatment plant. Although SIUs can contribute a significant mercury load to the treatment plant, non-SIU sources can also be identified as causing or contributing to the problem. For example, the Western Lake Superior Sanitary District (WLSSD) determined that one SIU and many small non-SIUs (dental facilities)

[24] EPA defines an SIU as (1) any industrial user (IU) subject to a categorical pretreatment standard (national effluent guidelines); (2) any user that discharges an average of 25,000 gallons per day or more of process wastewater or that contributes a process waste stream making up 5 percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant; or (3) any other user designated by the Control Authority (POTW) to be an SIU on the basis that it has a reasonable potential for adversely affecting the POTW's operation or for violating a pretreatment standard or requirement (40 CFR 403.4(v)).

contribute a major portion of the mercury in its wastewater. Sectors historically more difficult to control (e.g., residential) or beyond the POTW's direct control (e.g., pollutants in contaminated inflow/rainfall) can also contribute substantial loadings.

Effective mercury source reduction relies on the POTW's effectively communicating to sector entities that minimal individual efforts can collectively reduce the mercury loading to the environment. Forming partnerships and working with sector representatives to investigate mercury sources, explore alternatives, and assist in implementing selected options is integral to a successful reduction strategy. Permitting authorities developing a P2 plan should consider a POTW's role in compliance assistance. The sections below provide summary-level guidance for developing a POTW P2 plan.

Through the pretreatment program, POTWs should communicate with their permitting authority, as well as maintain close contact with local sewer dischargers and have a good understanding of specific industrial process operations. Thus, they can uniquely promote P2 to numerous facilities and provide public awareness and education. In general, the success of a POTW P2 effort depends on a behavioral change on the part of the POTW and the community. As noted by the City of Palo Alto, "Experience shows that people are more likely to change their behaviors if they fully understand environmental problems and the range of possible solutions, if they have participated in the process leading to a policy decision, and if they believe regulators are dealing with them in good faith...." (City of Palo Alto 1996). A POTW might minimize community resistance and apathy by undertaking the following activities prior to developing its plan:

- Conduct a preliminary investigation of the problem and potential sources. Verify that the problem is not a wastewater treatment plant operational issue. Identify internal sources and any area government facilities in addition to industrial, commercial, and uncontrollable sources that could be contributing to or causing the problem.

- Meet with upper management (e.g., utility director, mayor, council) and discuss the problem, preliminary findings, and potential ramifications. Upper management support will be essential for obtaining necessary resources, funding, equipment, and authority for implementing a P2 plan. Their support will also be necessary for resolving any wastewater treatment plant and government facility issues. Upper management may also advise development of a POTW mission statement that declares goals and the chosen approach. Exhibit 1 provides an example of the WLSSD mission statement (WLSSD 1997).

- Establish a workgroup composed of representatives from government, industry, community, and environmental organizations, preferably those that are familiar with P2 strategies or with the pollutant of concern. The workgroup likely will develop or help develop the plan, guide plan implementation, and measure plan success. Therefore, findings from the preliminary investigation will guide the POTW to select appropriate committee members and experts. Bear in mind that the workgroup size should ensure representation of most interests but not grow so large as to be counterproductive. This group could also prove valuable in disseminating information.

With the support and expertise needed, the POTW and workgroup can draft a plan by doing the following:

- *State the problem* to provide background information about the POTW, problems caused by mercury, and why the POTW is taking action (described in terms that most people can understand).
- *Identify the goals* to determine whether the POTW intends to help minimize mercury introduced to all environmental media (air, water, solid waste), known as "front-end" P2 or merely to minimize the amount of mercury discharged to the wastewater treatment plant. The latter option ignores mercury transfers to other media (e.g., air, solid waste) and is the less environmentally sound option. It may be essential for the POTW to implement a front-end P2 approach and establish waste collection programs for the proper recycling or disposal of mercury-bearing wastes (e.g., thermometers, fluorescent light bulbs).
- Define an approach that outlines the sectors selected for P2 efforts, the criteria for targeting efforts (e.g., size of the source loading, authority available to control the source or sector, time necessary to produce desired results), where efforts will be voluntary or mandatory, who will execute the various program efforts, and how the POTW will proceed where mercury introduction is beyond its control (e.g., contaminated stormwater).
- Identify resources necessary to implement the plan such as staffing, equipment, and funding.
- Create contingency plans that describe actions to be taken if the planned efforts do not succeed, such as obtaining the authority to mandate and enforce P2 or other source control requirements or installing wastewater treatment plant technology.

Exhibit 1. Example Mission Statement

The WLSSD Commitment to Zero Discharge

The WLSSD as a discharger to Lake Superior is committed to the goal of zero discharge of persistent toxic substances and will establish programs to make continuous progress toward that goal. The District recognizes step-wise progress is only possible when pollution prevention strategies are adopted and rigorously pursued. These approaches will focus upon our discharge as well as indirect sources.

WLSSD will work with its users to implement programs, practices, and policies which will support the goal. We will call upon the resources and assistance of the State and federal governments for support, including financial support of the programs to ensure that our users are not penalized unfairly.

WLSSD recognizes that airborne and other indirect sources beyond District control must be addressed in order for significant reductions to occur.

Plans might develop in response to a specific problem (e.g., elevated mercury levels in wastewater treatment plant effluent) or proactively to minimize potential problems. Plans will vary in complexity and in resources necessary to achieve goals. Plan updates should detail successful and failed efforts, such as in the form of lessons learned.

8.3 What regulations has EPA issued pursuant to the CAA to address air emissions of mercury?

As rules and standards pursuant to the CAA have been developed, proposed, and promulgated since the Amendments of 1990, compliance by emitting sources and actions taken voluntarily have already begun to reduce mercury emissions to the air across the country. EPA expects that a combination of ongoing activities will continue to reduce such emissions over the next decade.

EPA has made substantial progress in addressing mercury air emissions under the CAA. In particular, EPA has issued regulations addressing the major contributors of mercury to the air (including, for example, municipal waste combustors; hospital, medical, and infectious waste incinerators; chlor-alkali plants; and hazardous waste combustors). EPA issued regulations for these source categories under different sections of the CAA, including sections 111, 112, and 129. Indeed, as the result of EPA's regulatory efforts, the United States achieved a 58 percent reduction in domestic mercury air emissions between 1990 and 2005 (see figure 4 and http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewMidImg&lShowInd=0&subtop=341&lv=list.listByAlpha&r=216615#11215).

The relevant regulations that EPA has issued to date under the CAA are described briefly below. For more information about other CAA actions to control mercury, see http://www.epa.gov/mercury under "What EPA and Others Are Doing."

8.3.1 Municipal waste combustors

In 1995 EPA promulgated new source performance standards (NSPS) that apply to all new municipal waste combustor units (both waste-to-energy plants and incinerators) with the capacity to burn more than 250 tons of municipal solid waste, including garbage, per day and emission guidelines that apply to existing units with the same capacity through either an EPA-approved State plan or a promulgated Federal plan (see 60 FR 65,415 [December 19, 1995], codified at 40 CFR part 60, subparts Eb and Cb). These regulations cover approximately 130 existing waste-to-energy plants and incinerators, as well as any new plants and incinerators built in the future. The regulations have reduced emissions of a number of HAPs, including mercury, by approximately 145,000 tons per year. The regulations have resulted in about a 90 percent reduction in mercury emissions from domestic municipal waste combustors from 1990 emission levels (57 tons per year of mercury emitted from domestic municipal waste combustors in 1990 versus 2.3 tons per year in 2005). In 2000, EPA promulgated NSPS and emission guidelines establishing similar requirements for small municipal waste combustor units (units with a capacity of 35 to 250 tons per day) (see 65 FR 76,355 [December 6, 2000], codified at 40 CFR part 60, subparts AAAA and BBBB).

8.3.2 Hospital, medical, and infectious waste incinerators

Hospital/medical/infectious waste incinerators (HMIWIs) are used by hospitals, health care facilities, research laboratories, universities, and commercial waste disposal companies to dispose of hospital waste and/or medical/infectious waste. EPA adopted regulations controlling mercury and other emissions from HMIWIs on September 15, 1997 (62 FR 48,348, codified at 40 CFR part 60, subparts Ce and Ec). All existing HMIWIs were required to comply with the regulations by September 15, 2002. EPA estimated that the regulations would reduce mercury emissions from HMIWIs at existing facilities by 93–95 percent (from 16.5 to 0.9-1.2 tons per year). In fact, the actual mercury emission reductions achieved as a result of implementing the regulations were approximately 98 percent. At the time the regulations were issued, EPA expected that 50 to 80 percent of the 2,400 then-existing HMIWIs would close in response to the rule. EPA's rule resulted in a significant change in medical waste disposal practices in the United States. Because of the increased cost of on-site incineration under the 1997 rule, approximately 98 percent of the 2,400 HMIWIs operating at health care facilities in 1997

have shut down or obtained exemptions, and few facilities have installed new HMIWIs (5 new HMIWIs at 4 facilities). Instead, many facilities have switched to other methods of waste treatment and disposal, such as autoclaving and off-site commercial waste disposal. There are currently 57 existing HMIWIs operating at 52 facilities. EPA adopted revised regulations for HMIWIs on October 6, 2009 (74 FR 51,368). The revisions were issued in order to respond to a court remand of the 1997 rule and to satisfy the Clean Air Act section 129(a)(5) requirement to conduct a review of the standards every 5 years. EPA estimates that the revised regulations will reduce mercury emissions at existing HMIWIs by 89 percent (from 0.3 to 0.04 tons per year). The revised mercury standards are estimated to impact 20 HMIWIs, which are expected to employ mercury control technology (e.g., installing activated carbon injection systems or increasing current use of activated carbon). All existing HMIWIs are required to comply with the revised regulations by October 6, 2014.

8.3.3 Chlor-alkali plants

On December 19, 2003, EPA issued final regulations to reduce mercury emissions from chlorine production plants that rely on mercury cells (see 68 FR 70,904, codified at 40 CFR part 63, subpart IIIII). These air regulations have reduced mercury air emissions from existing chlor-alkali plants by approximately 50 percent since the compliance date of December 19, 2006. The regulation requires a combination of controls for point sources, such as vents, and BMPs to address fugitive air emissions, that are more stringent work practices than those required by a preexisting regulation that covered this source category. Today, there are four (4) such plants in the United States, compared to 20 when work on the rule began. In addition, EPA completed a study of fugitive mercury emissions at existing chlor-alkali plants and found the levels of elemental mercury emissions much lower than previously thought. Current total emissions from the four plants are estimated to be approximately 0.3 tons per year of mostly (>98%) elemental mercury.

8.3.4 Hazardous waste combustors

In 2005, EPA published standards under Section 112(d) of the CAA for hazardous waste combustors (HWCs)--incinerators, cement kilns, lightweight aggregate kilns, liquid fuel boilers, solid fuel boilers, and hydrochloric acid production furnaces that burn hazardous waste (70 FR 59402 (October 12, 2005)). The mercury standards for existing and new sources, respectively, are under 40 CFR 63.1216(a)(2) and (b)(2) for solid fuel boilers, 40 CFR 63.1217(a)(2) and (b)(2) for liquid fuel boilers, 40 CFR 63.1218(a)(2) and (b)(2) for hydrochloric acid production furnaces, 40 CFR 63.1219(a)(2) and (b)(2) for incinerators, 40 CFR 63.1220(a)(2) and (b)(2) for cement kilns, and 40 CFR 63.1221(a)(2) and (b)(2) for lightweight aggregate kilns. Approximately 200 HWCs are complying with these standards.

EPA will be reviewing these standards as a result of the D.C Circuit Court of Appeals' approval in June 2009 of EPA’s motion for voluntary remand of the emission standards. Any revised standards would be no less stringent than the current standards.

8.3.5 Coal-fired power plants

At present, the largest single source of anthropogenic mercury emissions in the country is coal-fired power plants. Mercury emissions from U.S. power plants are estimated to account for about one percent of total global mercury emissions (70 FR 15994; March 29, 2005). EPA has initiated a rulemaking effort to develop emission standards under Clean Air Act section 112(d) for emissions of hazardous air pollutants (including mercury) from coal- and oil-fired electric utility steam generating units. Consistent with a Consent Decree, the Agency intends to issue final emission standards for these units by the end of 2011.

8.3.6 Other

In addition to EPA's regulatory efforts under the CAA, in 1996 the United States eliminated the use of mercury in most batteries under the Mercury Containing and Rechargeable Battery Management Act. This action reduces the mercury content of the waste stream, which further reduces mercury emissions from waste combustion. In addition, voluntary measures to reduce use of mercury-containing products, such as the voluntary measures to which the American Hospital Association has committed, will contribute to reduced emissions from waste combustion.

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Appendix A. Methylmercury/Mercury Ratio Exhibited in Muscle Tissue of Various Freshwater Fish Species

Source	Ecosystem type	Fish species	MethylHg/ total Hg ratio
Hammerschmidt et al. 1999	Freshwater lakes in Wisconsin, USA	Yellow perch (*Perca flavescens*)	mean: 0.95 range: 0.84 to 0.97
Becker and Bigham 1995	Onondaga Lake, a chemically contaminated lake in New York, USA	Gizzard shad (*Dorosoma cepedianum*) White perch (*Morone americana*) Carp (*Cyprinus carpio*) Channel catfish (*Ictalurus punctatus*) Bluegill (*Lepomis macrochirus*) Smallmouth bass (*Micropterus dolomieui*) Walleye (*Stizostedion vitreum*)	> 0.90 Note: Authors did not provide specific percentages for individual species.
Grieb et al. 1990	Lakes in the Upper Michigan Peninsula, USA	Yellow perch (*Perca flavescens*) Northern pike (*Esox lucius*) Largemouth bass (*Micropterus salmoides*) White sucker (*Catostomus commersoni*)	0.99 Note: Authors did not provide data for each species separately—only mean value observed over all species.
Bloom 1992	Freshwater fish species collected from remote midwestern lakes and one mercury contaminated site USA	Yellow perch (*Perca flavescens*) Northern pike (*Esox lucius*) White sucker (*Catostomus commersoni*) Largemouth bass (*Micropterus salmoides*)	0.99 1.03 0.96 0.99
Lasorsa and Allen-Gil 1995	3 lakes in the Alaskan Arctic, USA	Arctic grayling Lake trout Arctic char Whitefish	1.00 all for species Note: Authors did not provide species-specific information on MeHg/total Hg ratio.
Kannan, et al. 1998	Estuaries in South Florida	Hardhead catfish (*Arius felis*) White grunt (*Haemulon plumieri*) Sand perch (*Diplectrum formosum*), Lane snapper (*Lutjanus synagris*) Gafftopsail catfish (*Bagre marinus*) Pinfish (*Lagodon rhomboides*) Spot (*Leiostomus xanthurus*) Pigfish (*Orthopristis chrysoptera*) Sand seatrout (*Cynoscion arenarius*) Brown shrimp (*Penaeus aztecus*)	0.90 0.91 0.91 0.97 0.71 0.78 0.75 0.82 0.85 0.72 Note: Author sampled the 10 fish species at 20 locations.
Jackson 1991	Lakes and reservoirs in northern Manitoba, Canada	Walleye (*Stizostedion vitreum*) Northern pike (*Esox lucius*) Lake whitefish (*Coregonus clupeaformis*)	range: 0.806% to 0.877% range: 0.824% to 0.899% range: 0.781% to 0.923% Note: Author sampled the 3 fish species at 4 lake locations.

Source	Ecosystem type	Fish species	MethylHg/ total Hg ratio
Wagemann et al. 1997	Sampling location not provided; presumed to be from Canadian waters	Walleye (*Stizostedion vitreum*)	mean 1.00 Note: Authors did not provide more specific information.

For trophic level assignments for specific fish species, refer to tables 6-4 and 6-6 of the 2000 Human Health BAF guidance (USEPA 2003). Additional information on trophic level assignments is in the appendix of that guidance (http://www.epa.gov/waterscience/criteria/humanhealth/method/tsdvol2.pdf).

Appendix B. Tables from Methylmercury Criteria Document

This appendix contains several tables taken directly from the 2001 methylmercury criteria document. They are repeated here to help the reader understand the development of the 2001 criterion.

Table B1. Exposure parameters used in derivation of the water quality criterion.

(References cited in this table can be found in the 2001 methylmercury criterion document.)

Parameter	Population			Source
	Children (0-14 years)	Women of Childbearing Age (15-44 years)	Adults in the General Population	
Body Weight, kg	30	67	70	USEPA (2000f)
Drinking Water Intake, L/day	1.0	2.0	2.0	USEPA (2000f)
Freshwater/Estuarine Fish Intake, g/day	156.3[a]	165.5[a]	17.5[b,c]	USEPA (2000f)
Inhalation, m^3/day	10.4	11	20	USEPA (1994, 1997d)[d]
Soil Ingestion, g/day	0.0001, 0.01[e]	0.00005	0.00005	USEPA (1997d)
Mean Marine Fish Intake, g/day	74.9[a]	91.04[a]	12.46[b]	USEPA (2000a)
Median Marine Fish intake, g/day	59.71[a]	75.48[a]	0[b]	USEPA (2000a)
90th Percentile Marine Fish Intake, g/day	152.29[a]	188.35[a]	49.16[b]	USEPA (2000a)

Notes:

[a] For children and women of childbearing age, intake rates are estimates of "consumers only" data (as described in USEPA 2000a).

[b] For adults in the general population, intake rates are estimates of all survey respondents to derive an estimate of long-term consumption (USEPA).

[c] This is the 90th percentile freshwater and estuarine fish consumption value.

[d] Inhalation rates for children and women of childbearing age from USEPA, 1997d. Inhalation rates for adults in the general population from USEPA (1994).

[e] Pica child soil ingestion.

Table B2. Average mercury concentrations in marine fish and shellfish[a]

(References cited in this table can be found in the 2001 methylmercury criteria document.)

Species	Concentration[b] (µg Hg/g Wet Wt.)	Species	Concentration (µg Hg/g Wet Wt.)
Finfish			
Anchovy	0.047	Pompano*	0.104
Barracuda, Pacific	0.177	Porgy*	0.522[d]
Cod*	0.121	Ray	0.176
Croaker, Atlantic	0.125	Salmon*	0.035
Eel, American	0.213	Sardines*	0.1
Flounder*[,c]	0.092	Sea Bass*	0.135
Haddock*	0.089	Shark*	1.327
Hake	0.145	Skate	0.176
Halibut*	0.25	Smelt, Rainbow*	0.1
Herring	0.013	Snapper*	0.25
Kingfish	0.10	Sturgeon	0.235
Mackerel*	0.081	Swordfish*	0.95[e]
Mullet	0.009	Tuna*	0.206
Ocean Perch*	0.116	Whiting (silver hake)*	0.041
Pollock*	0.15	Whitefish*	0.054[f]
Shellfish			
Abalone	0.016	Oysters	0.023
Clam*	0.023	Scallop*	0.042
Crab*	0.117	Shrimp	0.047
Lobster	0.232	Other shellfish*	0.012[d]
Molluscan Cephalopods			
Octopus*	0.029	Squid*	0.026

Notes:

*Denotes species used in calculation of methylmercury intake from marine fish for one or more populations of concern, based on existence of data for consumption in the CSFII (USEPA 2000a).

[a] More current information on commercial fish and shellfish is provided by the Food and Drug Administration at http://www.cfsan.fda.gov/%7Efrf/sea-mehg.html.

[b] Mercury concentrations are from NOAA (1978) as referenced in the NMFS database, as reported in USEPA (1997c) unless otherwise noted, measured as micrograms (µg) of mercury per gram (g) wet weight of fish tissue.

[c] Mercury data for flounder were used to estimate mercury concentration in marine flatfish for intake calculations.

[d] Mercury concentration data are from Stern et al. (1996) as cited in USEPA (1997f).

[e] Mercury concentration data are from U.S. FDA Compliance Testing as cited in USEPA (1997f).

[f] Mercury concentration data are from U.S. FDA (1978) compliance testing as described in the NMFS database, as cited in USEPA (1997f).

Table B3. Exposure estimates for methylmercury and percent of total exposure based on adults in the general population

Exposure Source	Exposure Estimate (mg/kg-day)	Percent of Total Exposure	Percent of RfD
Ambient water intake	4.3×10^{-9}	0.0047	0.004
Drinking water intake[a]	5.6×10^{-8}	0.0605	0.006
Nonfish dietary intake	0	0	0
Marine fish intake	2.7×10^{-5}	29.33	27
Air intake	4.6×10^{-9}	0.005	0.005
Soil intake	1.3×10^{-9}	0.0014	0.001

Note:

[a] This represents the high-end of the range of estimates. Because the contribution of ambient water or drinking water intake to total exposure is so negligible in comparison to the sum of intake from other sources, there is not difference in the total exposure estimated using either of these two alternatives.

Appendix C. Analytical Methods

Table C1. Analytical methods for determining mercury and methylmercury in tissue

Method	Form/species and applicable matrices	Quantitation Level or ML[a]	Technique	Known studies or literature references using the techniques in this method
Method 1630, with draft modifications for tissue (Recommended method – see section 4.1.3)	Methylmercury in tissue	0.001 mg/kg 0.002 mg/kg	Tissue modification: digest tissue with acid solution, neutralize with acetate buffer, and analyze as per Method 1630, i.e., distillation with heat and N_2 flow to separate methylHg from sample, ethylation with sodium tetraethyl borate, N_2 purging of methylethylHg onto graphite carbon (Carbotrap) column, thermal desorption of methylethylHg and reduction to Hg^0, followed by CVAFS detection.	• EPA Cook Inlet Contaminant Study • Lake Michigan fish and invertebrates, Mason and Sullivan 1997 • Northeastern Minnesota lake plankton, Monson and Brezonik 1998[b] • Method performance testing in freshwater and marine fish, Bloom 1989
Method 1631, draft appendix A (Recommended method – see section 4.1.3)	Total mercury in tissue, sludge, and sediment	0.002 mg/kg	Digest tissue with HNO_3/H_2SO_4. Dilute digestate with BrCl solution to destroy remaining organic material. Analyze digestate per method 1631: Add BrCl to oxidize all Hg compounds to Hg(II). Sequentially pre-reduced with hydroxylamine hydrochloride to destroy the free halogens and reduced with $SnCl_2$ to convert Hg(II) to Hg(0). Hg(0) is purged from solution onto gold-coated sand trap and thermally desorbed from trap for detection by CVAFS.	• EPA National Fish Tissue Study (>1,000 samples over 4-year period) • EPA Cook Inlet Contaminant Study • Lake Michigan fish and invertebrates, Mason and Sullivan 1997 • Northeastern Minnesota lake plankton, Monson and Brezonik 1998[b] • Method performance testing in freshwater and marine fish, Bloom 1989
Method 245.6	Total mercury in tissue	0.020 mg/kg	Sulfuric and nitric acid digestion, oxidation with potassium permanganate and potassium persulfate, $SnCl_2$ reduction, CVAAS detection	Unknown
Draft method 7474 (SW-846)	Total mercury in sediment and tissue	40 mg/kg	Microwave digestion of sample in nitric and hydrochloric acids, followed by cold digestion with bromate/bromide in HCl. Hg purged from sample and determined by CVAFS.	Reference materials cited in method. Niessen et al. 1999.

Notes:

[a] Quantitation level or minimum level (ML) is considered the lowest concentration at which a particular contaminant can be quantitatively measured using a specified laboratory procedure for monitoring of the contaminant.

[b] Used similar techniques but used a methylene chloride extraction instead of the distillation.

Table C2. Analytical methods for determining mercury and methylmercury in water, sediment, and other nontissue matrices

Method	Forms/species and applicable matrices	Quantitation Level or ML	Sample preparation	Known studies or literature references using the techniques in this method
EPA 1630[a] (Recommended method – see section 4.1.3)	Methylmercury in water	0.06 ng/L	Distillation with heat and N_2 flow, addition of acetate buffer and ethylation with sodium tetraethyl borate. Purge with N_2 onto Carbotrap. Thermal desorption and GC separation of ethylated mercury species, reduction to Hg^0 followed by CVAFS detection.	• USEPA Cook Inlet Study • USEPA Savannah River TMDL study • Northern Wisconsin Lakes, Watras et al. 1995 • Lake Michigan waters, Mason and Sullivan 1997 • Anacostia River Study, Mason and Sullivan 1998 • Northeastern Minnesota lakes, Monson and Brezonik 1998[b] • Poplar Creek, TN CERCLA Remedial Investigation of surface water, sediment, and pore water, Cambell et al. 1998[c] • Scheldt estuary study of water, polychaetes, and sediments, Baeyens et al. 1998
UW-Madison SOP for MeHg Analysis[a]	Methylmercury in water	0.01 ng/L	Distillation with heat and N_2 flow, with potassium chloride, sulfuric acid, and copper sulfate. Ethylation with sodium tetraethyl borate. Purge with N_2 onto Carbotrap. Thermal desorption and GC separation of ethylated mercury species, reduction to Hg^0 followed by CVAFS detection.	• Lake Michigan tributaries to support GLNPO's LMMB Study • Fox River, WI, waters and sediments, Hurley et al. 1998
USGS Wisconsin - Mercury Lab SOPs 004[a]	Methylmercury in water	0.05 ng/L	Distillation (heat), APDC solution, N_2 flow, potassium chloride, sulfuric acid, and copper sulfate. Ethylation with sodium tetraethyl borate. Purge with N_2 onto Carbotrap. Thermal desorption and GC separation of ethylated species, reduction to Hg^0, and CVAFS detection.	Aquatic Cycling of Mercury in the Everglades (ACME). cofunded by USGS, EPA, and others
USGS Open-File Report 01-445[a]	Methylmercury in water	0.04 ng/L	Distillation (heat) and N_2 flow, HCl and copper sulfate. Addition of acetate buffer and ethylation with sodium tetraethyl borate. Purge with N_2 onto Carbotrap. Thermal desorption and GC separation of ethylated mercury species, reduction to Hg(0) followed by CVAFS detection.	Formalized USGS method version of USGS Wisconsin Lab SOP 004. Report title is Determination of Methyl Mercury by Aqueous Phase Ethylation, Followed by GC Separation with CVAFS Detection.

Table C2. Analytical methods for determining mercury and methylmercury in water, sediment, and other nontissue matrices *(continued)*

Method	Forms/species and applicable matrices	Quantitation Level or ML	Sample preparation	Known studies or literature references using the techniques in this method
EPA 1631, revision E[d] (CVAFS) (Recommended method – see section 4.1.3)	Total or dissolved mercury in water	ML = 0.5 ng/L (MDL = 0.2 ng/L)	Oxidize all Hg compounds to Hg(II) with BrCl. Sequentially pre-reduce with hydroxylamine hydrochloride to destroy the free halogens and reduce with $SnCl_2$ to convert Hg(II) to Hg(0). Hg(0) is purged from solution with N_2 onto gold coated sand trap and thermally desorbed from trap for detection by CVAFS.	• USEPA Cook Inlet Study • State of Maine studies • USEPA Savannah River TMDL study • USEPA/U.S. Navy study for development of Uniform National Discharge Standards • Watras et al. 1995 • Anacostia River Study, Mason and Sullivan 1998 • Northeastern Minnesota lakes, Monson and Brezonik 1998 • Poplar Creek, TN, CERCLA Remedial Investigation Study, Cambell et al. 1998 • Scheldt Estuary Study, Baeyens et al. 1998
EPA 245.1[d] (CVAAS)	Total or dissolved mercury in wastewater	200 ng/L	H_2SO_4 and HNO_3 digestion, $KMnO_4$, $K_2S_2O_8$ oxidation + heat, cool +NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration. Detection by CVAAS.	Effluent guideline development studies for the Meat Products Industry, Metal Products and Machinery Industry, and Waste Incinerators
EPA 245.2[d] (CVAAS)	Total or dissolved mercury in wastewater and sewage	200 ng/L	H_2SO_4 and HNO_3 added, $SnSO_4$, NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $KMnO_4$, $K_2S_2O_8$, heat. Detection by CVAAS.	MPM Industry effluent guideline development study
EPA 245.5 (CVAAS)	Total or dissolved mercury in soils, sludge and sediment	200 ng/L	Dry sample, aqua regia, heat, $KMnO_4$ added, cool +NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration. Detection by CVAAS.	Pharmaceutical industry effluent guideline development study
EPA 245.7[d] (CVAFS) (Recommended method – see section 4.1.3)	Total or dissolved mercury in water	ML = 5 ng/L; (MDL = 1.8 ng/L) [e]	HCl, $KBrO_3$ /KBr, $NH_2OH{\cdot}HCl$, $SnCl_2$, liquid-vapor separation. CVAFS detection	Interlaboratory validation completed
EPA 7470A (CVAAS)	Total or dissolved mercury in liquid wastes and ground water	200 ng/L (IDL)	H_2SO_4 and HNO_3 added, $KMnO_4$ added, $K_2S_2O_8$ added + heat, cool +NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration of sample. CVAAS detection.	Method is similar to and cites performance data given in EPA 245.5.

Table C2. Analytical methods for determining mercury and methylmercury in water, sediment, and other nontissue matrices *(continued)*

Method	Forms/species and applicable matrices	Quantitation Level of ML	Sample preparation	Known studies or literature references using the techniques in this method
EPA 7471B (CVAAS)	Total or dissolved mercury in solid wastes and semisolid wastes	200 ng/L (IDL)	H_2SO_4 and HNO_3 added, $KMnO_4$ added, $K_2S_2O_8$ added + heat, cool +NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration of sample. CVAAS detection.	Method is similar to and cites performance data given in EPA 245.5.
EPA 7472 (Anodic stripping voltametry)	Total or dissolved mercury in water	100-300 ng/L	Acidify and chlorinate sample, GCE electrode	Unknown
EPA 7473 (Thermal decomposition, amalgamation, and CVAA)	Mercury in water, soil, and sediment	estimated to be as low as 20 ng/ L or 20 ng/kg	Sample aliquot decomposed at 750°C in oxygen atmosphere. Decomposition products carried into catalytical furnace for completed oxidations, then to algamated trap. Mercury is thermally desorbed and determined by CVAA.	Unknown
Draft Method 7474 (SW-846)[f]	Total mercury in sediment and tissue	20 ng/g	Microwave digestion of sample in nitric and hydrochloric acids, followed by cold digestion with bromate/bromide in HCl. Hg purged from sample and determined by CVAFS.	Reference materials cited in method. Niessen et al. 1999.
EPA 1620 (CVAAS)	Mercury in water, sludge, and soil	200 ng/L	H_2SO_4 and HNO_3 added, $KMnO_4$, $K_2S_2O_8$ + heat, cool +NaCl-$(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration. CVAAS detection.	Industry effluent guideline development studies
SM 3112B (CVAAS)	Total or dissolved mercury in water	500 ng/L	H_2SO_4 and HNO_3 added, $KMnO_4$ added, $K_2S_2O_8$ added + heat, cool +NaCl $(NH_2OH)_2{\cdot}H_2SO_4$, $SnCl_2$ or $SnSO_4$, aeration. CVAAS determination.	Unknown
ASTM D3223-97, 02 (CVAAS)	Total or dissolved mercury in water	500 ng/L	H_2SO_4 and HNO_3 added, $KMnO_4$ added,$K_2S_2O_8$ added + heat, cool +NaCl $(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration. CVAAS determination.	Unknown
AOAC 977.22 (Atomic absorption spectrometry)	Total or dissolved mercury in water	200 ng/L	H_2SO_4 and HNO_3 added, $KMnO_4$ added, $K_2S_2O_8$ added + heat, cool +NaCl $(NH_2OH)_2{\cdot}H_2SO_4$, $SnSO_4$, aeration. Determine mercury by CVAA.	Unknown

Notes: (1) CVAAS = cold vapor atomic absorption spectrometry.

(2) CVAFS = cold-vapor atomic fluorescence spectrometry.

(3) ASTM and AOAC analytical methods are available from the respective organization.

[a] All four methylmercury methods above are based on the work of Bloom 1989, as modified by Horvat et al. 1993, and are virtually identical as a result.

[b] Used similar techniques but used a methylene chloride extraction instead of the distillation.

[c] Used similar techniques but omitted the distillation procedure.

[d] Promulgated and approved under 40 CFR part 136, Table 1B.

[e] The method detection level (MDL) is the minimum concentration of an analyte (substance) that can be measured and reported with a 99 percent confidence that the analyte concentration is greater than zero as determined by the procedure set forth in appendix B of 40 CFR part 136.

[f] Provided for reference purposes only. EPA recommends using method 1631 for analyzing mercury for water and fish tissue.

Appendix D. Synopsized Mercury TMDLs Developed or Approved by EPA

I. Ochlockonee Watershed, Georgia

II. Arivaca Lake, Arizona

III. McPhee and Narraguinnep Reservoirs, Colorado

IV. Clear Lake, California

V. Cache Creek, California

VI. Minnesota Statewide Mercury Total Maximum Daily Load

I. Ochlockonee Watershed, Georgia

Description of the Applicable Water Quality Standards

TMDLs are established to attain and maintain the applicable narrative and numerical water quality standards. The State of Georgia's *Rules and Regulations for Water Quality Control* do not include a numeric criterion for the protection of human health from methylmercury, but they do provide a narrative "free from toxics" water quality standard. Because mercury can cause toxicity in humans, Georgia has used a numeric "interpretation" of its narrative water quality standard for toxic substances to ensure that a TMDL will protect human health. The numeric interpretation of its narrative water quality standard is a concentration of no more than 0.3 mg/kg methylmercury in fish tissue. This numeric interpretation protects the "general population," which is the population that consumes 17.5 g/day or less of freshwater fish.

This approach is consistent with EPA's recommended water quality criterion for the protection of human health from methylmercury, described in the document *Water Quality Criterion for the Protection of Human Health: Methylmercury* (USEPA 2001a). The methodology uses a "weighted consumption" approach. When only trophic level 3 and 4 fish have been collected, the methodology assumes that 8 g/day (58.4 percent) of the total fish consumption is trophic level 3 fish (e.g., catfish and sunfish) and 5.7 g/day (41.6 percent) is trophic level 4 fish (e.g., largemouth bass). EPA collected site-specific data from the Ochlockonee River on ambient mercury in fish tissue and in the water column in the summer of 2000 and in March and April 2001 at two locations. Using a weighted consumption approach, site-specific fish tissue concentration data collected in the Ochlockonee River yields a weighted fish tissue concentration of 0.6 mg/kg, which is greater than the state's current applicable water quality criterion of 0.3 mg/kg. This was calculated as

Weighted fish tissue concentration = (avg. trophic 4 conc. x .416) + (avg. trophic 3 conc. x .584)

where:

average trophic level 3 concentration = 0.2 mg/kg
average trophic level 4 concentration = 1.0 mg/kg
weighted fish tissue concentration = 0.6 mg/kg

To establish the TMDL, EPA determined the maximum allowable concentration of mercury in the ambient water that will prevent accumulation of methylmercury in fish tissue above the applicable water quality standard, 0.3 mg/kg. To determine this concentration, EPA used the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (USEPA 2000b). EPA also used the recommended national values from the *Methodology*, including the reference dose of 0.0001 mg/kg-day methylmercury, a standard average adult body weight of 70 kg, and the consumption rate for the general population of 17.5 g/day. For the other factors in the calculation, bioaccumulation and fraction of methylmercury, EPA used site-specific data from the Ochlockonee River collected in summer 2000 and March and April 2001. From this site-specific data, EPA determined a representative weighted BAF. The BAF was calculated

by taking the average calculated BAF from each of the two trophic levels. The BAF calculation also used 0.17 as the measured fraction of the total mercury as methylmercury. Using this approach, an allowable concentration of mercury in the ambient water of Ochlockonee River for the protection of human health is 1.6 ng/L. This concentration was calculated as

$$WQS = \frac{((\text{reference dose} - RSC) \times \text{body weight} \times \text{units conversion})}{(\text{consumption rate} \times \text{weighted BAF} \times \text{fraction MeHg})}$$

Where:

WQS = water quality standard = 1.6 ng/L
reference dose = 0.0001 mg/kg-day MeHg
RSC = relative source contribution from other fish species = 0.000027 mg/kg-day MeHg
body weight = 70 kg
units conversion = 1,000,000 mg/kg
consumption rate = 0.0175 kg/day fish
weighted bioaccumulation factor = 1,063,270 l/kg
fraction of the mercury as methylmercury = 0.17 as measured

Source Assessment

A TMDL evaluation must examine all known potential sources of the pollutant in the watershed, including point sources, nonpoint sources, and background levels. The source assessment was used as the basis of development of a model and the analysis of TMDL allocation options. This TMDL analysis includes contributions from point sources, nonpoint sources, and background levels. Sixteen water point sources in the Ochlockonee River watershed could have mercury in their discharges.

According to a review of the *Mercury Study Report to Congress* (USEPA 1997c), significant potential air emission sources include coal-fired power plants, waste incinerators, cement and lime kilns, smelters, and chlor-alkali factories. In the report, a national airshed model (RELMAP) was applied to the continental United States. This model provides a distribution of wet and dry deposition of mercury as a function of air emissions and global sources, and it was used to calculate wet and dry deposition rates for south Georgia.

The MDN includes a national database of weekly concentrations of mercury in precipitation and the seasonal and annual flux of mercury in wet deposition. EPA reviewed the MDN data for a sampling station near south Georgia. The MDN data were compared with the RELMAP deposition predictions and the MDN data were found to be substantially higher. Using the MDN data, the average annual wet deposition rate was determined to be 12.75 µg/square meter. The dry deposition rate was determined to be 6.375 µg/square meter on the basis of the RELMAP results.

Loading Capacity—Linking Water Quality and Pollutant Sources

The link between the fish tissue endpoint and the identified sources of mercury was the basis for the development of the TMDL. The linkage analysis helped estimate the total

assimilative capacity of the river and any needed load reductions. In this TMDL, models of watershed loading of mercury were combined with a model of mercury cycling and bioaccumulation in the water. This approach enabled a translation between the endpoint for the TMDL (expressed as a fish tissue concentration of mercury) and the mercury loads to the water. The loading capacity was then determined by the linkage analysis as a mercury loading rate that was consistent with meeting the endpoint fish tissue concentration.

Watershed-scale loading of water and sediment was simulated using the WCS. The complexity of this loading function model falls between that of a detailed simulation model (which attempts a mechanistic, time-dependent representation of pollutant load generation and transport) and simple export coefficient models (which do not represent temporal variability). The WCS provides a mechanistic, simplified simulation of precipitation-driven runoff and sediment delivery, yet it is intended to be applicable without calibration. Solids load, runoff, and ground water can then be used to estimate pollutant delivery to the receiving waterbody from the watershed. This estimate is based on pollutant concentrations in wet and dry deposition, processed by soils in the watershed and ultimately delivered to the receiving waterbody by runoff, erosion, and direct deposition. The WCS-calculated loads for each subbasin are shown in table D1.

Table D1. Annual average mercury load from each subbasin

Watershed	Total Hg load (mg)	Areal load (mg/ha)	Impervious area (mg/yr)	Sediment (mg/yr)	Runoff (mg/yr)	Deposition on water (mg/yr)
Barnett Creek	786098.4	25.6	116614.69	422879.88	177553.9	68850
Middle/Lower Ochlocklonee	307965.8	21.24	125771.73	89440.3	54786.29	37867.5
Tired Creek	827172.8	22.03	252386.89	317969.16	194751.7	61965
Lower Ochlockonee	359317.5	15.62	100125.11	130407.68	97802.16	30982.5
Little Ochlockonee	873773.4	19.89	140023.69	433136.75	219614.2	80898.75
Bridge Creek	454417.5	23.11	53496.45	261042.44	98468.66	41310
Upper/Middle Ochlockonee	627746.1	20.67	152881.42	254746.48	182250.7	37867.5
Upper Ochlockonee	766396.8	20.1	164465.44	320337	186825.6	94668.75

WASP5 (Ambrose et al. 1988) was chosen to simulate mercury fate in the Ochlockonee River. WASP5 is a general, dynamic mass balance framework for modeling contaminant fate and transport in surface waters. Environmental properties and chemical concentrations are modeled as spatially constant within segments. Each variable is advected and dispersed among water segments and exchanged with surficial benthic segments by diffusive mixing. Sorbed or particulate fractions can settle through water column segments and deposit to or erode from surficial benthic segments. Within the bed, dissolved variables can migrate downward or upward through percolation and pore water diffusion. Sorbed variables can migrate downward or upward through net sedimentation or erosion.

The toxics WASP model, TOXI5, combines a kinetic structure adapted from EXAMS2 with the WASP5 transport structure and simple sediment balance algorithms to predict dissolved and sorbed chemical concentrations in the bed and overlying waters. TOXI5 simulates the transport and transformation of chemicals as a neutral compound and up to four ionic species, as well as particulate material. Local equilibrium is assumed so that the distribution of the chemical among the species and phases is defined by distribution or partition coefficients. The predicted mercury concentrations are shown in table D2.

Table D2. Predicted mercury for annual average load and flow

Calculated concentrations	River reach					
	1	2	3	4	5	6
Total Hg: water column (ng/L)	6.33	5.84	5.55	5.76	5.65	5.17
Total Hg: sediment (ng/g)	7.05	9.07	9.81	8.17	7.63	6.97
Methyl Hg: water column (ng/L)	0.90	0.82	0.77	0.79	0.77	0.71

Allocations

To determine the total maximum load that can enter the Ochlockonee River, the current loading conditions were evaluated and the instream concentration was determined using the modeling approach described above. This allowed the development of a relationship between load and instream mercury concentrations. Using this developed relationship, the total maximum load could be determined. Because the water column mercury concentration response is linear with respect to changes in load, a proportion could be developed to calculate the total maximum mercury load from the watershed that would achieve the derived water quality target of 1.6 ng/L. The TMDL was calculated as the ratio of the water quality target to the highest segment concentration (1.6 ng/L divided by 6.3 ng/L) applied to the current annual average load of 5.00 kg/yr. This gave a TMDL load of 1.22 kg/yr mercury, which represents a 76 percent reduction from the current annual average load.

In a TMDL assessment, the total allowable load is divided and allocated to the various pollutant sources. The calculated allowable load of mercury that can come into the Ochlockonee River without exceeding the applicable water quality target of 1.6 ng/L is 1.22 kg/yr. Because EPA's assessment indicates that over 99 percent of the current loading of mercury is from atmospheric sources, 99 percent of the allowable load is assigned to the load allocation and 1 percent of the allowable load is assigned to the wasteload allocation. Therefore, the load allocation and the wasteload allocation for the Ochlockonee River are:

Load allocation (atmospheric sources) = 1.16 kilograms/year
Wasteload allocation (NPDES sources) = 0.06 kilograms/year

EPA estimates that atmospheric deposition contributes over 99 percent of current mercury loadings to the river; therefore, significant reductions in atmospheric deposition will be necessary if the applicable water quality standard is to be attained. On the basis of the total allowable load of 1.22 kg/year, a 76 percent reduction of mercury loading is needed to achieve the applicable water quality standard. EPA believes that an estimated

31 percent to 41 percent reduction in mercury deposition to the Ochlockonee River watershed can be achieved by 2010 through full implementation of existing CAA requirements. In addition, a number of activities to address remaining sources of mercury are planned or under way, and EPA expects that further reductions in mercury loadings will occur over time as a result of those activities. EPA is not able to estimate the reductions in mercury deposition to the Ochlockonee River watershed that will be achieved from future activities. As contemplated by CWA section 303(d)(1)(C), however, this TMDL quantifies the water quality problem facing the Ochlockonee River watershed and identifies the needed reductions in loadings from atmospheric deposition—by CAA initiatives or under other authorities—for the watershed to achieve applicable standards for mercury. In addition, as EPA collects additional data and information for the Ochlockonee River watershed and as new legal requirements are imposed under the CAA, EPA will continue to evaluate the effectiveness of regulatory and nonregulatory air programs in achieving the TMDL's water quality target.

The analysis of NPDES point sources in the watershed indicates that the cumulative loading of mercury from these facilities is less than 1 percent of the total estimated current loading. Even if this TMDL allocated none of the calculated allowable load to NPDES point sources (a wasteload allocation of zero), the waterbody would not attain the applicable water quality standards for mercury because of the very high mercury loadings from atmospheric deposition. At the same time, however, EPA recognizes that mercury is an environmentally persistent bioaccumulative toxic with detrimental effects on human fetuses even at minute quantities and that it should be eliminated from discharges to the extent practicable. Taking these two considerations into account, this TMDL provides a wasteload allocation applicable to all Georgia NPDES-permitted facilities in the watershed in the amount of 0.06 kg/year. The TMDL was written so that all NPDES-permitted facilities will achieve this wasteload allocation by discharging mercury only at concentrations below the applicable water quality standard, 1.6 ng/L, or by implementing a pollutant minimization program.

In the context of this TMDL, EPA believes it can reasonably offer the choice of the two approaches to the permitting authority for the following reasons. First, on the basis of EPA's analysis, the Agency expects either wasteload allocation option, in the aggregate, to result in point source mercury loadings lower than the wasteload allocation. Second, EPA believes this flexibility is the best way of ensuring that the necessary load reductions are achieved without causing significant social and economic disruption. EPA recognizes that NPDES point sources contribute a small share of the mercury contributions to the Ochlockonee River. EPA also recognizes, however, that mercury is a highly persistent toxic pollutant that can bioaccumulate in fish tissue at levels harmful to human health. Therefore, EPA has determined, as a matter of policy, that NPDES point sources known to discharge mercury at levels above the amount present in their source water should reduce their loadings of mercury using appropriate, cost-effective mercury minimization measures to ensure that the total point source discharges are at a level equal to or less than the wasteload allocation specified in this TMDL. The point sources' waste load allocation will be applied to the increment of mercury in their discharge that is above the amount of mercury in their source water. EPA recommends that the permitting authority make this choice between the two options in consultation with the affected dischargers

because EPA is not able to make the case-by-case judgments in this TMDL that EPA believes are appropriate.

II. Arivaca Lake, Arizona

Description of the Applicable Water Quality Standards

Authorities develop TMDLs to meet applicable water quality standards. These standards may include numeric water quality standards, narrative standards describing designated uses, and other associated indicators supporting designated uses (beneficial uses apply only to California). A numeric target identifies the specific goals or endpoints for the TMDL that equate to attainment of the water quality standard. The numeric target may be equivalent to a numeric water quality standard (where one exists), or it may represent a quantitative interpretation of a narrative standard.

The applicable numeric targets for the Arivaca TMDL are the Arizona water quality standard of 0.2 µg/L mercury in the water column and the Arizona Fish Consumption Guideline criterion of 1 mg/kg mercury concentration in fish tissue. Arizona has adopted water quality standards for mercury that apply to a number of the designated uses specified for Arivaca Lake, including protection of aquatic life and wildlife and protection of human and agricultural uses. Of these numeric criteria, the most stringent is the chronic aquatic life criterion of 0.01 µg/L dissolved mercury (see table 7 on page 15 in the TMDL). Arizona has also issued a fish consumption advisory for this lake because mercury concentrations in fish tissue exceed 1 mg/kg.

Mercury bioaccumulates in the food chain. Within a lake fish community, top predators usually have higher mercury concentrations than forage fish, and tissue concentrations generally increase with age class. Top predators (such as largemouth bass) are often target species for sport fishermen. Arizona bases its Fish Consumption Guideline on average concentrations in a sample of sport fish. Therefore, the criterion should not apply to the extreme case of the most-contaminated age class of fish within a target species; instead, the criterion is most applicable to an average-age top predator. Within Arivaca Lake, the top predator sport fish is the largemouth bass. The selected target for the TMDL analysis is an average tissue concentration in 5-year-old largemouth bass of 1.0 mg/kg.

Source Assessment

A TMDL evaluation must examine all known potential sources of the pollutant in the watershed, including point sources, nonpoint sources, and background levels. The source assessment is used as the basis for developing a model and analyzing TMDL allocation options. There are no permitted point source discharges and no known sources of mercury-containing effluent in the Arivaca watershed. External sources of the mercury load to the lake include natural background load from the watershed, atmospheric deposition, and possible nonpoint load from past mining activities.

Watershed background load. The watershed background load of mercury was derived from mercury in the parent rock and from the net effects of atmospheric deposition of mercury on the watershed. Some mercury is also present within the parent rock formations of the Arivaca watershed, although no concentrated ore deposits are known.

The net contributions of atmospheric deposition and weathering of native rock were assessed by measuring concentrations in sediment of tributaries to Arivaca Lake. EPA collected 25 sediment and rock samples from dry tributaries in the Arivaca watershed and analyzed them for mercury. These data show that most of the sediment samples from the Arivaca watershed were considered at or near background mercury levels.

Nonpoint loadings from mining. No known mining for mercury itself has occurred in the watershed. However, mining activities for minerals other than mercury, especially historical mining practices for gold, might contribute to mercury loading in the watershed. Gold and silver mining commonly occurred in the area surrounding Arivaca Lake but apparently not within the watershed itself. The U.S. Bureau of Mines identified only one exploratory prospect, for manganese and uranium, within the Arivaca watershed.

Ruby Dump. Ruby Dump is in the southern portion of Arivaca watershed at the very upstream end of Cedar Canyon Wash. The dump apparently served the town of Ruby and the Montana Mine. The waste is characterized by numerous mining artifacts (e.g., crucibles) but also includes many common household items like bottles and plates. Samples were taken at three different locations of the Ruby Dump: the top of the hill (just below the fire pit), the middle of the hill, and the base of the dump. The mercury results for these samples, from the top of the hill to the bottom, were 1,467 ppb, 1,244 ppb (blind duplicate was 495 ppb), and 486 ppb. The average of these four samples is 918 ppb, which is the number used in the watershed modeling to represent the mercury concentration in sediment eroding from this site.

Near-field atmospheric deposition. Significant atmospheric point sources of mercury often cause locally elevated areas of near-field atmospheric deposition downwind. A review of *Mercury Study Report to Congress* (USEPA 1997c) and a search of EPA's AIRS database of permitted point sources found no significant U.S. sources of airborne mercury within or near the Arivaca watershed. Also, the most nearby parts of Mexico immediately to the southwest (prevailing wind direction) of the watershed are sparsely populated. Because of the lack of major nearby sources, especially sources along the axis of the prevailing wind, EPA does not believe that near-field atmospheric deposition of mercury attributable to individual emitters is a major component of mercury loading to the Arivaca watershed. Because no significant near-field sources of mercury deposition were identified, mercury from atmospheric deposition onto the watershed is treated as part of a general watershed background load in this analysis.

Far-field atmospheric deposition. In May 1997 the MDN began collecting deposition data at a new station in Caballo, in the southwestern quadrant of New Mexico. This station is the closest MDN station to the Arivaca Lake and was used to estimate loads to Arivaca Lake. Because the climate at Arivaca is wetter than that at Caballo, the distribution of wet and dry deposition is likely to be different. Monthly wet deposition rates at Arivaca were estimated as the product of the volume-weighted mean concentration for wet deposition at Caballo times the rainfall depth at Arivaca. This approach was used because volume-weighted mean concentrations are usually much more stable between sites than wet deposition rates, which are sensitive to rainfall amount. Dry deposition at Arivaca was then calculated as the difference between the total deposition rate at Caballo and the estimated Arivaca wet deposition rate. The estimates

derived for Arivaca were 5.3 μg/m^2/yr by wet deposition and 7.1 μg/m^2/yr by dry deposition. In sum, mercury deposition at Arivaca is assumed to be equivalent to that estimated for Caballo, New Mexico, but Arivaca is estimated to receive more wet deposition and less dry deposition than Caballo because more of the particulate mercury and reactive gaseous mercury that contribute to dry deposition are scavenged at a site with higher rainfall.

Loading Capacity—Linking Water Quality and Pollutant Sources

The linkage analysis in a TMDL defines the connection between numeric targets and identified sources. The linkage is defined as the cause-and-effect relationship between the selected indicators, the associated numeric targets, and the identified sources. This linkage analysis provides the basis for estimating total assimilative capacity and any needed load reductions. Specifically, for the linkage analysis in the Arivaca TMDL, models of watershed loading of mercury were used together with a model of mercury cycling and bioaccumulation in the lake. This approach enabled a translation between the numeric target (expressed as a fish tissue concentration of mercury) and mercury loading rates. The loading capacity was then determined through the linkage analysis as the mercury loading rate that is consistent with meeting the target fish tissue concentration.

Watershed model, Watershed-scale loading of water and sediment was simulated using the Generalized Watershed Loading Function (GWLF) model. The complexity of this loading function model falls between that of detailed simulation models (which attempt a mechanistic, time-dependent representation of pollutant load generation and transport) and simple export coefficient models (which do not represent temporal variability). GWLF provides a mechanistic, simplified simulation of precipitation-driven runoff and sediment delivery, yet it is intended to be applicable without calibration. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, on the basis of pollutant concentrations in soil, runoff, and ground water. Applying the GWLF model to the period from October 1985 through September 1998 yielded an average of 11.0 cm/year runoff and 2,520,000 kg sediment yield by sheet and rill erosion. The sediment yield estimate is likely to be less than the actual yield rate from the watershed because mass wasting loads were not accounted for; however, mass wasting loads are thought to be of minor significance for loading of bioavailable mercury to the lake.

Estimates of watershed mercury loading were based on the sediment loading estimates generated by GWLF by applying a sediment potency factor. These estimates are shown in table D3. A background loading estimate was first calculated and then combined with estimates of loads from individual hot spots. Most of the EPA sediment samples showed no clear spatial patterns, with the exception of the hot spot area identified at Ruby Dump. Therefore, background loading was calculated using the central tendency of sediment concentrations from all samples excluding Ruby Dump. The background sediment mercury concentrations were assumed to be distributed lognormally, as is typical for environmental concentration samples, and an estimate of the arithmetic mean of 70.9 ppb was calculated from the observed geometric mean and coefficient of variation. Applying this assumption to the GWLF estimates of sediment transport yields an estimated rate of mercury loading from watershed background of 178.9 g/yr.

Table D3. Annual total mercury load to Arivaca Lake

Watershed year	Mercury loading to lake (g/year)			
	From watershed	From Ruby Dump	From direct atmospheric deposition to lake	Total
1986	170.16	0.65	4.208	175.018
1987	184.34	0.7	4.208	189.248
1988	205.61	0.79	4.208	210.608
1989	70.9	0.27	4.208	75.378
1990	198.52	0.76	4.208	203.488
1991	99.26	0.38	4.208	103.848
1992	163.07	0.62	4.208	167.898
1993	233.97	0.89	4.208	239.068
1994	141.8	0.54	4.208	146.548
1995	219.79	0.84	4.208	224.838
1996	170.16	0.65	4.208	175.018
1997	191.43	0.73	4.208	196.368
1998	276.51	1.06	4.208	281.778
Grand total	2,325.52	8.88	54.704	2,389.10
Annual average	178.89	0.68	4.21	183.78

Loading from the Ruby Dump was calculated separately, but it was also based on the GWLF estimate of sediment load generated per hectare of rangeland (the land use surrounding the hot spots), as reduced by the sediment delivery ratio for the watershed. The extent of the hot spot was observed to be 200 feet by 50 feet. The mercury concentration assigned to surface sediments at the dump was the arithmetic average of the four EPA samples taken in October 1997, or 918 ppb. From these assumptions, less than 1 percent of the watershed mercury load to Arivaca Lake appears to originate from Ruby Dump, which is the only identified hot spot in the watershed.

The direct deposition of mercury from the atmosphere onto the Arivaca Lake surface was calculated by multiplying the estimated atmospheric deposition rates times the lake surface area, resulting in a load of 4.2 g/yr.

Lake hydrology model. The water level in Arivaca Lake is not actively managed, and releases occur only when storage capacity is exceeded. Therefore, lake hydrology was represented by a simple monthly water balance. Applying the water balance model requires pan evaporation data as an input, in addition to the watershed meteorological data. Because no evaporation data were available at the local Cooperative Summary of the Day meteorological station, pan evaporation data for Tucson were used. Pan evaporation data for 1980 through 1995 were obtained from the BASINS 2.0 Region 9 data files. Later pan evaporation data were not available for Tucson, so monthly averages were used for the 1996 through 1998 water balance. The water balance model was run for the period 1985 through 1998. This water balance approach provides a rough approximation of the seasonal cycle of changes in volume and surface area of Arivaca

Lake and of the amount of water released downstream over the spillway. It cannot capture daily or event-scale movement of water in and out of the lake.

Mercury cycling and bioaccumulation model. Cycling and bioaccumulation of mercury within the lake were simulated using the D-MCM (EPRI 1999). D-MCM predicts the cycling and fate of the major forms of mercury in lakes, including methylmercury, Hg(II), and elemental mercury. D-MCM is a time-dependent mechanistic model, designed to consider the most important physical, chemical, and biological factors affecting fish mercury concentrations in lakes. It can be used to develop and test hypotheses, scope field studies, improve understanding of cause/effect relationships, predict responses to changes in loading, and help design and evaluate mitigation options.

Because strong anoxia in the hypolimnion is a prominent feature during summer stratification for the Arizona lakes simulated in this study, D-MCM was modified to explicitly allow significant methylation to occur in the hypolimnion. In previous applications of D-MCM, the occurrence of methylation was restricted to primarily within surficial sediments. That the locus of methylation likely includes or is even largely within the hypolimnion is supported by (1) the detection of very high methylmercury concentrations in the hypolimnia of Arivaca Lake and (2) almost complete losses of sulfate in Arivaca Lake in the hypolimnion resulting from sulfate reduction. An input was added to the model to specify the rate constant for hypolimnetic methylation, distinct from sediment methylation.

The results of the model calibration are shown in table D4. The model calculations are the predicted annual ranges after the model has reached steady state. The observed concentrations are from July 1997.

Table D4. Predicted and observed mercury for annual average load and flow

	Predicted	Observed
Methyl Hg: Water column (ng/L)	0.00–12.07	14.3
Hg II: Water column (ng/L)	0.00–6.28	1.46–8.3
Methyl Hg: 5-year-old largemouth bass (mg/kg)	1.18	1.18

Allocations

A TMDL represents the sum of all individual allocations of portions of the waterbody's loading capacity. Allocations may be made to point sources (wasteload allocations) or nonpoint sources (load allocations). The TMDL (sum of allocations) must be less than or equal to the loading capacity; it is equal to the loading capacity only if the entire loading capacity is allocated. In many cases, it is appropriate to hold a portion of the loading capacity in reserve to provide a margin of safety (MOS), as provided for in the TMDL regulation. The allocations and MOS are shown in table D5. These allocations, from the best currently available information, predict attainment of acceptable fish tissue concentrations within a time horizon of approximately 10 years. A delay in achieving standards is unavoidable because time will be required for mercury to cycle through the lake and food chain after load reductions occur.

Table D5. Summary of TMDL allocations and needed load reductions (in g-Hg/yr)

Source	Allocation	Existing load	Needed reduction
Wasteload allocations	0.0	0.0	0.0
Load allocations			
Atmospheric deposition	4.2	4.2	0
Ruby Dump	0.7	0.7	0
Watershed background	111.2	178.9	67.7
Total	116.1	183.8	67.7
Unallocated reserve	38.7		
Loading capacity	154.8		

The model was used to evaluate the load reductions necessary to meet the numeric target. The response of concentrations of mercury in 5-year-old largemouth bass to changes in external mercury loads is nearly linear. This is because the sediment burial rates are high and sediment recycling is low, with most of the methylmercury that enters the food chain being created in the anoxic portion of the water column. The model calculates that the numeric target of 1 mg/kg in 5-year-old largemouth bass is predicted to be met with a 16 percent reduction in total watershed loads to Arivaca Lake, which results in a loading capacity of 154.8 g/year of mercury.

There are uncertainties associated with mercury sources and the linkage between mercury sources and fish tissue concentrations in Arivaca Lake. As a result, the TMDL reserves 38.7 g-Hg/yr (25 percent of the loading capacity) for the MOS and allots the remaining load of 116.1 g-Hg/yr for sources. Because no permitted point source discharges occur within the Arivaca watershed, the wasteload allocation is zero and the load allocation is 116.1 g-Hg/yr.

The load allocation provides loads for three general sources: direct atmospheric deposition onto the lake surface, hot spot loading from Ruby Dump, and generalized background watershed loading, including mercury derived from parent rock and soil material, small amounts of residual mercury from past mining operations, and the net contribution of atmospheric deposition onto the watershed. Direct deposition to the lake surface is a small part of the total load and is believed to derive from long-range transport of global sources, which are not readily controllable. The load from Ruby Dump is also small. As a result, the TMDL does not require reductions from these sources, and their load allocations are their existing loads.

Background watershed loading appears to be the major source of mercury to Arivaca Lake. The intensive watershed survey conducted for this TMDL did not identify any significant terrestrial sources of mercury. Regarding air deposition to the watershed land surface, insufficient data were available to calculate reliable estimates of the proportion of mercury deposited from the air that actually reaches Arivaca Lake. Therefore, a load allocation of 111.2 g-Hg/yr was established for overall background watershed loading. This requires a 38 percent reduction from existing estimated loads from this source. This reduction is believed feasible for several reasons.

Potential for erosion control. Reduction of mercury loading from the watershed to Arivaca Lake depends on reduction in sediment erosion rates. Improved livestock management practices could obtain significant reductions in erosion rates. As a side benefit, implementation of livestock BMPs could result in significant reductions in loadings of DOC and nutrients to the lake. The availability of high levels of DOC and nutrients in the lake appears to affect the methylation process. Reduction of DOC and nutrient levels should reduce the efficiency of the methylation process at Arivaca Lake, effectively increasing the lake's mercury loading capacity.

Reductions in atmospheric deposition of mercury. Although no reliable estimates are available, new mercury air emissions to the environment appear to be declining. U.S. mercury emissions have declined significantly since 1990 and are expected to decline further upon implementation of new emission limits on incinerators as required by recent EPA regulations. Reductions in air deposition in Arivaca Lake watershed would eventually result in decreases in mercury loading to the lake itself.

Potential location and remediation of undiscovered mercury sources. Although investigation of the watershed did not reveal any significant localized sources of mercury in the watershed (with the possible exception of Ruby Dump), additional site investigation is warranted to ensure that no significant sources were missed. From past experience with mine site remediation in similar circumstances in Arizona, newly discovered sites could be effectively eliminated as ongoing mercury sources.

Alternative management strategies. Any alterations in rates of methylation or in rates of mercury loss to deep sediments will change the relationship between external mercury load and fish tissue concentration and would thus result in a change in the loading capacity for external mercury loads. The loading capacity could be increased by management intervention methods that decrease rates of bacterial methylmercury production within the lake or increase rates of burial and sequestration of mercury in lake sediment. Selection of such an approach would require further research and feasibility studies. Some alternative strategies that might be suitable for further investigation include the following:

- Hypolimnion aeration or mixing
- Sulfur chemistry modification
- Alum treatment
- Reduction of DOC and nutrient levels
- Dredging of lake sediments

III. McPhee and Narraguinnep Reservoirs, Colorado

Description of the Applicable Water Quality Standards

The TMDL for McPhee and Narraguinnep Reservoirs in southwestern Colorado was based on the Fish Consumption Advisory action level of 0.5 mg/kg mercury concentration in fish tissue. Colorado Department of Public Health and the Environment listings are based on the risk analysis presented in the May 6, 1991, Disease Control and

Epidemiology Division position paper for *Draft Colorado Health Advisory for Consumption of Fish Contaminated with Methylmercury.* This paper, using a toxicity value RfD of 0.3 µg/kg/day, establishes a fish tissue concentration of 0.5 mg/kg as the approximate center of the range at which the safe consumption level is four meals per month for nonpregnant adults and one meal per month for women who are pregnant, nursing, or planning to become pregnant and children nine years of age or younger. The criterion is applied to an average-age top predator. In McPhee Reservoir, the top predator among sport fish regularly taken is the smallmouth bass (19 percent of the total catch in 1993); the top predator sport fish in Narraguinnep Reservoir is the walleye. The lake water quality model D-MCM (EPRI 1999) is capable of predicting mercury concentrations in fish tissue for each age class at each trophic level. Average mercury concentrations in fish tissue of target species are assumed to be approximated by the average concentration in 15-inch smallmouth bass in McPhee and the 18-inch walleye in Narraguinnep. Therefore, the selected target for the TMDL analysis in McPhee Reservoir is an average tissue concentration in 15-inch smallmouth bass of 0.5 mg/kg or less. The selected target in Narraguinnep Reservoir is the 18-inch walleye of 0.5 mg/kg or less.

Source Assessment

McPhee and Narraguinnep reservoirs have several sources of mercury. The sources external to the reservoirs separate into direct atmospheric deposition onto the lakes (from both near- and far-field sources) and transport into the lakes from the watershed. The watershed loading occurs in both dissolved and sediment-sorbed forms. Ultimate sources in the watershed include mercury in parent rock, mercury residue from mine tailings and mine seeps, point source discharges, and atmospheric deposition onto the watershed, including deposition and storage in snowpack. A summary of the mercury load estimates for McPhee Reservoir is presented in table D6.

Table D6. Summary of mercury load estimates for McPhee Reservoir

Reservoir	Water-shed runoff (g/yr)	Water-shed sediment (g/yr)	Inter-basin transfer (g/yr)	Atmos. deposition (g/yr)	Total (g/yr)	Load per volume (mg/ac-ft)	Load per surface area (mg/m^2)
McPhee	2,576	222		251	3,049	4.66	0.098
Narraguinnep	2.7	22.7	15.9	36.8	78.1	4.59	0.035

Past mining activities likely provide an important source of mercury load to the McPhee and Narraguinnep watershed. There are large mining districts in the Dolores River watershed, the LaPlata, the Rico, and the area around Dunton on the West Dolores River. The quantity of mercury loading from mining operations has been estimated through a combination of observed data in the water column and sediment coupled with the watershed linkage analysis.

Significant atmospheric point sources of mercury often cause locally elevated areas of near-field atmospheric deposition downwind. Two large coal-fired power plants are in the Four Corners area within about 50 miles of the McPhee and Narraguinnep reservoirs. The plants in the Four Corners area (2,040 megawatt (MW) capacity) and the Navajo plant (1,500 MW capacity) are upwind of McPhee and Narraguinnep reservoirs. It is likely that the

mercury emitted from these plants contributes to the mercury loading of the two reservoirs. Because no direct measurements of atmospheric deposition of mercury are available, EPA cannot assess the significance of this loading and must await further investigation, including the establishment of a mercury deposition monitoring site in the area.

Loading Capacity—Linking Water Quality and Pollutant Sources

Models of watershed loading of mercury are combined with a model of mercury cycling and bioaccumulation in the lake to translate the numeric target, expressed as a fish tissue concentration of mercury, to mercury loading rates. The coupled models estimate mercury loading to the reservoirs and predict mercury cycling and speciation within the reservoir. An estimated load reduction of 52 percent is needed for long-term average mercury concentrations in a standardized 15-inch smallmouth bass to drop to 0.5 mg/kg wet muscle.

Allocations

The loading capacity for McPhee Reservoir was estimated to be 2,592 g/year of mercury. Narraguinnep Reservoir's loading capacity was estimated at 39.1 g/year of mercury. This is the maximum rate of loading consistent with meeting the numeric target of 0.5 mg/kg in fish tissue. Because of the uncertainties regarding the linkage between mercury sources and fish tissue concentrations in McPhee and Narraguinnep reservoirs, an allocation of 70 percent of the loading capacity was used for this TMDL. The TMDL calculated for McPhee Reservoir is equivalent to a total annual mercury loading rate of 1,814 g/yr (70 percent of the loading capacity of 2,592 g/yr), while that for Narraguinnep Reservoir is equivalent to a total annual mercury loading rate of 27.3 g-Hg/yr (70 percent of 39.1 g-Hg/yr). Summaries of the TMDL allocations and needed load reductions for the McPhee and Narraguinnep Reservoirs are presented in tables D7 and D8, respectively.

Table D7. Summary of TMDL allocations and needed load reductions for McPhee Reservoir

Source	Allocation	Existing load	Needed reduction
Atmospheric deposition	63	251	188
Rico/Silver Creek mining area	507	1030	523
Dunton mining area	348	708	360
La Plata mining area	69	141	72
Watershed background	827	919	92
Total	1,814	3,049	1,235
Unallocated reserve	778		
Loading capacity	2,592		

Note: Measurements in g/year of mercury.

Table D8. Summary of TMDL allocations and needed load reductions for Narraguinnep Reservoir

Source	Allocation	Existing load	Needed reduction
Atmospheric deposition	9.2	36.8	27.6
Interbasin transfer from McPhee Reservoir	9.5	15.9	6.4
Watershed background	8.6	25.4	16.8
Total	27.3	78.1	50.8
Unallocated reserve	11.8		
Loading capacity	39.1		

Note: Measurements in g/year of mercury.

IV. Clear Lake, California

Description of the Applicable Water Quality Standards

EPA promulgated the California Toxics Rule (CTR) in May 2000 (65 FR 31682). The CTR contains a water quality criterion of 50 ng/L total recoverable mercury for water and organism consumption and is intended to protect humans from exposure to mercury in drinking water and through fish and shellfish consumption. This criterion is enforceable in California for all waters with a municipal or domestic water supply designated use and is applicable to Clear Lake. However, the state of California does not consider this criterion sufficiently protective of the consumers of fish from Clear Lake.

The water quality management plan or Basin Plan for the Central Valley Regional Water Quality Control Board adopted new water quality standards for mercury for Clear Lake at the same time it adopted mercury TMDLs for Clear Lake. The state's water quality criteria are for fish tissue and are intended to protect designated uses for fishing and wildlife habitat. The applicable criteria are 0.09 mg/kg and 0.19 mg/kg of mercury in fish tissue for trophic levels 3 and 4 fish, respectively. These levels were recommended by the U.S. Fish and Wildlife Service to protect wildlife, including osprey and bald eagles, at Clear Lake; these levels allow adults to safely consume about 3.5 fish meals per month (26 grams/day) if eating mainly trophic level 4 fish such as catfish and bass. The 26 grams/day assumes a diet composed of 70 percent trophic level 4 fish and 30 percent trophic level 3 fish. The 90th percentile consumption rate of a small group of residents of Clear Lake, primarily members of the Elem Pomo Indian Tribe, is 30 grams/day of Clear Lake fish, as reported in 1997.

Source Assessment

Clear Lake is in Lake County in northern California. It is a shallow, eutrophic waterbody that consists of three basins—the Upper, Lower, and Oaks Arms. It is the largest natural lake entirely within California's boundaries. Tourism and sport fishing are important sectors of the local economy. Five American Indian tribes use the resources of the lake and its watershed.

The Clear Lake watershed lies within a region naturally enriched in mercury. The Sulphur Bank Mercury Mine (SBMM) site, on the shores of Oak Arm, was a highly productive source of mercury between 1872 and 1957. Similar smaller mines were

present in the Clear Lake watershed, all of which are now inactive. Levels of mercury in Clear Lake sediments rose significantly after 1927, when open-pit operations became the dominant mining method at SBMM. EPA declared the SBMM a federal Superfund site in 1991, and since then several remediation projects have been completed, including regrading and vegetation of mine waste piles along the shoreline and construction of a diversion system for surface water runoff. EPA is conducting a remedial investigation to fully characterize the SBMM site to propose final remedies.

Inorganic mercury loads entering Clear Lake come from ground water and surface water from the SBMM site; tributaries and other surface water that flows directly into the lake; and atmospheric deposition, including atmospheric flux from SBMM. Some mercury deposited historically in the lake due to mining operations or erosion at SBMM might also contribute to mercury concentrations in fish today.

Ground water and surface water from the SBMM site. SBMM covers approximately 1 square mile on the east shore of the Oaks Arm of Clear Lake. The site contains approximately 120 acres of exposed mine overburden and tailings (referred to as waste rock). Two small unprocessed ore piles are also on the site. Mercury in samples of mine materials ranged from 50 to 4,000 mg/kg. All piles of mine materials exhibit the potential to generate acid rock drainage. The abandoned mine pit, the Herman Impoundment, is filled with 90 feet of acidic water (pH 3) and has a surface area of about 20 acres. The average concentrations in the Herman Impoundment of water and sediment are around 800 ng/L and 26 mg/kg, respectively. A geothermal vent at the bottom of the impoundment continues to discharge gases, minerals (including mercury), and fluids into the pit.

A large pile of waste rock, known as the waste rock dam (WRD), stretches about 2,000 feet along the shore of the western side of the SBMM site. The WRD lies between Herman Impoundment and Clear Lake. The surface water in the impoundment is 10–14 feet above the surface of Clear Lake, which creates a gradient of ground water flow toward the lake. Surface runoff from the northern side of the site is bounded by a wetland that drains to Clear Lake. Surface runoff from the northern waste rock piles is directed through culverts into the northern wetland. In 1990 rock and geofabric barriers were installed at the culverts to reduce the transport of suspended solids. The northern wetland is used for cattle grazing and as a source of fish, tules, and other resources used by the members of the Elem Pomo Tribe. Waste rock piles extend into the wetlands.

Inputs of mercury from SBMM are estimated to be between 1 and 568 kg/year. EPA Superfund program's estimate of mercury transported in ground water from the WRD is used as the lower-bound input. Regional Board staff estimate that 568 kg/year is the maximum upper-bound estimate of all inputs from SBMM, including past and continuing contributions to the active sediment layer. This is approximately 96.5 percent of total sources.

Ground water from SBMM appears to contribute mercury that is readily methylated, relative to mercury from other inputs. Ground water flow from the mine site has been detected entering Clear Lake by subsurface flow through lake sediments. Mercury in ground water from the WRD is solubilized and likely in chemical forms that are easily taken up by methylating bacteria. Acidic drainage from the mine site also contains high

sulfate concentrations that enhance the rates of methylation by sulfate-reducing bacteria. This assertion is supported by data showing that methylation rates near the mine site are significantly higher than those in other parts of Clear Lake. In contrast to the mercury in SBMM ground water, the mercury in lakebed and tributary sediments originates primarily as cinnabar, which has low solubility in water.

Tributaries and other surface water flowing directly into the lake. Mercury entering Clear Lake from its tributaries originates in runoff from naturally mercury-enriched soils, sites of historical mining activities, and mercury deposited in the watershed from the atmosphere. Geothermal springs might contribute to tributary loads, especially in the Schindler Creek tributary to Oaks Arm. Tributary and watershed runoff loads of mercury range from 1 to 60 kg/year, depending on flow rates. Loads in average water years are 18 kg/year, approximately 3 percent of the total sources.

Geothermal springs and lava tubes that directly discharge to Clear Lake do not appear to be significant sources of mercury. Mercury concentrations in surficial sediment samples collected near lakebed geothermal springs were not elevated relative to levels in sediment away from geothermal springs.

Atmospheric deposition, including flux from the SBMM site. Small amounts of mercury deposit directly on the surface of Clear Lake from the global atmospheric pool and potentially from local, mercury-enriched sources. Atmospheric loads to the lake surface from the global pool were estimated using data from MDN monitoring stations in Mendocino County and San Jose. Estimates ranged from 0.6 to 2.0 kg/year, approximately 0.3 percent of the total sources.

Loading Capacity—Linking Water Quality and Pollutant Sources

The Regional Board staff assumes that there is a directly proportional relationship between methylmercury in fish and mercury in the surficial sediment. This is a simplification of a highly complex process. Many factors, such as sulfide and sulfate concentrations, temperature, and organic carbon, affect methylation or concentrations of methylmercury. Factors that affect accumulation of methylmercury in fish include species, growth rate, prey availability, and the like. To reduce levels of methylmercury in fish, loads of mercury to the lake must be reduced. Section 5.3.1 of the Staff Report provides examples of remediation projects demonstrating that removal of inorganic mercury from a range of aquatic environments has been effective in reducing concentrations of mercury in fish.

A set of first-order relationships, each controlled by a single variable of concentration of mercury or methylmercury, provide the basis for the assumption of a directly proportional relationship between mercury in fish and in surficial sediment in Clear Lake. Concentrations of methylmercury in water and methylmercury in biota are related by BAFs. Relationships between methylmercury in the water column and in sediment can be described as a flux rate of methylmercury from sediment. Concentrations of methylmercury and mercury in sediment are related through calculation of a methylation efficiency index (ratio of methylmercury to mercury in surficial sediment).

In each of these steps in the linkage analysis, one variable is related to another by a simple ratio or linear equation. For example, BAFs are calculated by dividing the

concentration of methylmercury in fish by the concentration of methylmercury in the water. Data are available to determine BAF and methylation indices that are specific for Clear Lake. With the current understanding of the transport, methylation, and uptake processes in Clear Lake, the Regional Board staff was unable to refine these relationships to incorporate the effects of other factors. The end result was that methylmercury in biota was related linearly to mercury in surficial sediment.

Meeting the recommended water quality standards would require reducing existing fish tissue concentrations by 60 percent. Using the linear relationship, the linkage analysis indicates that overall mercury loads to Clear Lake sediment must be reduced by 60 percent to reduce methylmercury concentrations in fish tissue by the proportional amount. The Regional Board is establishing the assimilative capacity of inorganic mercury in Clear Lake sediments as 70 percent of existing levels to include a margin of safety of 10 percent to account for the uncertainties in the linkage analysis.

Allocations

The strategy for meeting the fish tissue criteria is to reduce the inputs of mercury to the lake from tributaries and the SBMM site, combined with active and passive remediation of contaminated lake sediments. The load allocations for Clear Lake will result in a reduction in the overall mercury sediment concentration by 70 percent of existing concentrations. The load allocations are assigned to the active sediment layer of the lakebed, the SBMM terrestrial site, the tributary creeks and surface water runoff to Clear Lake, and atmospheric deposition. Table D9 summarizes the load allocations. The load allocation to the active sediment layer is expressed as reducing concentrations of mercury in the active sediment layer to 30 percent of current concentrations. The load allocation to the SBMM terrestrial site is 5 percent of the ongoing loads from the terrestrial mine site. The load allocation for the mine also includes reducing mercury concentrations in surficial sediment to achieve the sediment compliance goals for Oaks Arm, shown in table D10. The load allocation to tributary and surface water runoff is 80 percent of existing loads. These load allocations account for seasonal variation in mercury loads, which vary with water flow and rainfall. The analysis includes an implicit margin of safety in the reference doses for methylmercury that were used to develop the fish tissue objectives. It also includes an explicit margin of safety of 10 percent to account for uncertainty in the relationship between fish tissue concentrations and loads of mercury. The reductions in loads of mercury from all sources are expected to result in attainment of water quality objectives.

Table D9. Summary of mercury load allocations

Source	Existing load (kg/year)	Needed reduction
Clear Lake sediment	695	70% of existing concentration
Sulphur Bank Mercury Mine		95% of existing load
Tributaries	18	20% of existing load
Atmosphere	2	no change

Table D10. Sediment goals for mercury in Clear Lake

Site designation	Location	Sediment mercury goal (mg/kg dry weight)[a]
Upper Arm UA-03	Center of Upper Arm on transect from Lakeport to Lucerne	0.8
Lower Arm LA-03	Center of Lower Arm, north and west of Monitor Point	1.0
Oaks Arm		
OA-01[b]	0.3 km from SBMM 0.3 km from SBMM	16[c]
OA-02[b]	0.8 km from SBMM	16[c]
OA-03[b]	1.8 km from SBMM	16
OA-04[b]	3.0 km from SBMM	10
Narrows O1	7.7 km from SBMM	3

Notes:

[a]Sediment goals are 30 percent of existing concentrations. Existing concentrations are taken as the average mercury concentrations in samples collected in 1996–2000 (Clear Lake Basin Plan Amendment Staff Report).

[b]Sediment goal is part of the load allocation for SBMM.

[c]Due to the exceptionally high concentrations existing at the eastern end of Oaks Arm, sediment goals at OA-01 and OA-02 are not 70 percent of existing concentrations. These goals are equal to the sediment goal established for OA-03.

Clear Lake sediment. Reducing mercury concentrations in surficial sediment by 70 percent is an overall goal for the entire lake. To achieve water quality objectives, extremely high levels of mercury in the eastern end of Oaks Arm near SBMM must be reduced by more than 70 percent. To evaluate progress in lowering sediment concentrations, the following sediment compliance goals are established at sites that have been sampled previously.

Sulphur Bank Mercury Mine. Current and past releases from SBMM are a significant source of mercury loading to Clear Lake. Ongoing annual loads from the terrestrial mine site to the lakebed sediments occur through ground water, surface water, and atmospheric routes. Loads from ongoing releases from the terrestrial mine site should be reduced to 5 percent of existing inputs. Because of its high potential for methylation relative to mercury in lakebed sediments, mercury entering the lake through ground water from the mine site should be reduced to 0.5 kg/year.

Past releases from the mine site are a current source of exposure through remobilization of mercury that exists in the lakebed sediments as a result of past releases to the lake from the terrestrial mine site. Past active mining operations, erosion, and other mercury transport processes at SBMM have contaminated sediment in Oaks Arm. The load allocation assigned to SBMM includes reducing surficial sediment concentrations in Oaks Arm by 70 percent (more at sites nearest the mine site) to meet the sediment compliance goals in table D10.

EPA anticipates implementing additional actions to address the ongoing surface and ground water releases from SBMM over the next several years. These actions are expected to lead to significant reductions in the ongoing releases from the mine pit, the mine waste piles, and other ongoing sources of mercury releases from the terrestrial mine

site. EPA also plans to investigate what steps are appropriate under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the existing contamination in the lakebed sediments from past releases from SBMM. The Regional Board will continue to work closely with EPA on these important activities. In addition, the Regional Board will coordinate monitoring activities to investigate other sources of mercury loads to Clear Lake. These investigations by EPA and the Regional Board should reduce the uncertainty that exists regarding the annual load of mercury to the lake, the contribution of each source to that load, and the degree to which those sources lead to methylmercury exposure of and mercury uptake by fish in the lake. This information should lead to more refined decisions about what additional steps are appropriate and feasible to achieve the applicable water quality criteria.

Tributaries and surface water runoff. Past and current loads of mercury from the tributaries and direct surface water runoff are also a source of mercury loading to the lake and to the active sediment layer in the lakebed. This section excludes loads from surface water runoff associated with SBMM, which are addressed separately above. The loads of mercury from the tributaries and surface water runoff to Clear Lake should be reduced by 20 percent of existing levels. In an average water year, existing loads are estimated to be 18 kg/year. Loads range from 1 to 60 kg/year, depending on water flow rates and other factors. The load allocation applies to tributary inputs as a whole, instead of to individual tributaries. Efforts should be focused on identifying and controlling inputs from hot spots. The U.S. Bureau of Land Management, U.S. Forest Service, other land management agencies in the Clear Lake Basin, and Lake County will submit plans for monitoring and implementation to achieve the necessary load reductions. The Regional Board will coordinate with those agencies and other interested parties to develop the monitoring and implementation plans. The purpose of the monitoring is to refine load estimates and identify potential hot spots of mercury loading from tributaries or direct surface runoff into Clear Lake. Hot spots can include erosion of soils with concentrations of mercury above the average for the rest of the tributary. If significant sources are identified, the Regional Board will coordinate with the agencies to develop and implement load reductions. The implementation plans will include a summation of existing erosion control efforts and a discussion of feasibility and proposed actions to control loads from identified hot spots. The agencies will provide monitoring and implementation plans within five years after the effective date of this amendment and implement load reduction plans within five years thereafter. The goal is to complete the load reductions within 10 years of implementation plan approval.

The Regional Board will work with the American Indian tribes in the Clear Lake watershed on mercury reduction programs for the tributaries and surface water runoff. It will solicit the tribes' participation in developing monitoring and implementation plans.

Wetlands. The Regional Board is concerned about the potential for wetland areas to be significant sources of methylmercury. Loads and fate of methylmercury from wetlands that drain to Clear Lake are not fully understood. The potential for production of methylmercury should be assessed during the planning of any wetlands or floodplain restoration projects within the Clear Lake watershed. The Regional Board established a goal of no significant increases of methylmercury to Clear Lake resulting from such activities. As factors contributing to mercury methylation are better understood, the

Regional Board should examine the possible control of existing methylmercury production within tributary watersheds.

Atmospheric deposition. Atmospheric loads of mercury originating outside the Clear Lake watershed and depositing locally are minimal. Global and regional atmospheric inputs of mercury are not under the jurisdiction of the Regional Water Board. Loads of mercury from outside the Clear Lake watershed and depositing from air onto the lake surface are established at the existing input rate, estimated to be 1 to 2 kg/year.

V. Cache Creek, California

Description of the Applicable Water Quality Standards

EPA promulgated the California Toxics Rule (CTR) in May 2000 (65 FR 31682). The CTR contains a water quality criterion of 50 ng/L total recoverable mercury for waters designated for water and organism consumption, and it was intended to protect humans from exposure to mercury in drinking water and through fish and shellfish consumption. This criterion is enforceable in California for all waters with a municipal or domestic water supply designated use, and it is applicable to all waters in the Cache Creek watershed. The State of California, however, does not consider this criterion sufficiently protective of human and wildlife consumers of fish in the watershed.

The water quality management plan or Basin Plan for the Central Valley Regional Water Quality Control Board adopted new water quality standards for mercury for Cache Creek, Bear Creek, and Harley Gulch at the same time it adopted mercury TMDLs for those waterbodies. The state's water quality criteria are expressed as concentrations in fish tissue and are intended to protect designated uses, which include human and wildlife fish consumption. The applicable criteria are as follows: for Cache Creek and Bear Creek, the average methylmercury concentration shall not exceed 0.23 mg methylmercury/kg wet weight of muscle tissue in trophic level 4 fish 250–350 mm (piscivorous species, including bass and catfish), and 0.12 mg methylmercury/kg wet weight of muscle tissue in trophic level 3 fish 250–350 mm, or if not available, a minimum of 125 mm (bluegill, sunfish, and sucker); for Harley Gulch, the average methylmercury concentration shall not exceed 0.05 mg methylmercury/kg wet weight in whole, trophic level 2 and 3 fish 75–100 mm total length (hardhead, California roach, or other small resident species). Because Harley Gulch does not support larger, trophic level 3 and 4 fish, no water quality criteria for these larger fish were proposed in that waterbody.

These water quality standards permit safe consumption of about 22–40 g/day of Cache or Bear Creek fish (3 to 5.4 meals/month). In Cache and Bear creeks, the standards protect wildlife species, including bald eagle, peregrine falcon (state endangered), river otter, American mink, mergansers, grebes, and kingfishers. In Harley Gulch, the standards protect wildlife species, including small mammals, herons, and kingfishers.

Source Assessment

The Cache Creek watershed is impaired due to elevated levels of mercury in the water and in fish tissue. Because Cache Creek is a primary source of mercury to the Sacramento-San Joaquin Delta Estuary, lowering mercury levels in the Cache Creek watershed will assist in protecting human and wildlife health in the delta. The TMDL

encompasses the 81-mile reach of Cache Creek between Clear Lake Dam and the outflow of the Cache Creek Settling Basin, Bear Creek from its headwaters to its confluence with Cache Creek, and the 8-mile length of Harley Gulch.

Sources of mercury entering the watershed include waste rock and tailings from historical mercury mines, erosion of naturally mercury-enriched soils, geothermal springs, and atmospheric deposition. There are multiple inactive mercury mines in the Cache Creek watershed. The Sulphur Bank Mercury Mine contributes mercury to Cache Creek at the Clear Lake outflow. The Sulphur Creek mining district includes eight mines that drain predominately to Bear Creek via Sulphur Creek and four mines in the Bear Creek Basin. Harley Gulch receives inputs from the Turkey Run and Abbott mines. The Reed Mine drains to Davis Creek, a tributary to Cache Creek.

Historical mining activities in the Cache Creek watershed discharged and continue to discharge large volumes of inorganic mercury (termed total mercury) to creeks in the watershed. Much of the mercury discharged from the mines is now distributed in the creek channels and floodplain downstream from the mines. Natural erosion processes can be expected to slowly move the mercury downstream out of the watershed over the next several hundred years. However, current and proposed activities in and around the creek channel can enhance mobilization of this mercury. Activities in upland areas, such as road maintenance and grazing and timber activities, can add to the mercury loads reaching Cache Creek, particularly when the activities take place in areas that have elevated mercury levels. Mercury can be transformed to methylmercury in sediment by sulfate-reducing bacteria.

Cache Creek. In Cache Creek the watershed above Rumsey is the major source of methylmercury. The highest concentrations and production rates were observed below the mercury mines in Harley Gulch, in Sulphur and Bear creeks, and in the canyon above Rumsey. Lower methylmercury concentrations in water were measured in the North Fork and Cache Creek below Clear Lake Dam, which have lower inorganic mercury concentrations in sediment.

The sources of total mercury in Cache Creek largely parallel the sources of methylmercury. Most mercury derives from the watershed upstream of Rumsey. On a five-year average, mercury loads from the mine-related tributaries (Bear Creek, Harley Gulch, and Davis Creek), North Fork Cache Creek and Clear Lake contributed about 15 percent of the mercury loads measured in Cache Creek at Rumsey. In years with high degrees of runoff or extreme erosional events, inputs from the inactive mines would be much greater. The majority of the inorganic mercury loads were from unnamed sources, which include smaller, unmeasured tributaries and mercury in the Cache Creek bed and banks. Clean sediment entering the watershed below Rumsey diluted sediment mercury concentrations.

Bear Creek. The Bear Creek watershed upstream of all mine inputs contributes less than 10 percent to each of the loads of methylmercury and total mercury in Bear Creek. Sulphur Creek contributes about half of each of the methylmercury and total mercury loads in Bear Creek. The remainder of the Bear Creek methylmercury likely comes from production within the channel and seepage of underground springs. The rest of the mercury load in Bear Creek likely derives from the remobilization of mine waste deposited in the floodplain.

Harley Gulch. Much of the methylmercury in Harley Gulch is likely produced in a wetland area in the West Branch Harley Gulch, downstream of the inactive mercury mines. Over 90 percent the total mercury load in Harley Gulch is estimated to come from the West Branch, where the mines are. Total mercury loads from the mines may be underestimated due to a lack of data collected during heavy rainfall events. An alluvial fan, likely containing mine waste, at the confluence of Harley Gulch and Cache Creek, might contribute to the unknown source of mercury in the Cache Creek canyon.

Loading Capacity—Linking Water Quality Pollutant Sources

Total mercury in the creeks is converted to methylmercury by bacteria in the sediment. The concentration of methylmercury in fish tissue is directly related to the concentration of methylmercury in the water. The concentration of methylmercury in the water column is controlled in part by the concentration of total mercury in the sediment and the rate at which the total mercury is converted to methylmercury. The rate at which total mercury is converted to methylmercury varies from site to site; some sites (wetlands and marshes) having greatly enhanced methylation rates.

The linkage analysis describes the relationship between methylmercury concentrations in water and in large fish. Data collected in 2000 and 2001 show statistically significant relationships between concentrations of aqueous unfiltered methylmercury in water and large trophic level 3 and 4 fish. In Cache Creek, large trophic level 3 fish tissue concentrations (Sacramento sucker), normalized to 290 mm (from Slotten et al. 2004), were regressed against aqueous unfiltered methylmercury concentrations ($Y= 584.8X + 30.2$; $P < 0.001$, $R2 = 0.98$). In Cache Creek, large trophic level 4 fish tissue concentrations (largemouth bass, small mouth bass, and pikeminnow, depending on site), normalized to 305 mm (from Slotton et al. 2004), were regressed against aqueous unfiltered methylmercury concentrations ($Y = 2970.8X – 180.6$; $P < 0.01$, $R2 = 0.9$). Using these relationships, staff determined concentrations of unfiltered methylmercury in water that correspond to the proposed criteria for trophic levels 3 and 4 fish (0.12 mg/kg and 0.23 mg/kg, respectively). These concentrations are 0.15 ng/l for trophic level 3 fish and 0.14 ng/L for trophic level 4 fish. To ensure meeting both fish tissue criteria, staff selected 0.14 ng/L as the aqueous unfiltered methylmercury goal for Cache Creek.

For Bear Creek, the methylmercury goal of 0.06 ng/L represents the best estimate of the annual, median aqueous (unfiltered) concentration of methylmercury needed to attain the target of 0.23 mg/kg wet weight in trophic level 4 fish. Harley Gulch has no trophic level 4 fish, so the above relationships could not be used. Based on bioaccumulation factors specific to Harley Gulch, the aqueous methylmercury goal for Harley Gulch is 0.09 ng/L.

Allocations

The TMDL presents a plan to reduce mercury and methylmercury loads. Reducing the methylmercury loads will require a multi-faceted approach that includes controlling inorganic mercury loads and limiting the entry of inorganic mercury into sites with high rates of methylmercury production. Inorganic mercury loads may be controlled through remediation of mercury mines, erosion control, removal of highly contaminated sediment, and other activities. In addition to addressing inorganic mercury loads, the TMDL discusses limits to the production of methylmercury in constructed

impoundments, such as gravel pits and water storage facilities. Identification and evaluation of the unknown mercury source(s) in the upper basin are essential to attain the Cache Creek methylmercury targets in fish tissue and to help reduce mercury in sediment of the Sacramento-San Joaquin Delta Estuary.

Since methylmercury in the water column is directly related to mercury levels in fish, the following methylmercury load allocations are assigned to tributaries and the main stem of Cache Creek.

Methylmercury Load Allocations. Tables D11 and D12 provide methylmercury load allocations for Cache Creek, its tributaries, and instream methylmercury production. Allocations are expressed as a percent of existing methylmercury loads. The methylmercury allocations will be achieved by reducing the annual average methylmercury (unfiltered) concentrations to site- specific, aqueous methylmercury goals, which are 0.14 ng/L in Cache Creek, 0.06 ng/L in Bear Creek, and 0.09 ng/L in Harley Gulch. The allocations in tables D11 and D12 apply to sources of methylmercury entering each tributary or stream segment. In aggregate, the sources to each tributary or stream segment must have reductions of methylmercury loads as shown below.

Table D12 provides the load allocation within Bear Creek and its tributaries to attain the allocation for Bear Creek described in table D11. The inactive mines listed in the implementation summary are assigned a 95 percent total mercury load reduction. These mines include mines in the Harley Gulch Sulphur Creek and Bear Creek watersheds. Reductions in mercury loads from mines, erosion, and other sources in the Sulphur Creek watershed are expected to reduce in-channel production of methylmercury to meet the Sulphur Creek methylmercury allocation.

Table D11. Cache Creek methylmercury allocations

Source	Existing annual load (g/yr)	Acceptable annual load (g/yr)	Allocation (% of existing load)
Cache Creek (Clear Lake to North Fork confluence)	36.8	11	30%
North Fork Cache Creek	12.4	12.4	100%
Harley Gulch	1.0	0.04	4%
Davis Creek	1.3	0.7	50%
Bear Creek at Highway 20	21.1	3	15%
Within-channel production and ungauged tributaries	49.5	32	65%
		7[a]	10%[a]
Total of loads	122	66	54%
Cache Creek at Yolo[b]	72.5	39	54%
Cache Creek Settling Basin Outflow[c]	87	12	14%

Notes:

[a]The allocation includes a margin of safety, which is set to 10% of the acceptable loads. In terms of acceptable annual load estimates, the margin of safety is 7 g/yr.

[b]Cache Creek at Yolo is the compliance point for the tributaries and Cache Creek channel for meeting the allocations and aqueous goals. Agricultural water diversions upstream of Yolo remove methylmercury (50 g/yr existing load).

[c]The Settling Basin Outflow is the compliance point for methylmercury produced in the Settling Basin.

Table D12. Bear Creek methylmercury allocations

Source	Existing Annual Load (g/yr)	Acceptable Annual Load (g/yr)	Allocation (% of existing load)
Bear Creek at Bear Valley Road	1.7	0.9	50%
Sulphur Creek	8	0.8	10%
In-channel production and ungauged tributaries	11.4	1	10%
		0.3[a]	10%[a]
Total of loads	21.1	3	15%
Bear Creek at Highway 20[b]	21.1	3	15%

Notes:

[a]The allocation includes a margin of safety, which is set to 10% of the acceptable loads. In terms of acceptable annual load estimates, the margin of safety is 0.3 g/yr.

[b]Bear Creek at Highway 20 is the compliance point for Bear Creek and its tributaries.

To achieve the water quality objectives and the methylmercury allocations listed in tables D11 and D12, the following actions are needed: (1) reduce loads of total mercury from inactive mines; (2) where feasible, implement projects to reduce total mercury inputs from existing mercury-containing sediment deposits in creek channels and creek banks downstream from historical mine discharges; (3) reduce erosion of soils with enriched total mercury concentrations; (4) limit activities in the watershed that will increase methylmercury discharges to the creeks and, where feasible, reduce discharges of methylmercury from existing sources; and (5) evaluate other remediation actions that are not directly linked to activities of a discharger. Because methylmercury is a function of total mercury, reductions in total mercury loads are needed to achieve the methylmercury load allocations. Methylmercury allocations will be achieved in part by natural erosion processes that remove mercury that has deposited in creek beds and banks since the start of mining.

The proposed Basin Plan Amendment for mercury in San Francisco Bay assigns a reduction in total mercury loads from the Sacramento–San Joaquin River Delta of 110 kg/yr. Cache Creek is a major source of mercury to the Delta. To attain the San Francisco Bay reduction, loads of total mercury exiting Cache Creek should be reduced. Reductions in total mercury loads to the inactive mines in Harley Gulch and the Bear Creek watershed assigned by this TMDL and proposed changes to the Cache Creek Settling Basin, which would increase the mass of mercury retained in the basin, would create significant reductions in loads from Cache Creek.

VI. Minnesota Statewide[27] Mercury Total Maximum Daily Load

Description of the Applicable Water Quality Standards and TMDL Target

Minnesota Rules Chapters 7050.0222 and 7052.0100 set forth chronic numeric water quality standards based on total mercury concentrations in the water column. The wildlife-based standard applicable to only the waters of the Lake Superior Basin is 1.3 ng/L, while the human health-based standard applicable to waters outside the Lake Superior Basin is 6.9 ng/L. In addition to these numeric standards, Chapter 7050.0150, subpart 7, provides a narrative standard for assessing the contaminants in fish tissue. The narrative standard states that a waterbody is impaired when the Minnesota Department of Health recommends a consumption frequency of less than one meal per week for any member of the population.

To establish the two regional TMDLs, Minnesota selected a target of 0.2 mg/kg fish tissue mercury concentration. Fish tissue mercury concentration was selected as the water quality target for the TMDLs because it was consistent with EPA's 2001 methylmercury fish tissue criterion. In the 2001 guidance, EPA chose to express the water quality criterion as a fish tissue concentration rather than as a water column value because fish consumption is the primary route of human exposure. Two aspects of EPA's criterion are toxicity and exposure. Minnesota relied on EPA's assessments of toxicity to humans but selected a more state-specific exposure rate. For purposes of calculating its recommended human health-based fish tissue criterion, EPA assumes that people consume 17.5 g/day of fish. Minnesota selected a higher consumption rate, 30 g/day of fish, based on several surveys of the fish-eating habits of upper-Midwest recreational fishers.

Since Minnesota's water quality standards are water column chronic standards for total mercury, not fish tissue concentration standards, Minnesota demonstrated a link from the fish tissue mercury concentration TMDL target to the numeric water column water quality standards. Bioaccumulation factors for 14 lakes representing agricultural areas, urban areas, and forested areas were used to calculate the water column concentration that would be equivalent to the 0.2 mg/kg fish tissue mercury concentration target.

Source Assessment

Sources that Minnesota considered in developing the two regional TMDLs included atmospheric deposition, wastewater treatment plants, non-municipal waste discharges, and stormwater. Atmospheric deposition was the only significant nonpoint source of mercury identified by Minnesota. The state identified 99 percent of the total mercury load to the state as coming from atmospheric deposition. Both natural and anthropogenic

[27] As described in Section 6 of this guidance, Minnesota divided the state into two regions, a northeast region and a southwest region, and developed a TMDL for each region. Although Minnesota's report is called a "statewide TMDL," the two regional TMDLs do not address all the mercury impairments in the state. The TMDLs address 511 of the lake and river reach impairments in Category 5 of Minnesota's 2006 Integrated Report.

sources contribute to the atmospheric deposition mercury load. Minnesota identified natural sources as contributing 30 percent to the atmospheric deposition mercury load, while the remaining 70 percent is from worldwide anthropogenic sources. Point sources that Minnesota considered included wastewater treatment plants, pulp and paper mills, taconite mines, coal-fired power plants, and one refinery. The state recognized that stormwater is considered a point source and therefore subject to wasteload allocations; however, for purposes of estimating a baseline mercury load (referred to in the TMDL report as the total source load), the mercury loadings from stormwater were included in the estimate of loadings from atmospheric deposition. Using data from two studies in Minnesota, the state concluded that the primary source of mercury to stormwater is atmospheric deposition rather than specific anthropogenic sources.

Loading Capacity

Minnesota established a loading capacity for each of the two regional TMDLs. Each loading capacity was calculated by multiplying a regional reduction factor[28] needed to achieve the fish tissue mercury concentration target by the total source load[29] for each region, thus calculating a regional load reduction goal.[30] The load reduction goal was subtracted from the total source load to arrive at the loading capacities.

The total source load was considered the baseline condition from which reductions would be needed to achieve water quality standards. Minnesota selected the year 1990 as the baseline to which reductions would be applied. Minnesota selected 1990 as the baseline for three reasons. First, the total source load is the sum of the point source load and the nonpoint source load. The nonpoint source load is represented by total (wet and dry) mercury deposition. Minnesota's estimate of both wet and dry deposition is from lake sediment cores collected in a study conducted from 1988 to 1990. The second reason for selecting 1990 was to remain consistent with other mercury reduction baselines. The state uses 1990 as its mercury emission inventory baseline, and other state and federal plans, such as the Great Lakes Binational Toxics Strategy and the Lake Superior Lakewide Management Plan, use 1990 as a baseline for assessing mercury reductions. Minnesota selected a baseline year that was consistent with other reduction goals and targets. Last, Minnesota selected 1990 because prior to 1990 mercury use was relatively high, and then beginning in around 1990, mercury use dropped precipitously as mercury was removed from many products. For this reason Minnesota concluded that 1990 represents the end of a period when mercury emissions and fish tissue concentrations were in a steady state.

The sum of the point source load and nonpoint source load are the total source load for each region. The total source load for each region simply defines the 1990 baseline condition for the region to which the applicable reduction factor is applied.

The existing point source contribution to the total source load was calculated based on the sum of design flows for point sources within each region and mean effluent mercury concentrations. The design flows were current-day design flows, while the mean effluent

[28] The northeast regional reduction factor is 65 percent, and the southwest regional reduction factor is 51 percent.

[29] The baseline load for the northeast region is 1153 kg/yr, and the baseline load for the southwest region is 1628 kg/yr.

[30] The load reduction goal for the northeast region is 749 kg/yr, and the load reduction goal for the southwest region is 830 kg/yr.

mercury concentrations were "typical" mercury concentrations unless actual facility effluent concentrations were available. Actual facility effluent concentrations were used for the coal-fired power plants, the one refinery, and the Metro and Western Lake Superior Sanitary District wastewater treatment plants. For all other point sources, typical mercury concentrations were used. A typical effluent concentration of 5 ng/L was used for wastewater treatment plants. It was based on a study by the Association of Metropolitan Sewerage Agencies, a state study of 37 NPDES facilities, and the Mercury Maps report. Minnesota relied on the Mercury Maps report in support of the mean effluent mercury concentration of 13 ng/L for pulp and paper mills, although effluent reports from one Wisconsin and one Minnesota facility show effluent concentrations in the range of 1.6 ng/L to 2 ng/L. Minnesota used its discharge monitoring database to calculate 1.5 ng/L as the mean mercury effluent concentration for taconite mines.

The existing nonpoint source contribution to the total source load was based on total mercury deposition to the state. Minnesota used sediment cores from Minnesota lakes to estimate total statewide mercury deposition as 12.5 g km^{-2} yr^{-1}. Minnesota used the regional surface areas for each of the two regions, along with the total mercury deposition, to estimate the nonpoint source contribution to the total source load.

The reduction factor for each region is the percent reduction in total mercury load needed to achieve the fish tissue target of 0.2 mg/kg for the 90th percentile of the standard-length fish. Fish tissue data were reviewed for the standard-size top predator fish in each region. The 90th percentile fish tissue mercury concentration and median concentrations were calculated for each region for top predator fish (walleye and northern pike). Minnesota used the difference between the 90th percentile mercury concentration in top predator fish within each region and the 0.2 mg/kg target to calculate the reduction factors. Minnesota used fish tissue data from 1988 to 1992 to establish the reduction factors. The state looked at fish tissue data from 1970 to 2002; however, to be consistent with the baseline year of 1990, fish tissue data from 1988 to 1992 were selected. Multiyear data better represent real conditions over time because they account for year-to-year variability in weather, fish populations, and sampling locations. Data for the standard-size top predator fish were used to calculate the reduction factor. Mercury bioaccumulates in fish; therefore, mercury concentrations are typically highest in the top predator fish. To account for temporal and spatial comparisons of mercury concentrations in these top predator fish, Minnesota used the standard-size top predator fish.[31] Top predator fish that are collected for fish tissue analysis vary in size and age. Because mercury concentrations vary with the size of fish and age of fish, it is difficult to make comparisons regarding mercury concentrations in fish without establishing a standard of comparison. Use of the standard-size fish accounted for differences in mercury concentrations due to age and size and allowed Minnesota to compare mercury concentrations across waterbodies.

[31] Minnesota uses a standard size of 40 cm (approximately 22 inches) for walleye and 55 cm (approximately 16 inches) for northern pike.

Allocations

Consistent with the regional approach used to establish the loading capacities, Minnesota did not assign waterbody-specific allocations; rather, the state established gross allocations for each region.

Minnesota assigned 1 percent of the loading capacity to point sources as the wasteload allocation for each regional TMDL. Minnesota chose 1 percent of the loading capacity based on an approach used in the Mercury Maps report to screen watersheds for significant point source impacts to identify waterbodies impaired primarily by atmospheric mercury (see appendix E on Mercury Maps). The northeast region wasteload allocation was set at 1 percent of the loading capacity, while the southwest region's wasteload allocation was set equal to the point source load portion of the total source load. The state set the southwest region's wasteload allocation equal to the point source load portion of the total source load because it was slightly less than 1 percent of the southwest region's loading capacity and the state chose the more restrictive allocation.

Load allocations for each region were established by subtracting the wasteload allocation and any explicit margin of safety from the established loading capacity. The remaining load within each region was assigned to the load allocation. The approved loading capacity and allocations for both regional TMDLs are shown in table D13.

Table D13. Approved northeast and southwest mercury TMDLs

Region	Loading capacity	Load allocation	Wasteload allocation	Margin of safety
Northeast	1.10 kg/day	1.09 kg/day	0.01 kg/day	Implicit
Southwest	2.18 kg/day	1.55 kg/day	0.02 kg/day	0.61 kg/day

Appendix E. Model Descriptions

This appendix describes currently available models discussed in this guidance. These models aid in developing bioaccumulation factors and modifying fish tissue criteria (see chapter 3), making assessments (see chapter 4), developing total maximum daily loads (TMDLs) (see chapter 6), and in carrying out related programs such as 319 Nonpoint Source Program activities, watershed management, stormwater permits, and National Pollutant Discharge Elimination System (NPDES) discharge evaluations. This appendix provides a description of each model, some examples of how or where it has been used, and a Web site for further information about each model.

BASS (Bioaccumulation and Aquatic System Simulator)

The Bioaccumulation and Aquatic System Simulator (BASS) is a model that simulates the population and bioaccumulation dynamics of age-structured fish communities. Although BASS was specifically developed to investigate the bioaccumulation of chemical pollutants within a community or ecosystem context, it can also be used to explore population and community dynamics of fish assemblages that are exposed to a variety of non-chemical stressors such as altered thermal regimes associated with hydrological alterations or industrial activities, commercial or sports fisheries, and introductions of non native or exotic fish species.

BASS is being used to investigate methylmercury bioaccumulation in the Florida Everglades and to predict population and community dimensions of "fish health" for a regional analysis of the ecological sustainability of the Albemarle Pamlico drainage basin in North Carolina and Virginia.

Information on BASS can be found at: http://www.epa.gov/athens/research/modeling/bass.html.

Community Multi-Scale Air Quality (CMAQ) Model

The CMAQ modeling system is a comprehensive, three-dimensional, grid-based Eulerian air quality model designed to estimate pollutant concentrations and depositions over large spatial scales (Byun and Ching 1999; Byun and Schere 2006; Dennis et al. 1996). The CMAQ model is a publicly available, peer-reviewed, state-of-the-science model consisting of a number of science attributes that are critical for simulating the oxidant precursors and nonlinear chemical relationships associated with the formation of mercury. Version 4.3 of CMAQ (Bullock and Brehme 2002; Byun and Schere 2006) reflects updates to earlier versions in a number of areas to improve the underlying science and address comments from peer review. The updates in mercury chemistry in version 4.3 from that described in Bullock and Brehme (2002) are as follows:

1. The elemental mercury (Hg^0) reaction with H_2O_2 assumes the formation of 100 percent reactive gaseous mercury (RGM) rather than 100 percent particulate mercury (Hg_P).

2. The Hg^0 reaction with ozone assumes the formation of 50 percent RGM and 50 percent Hg_P rather than 100 percent Hg_P.

3. The Hg^0 reaction with OH assumes the formation of 50 percent RGM and 50 percent Hg_P rather than 100 percent Hg_P.

4. The rate constant for the Hg^0 + OH reaction was lowered from 8.7 to 7.7 x 10^{-14} cm^3 $molecules^{-1}s^{-1}$.

CMAQ simulates every hour of every day of the year and requires a variety of input files that contain information pertaining to the modeling domain and simulation period. These include hourly emissions estimates and meteorological data in every grid cell and a set of pollutant concentrations to initialize the model and to specify concentrations along the modeling domain boundaries.

Meteorological data, such as temperature, wind, stability parameters, and atmospheric moisture content influence the formation, transport, and removal of air pollution. The CMAQ model requires a specific suite of meteorological input files to simulate these physical and chemical processes. For recent CMAQ modeling, meteorological input files were derived from a simulation of the Pennsylvania State University's National Center for Atmospheric Research Mesoscale Model (Grell et al. 1994) for the entire year of 2001. This model, commonly referred to as MM5, is a limited-area, nonhydrostatic, terrain-following system that solves for the full set of physical and thermodynamic equations that govern atmospheric motions. For this analysis, version 3.6.1 of MM5 was used. A complete description of the configuration and evaluation of the 2001 meteorological modeling is provided by McNally (2003).

These initial and boundary concentrations were obtained from the output of a global chemistry model, Harvard's GEOS-CHEM model (Yantosca 2004), to provide the boundary concentrations and initial concentrations. The global GEOS-CHEM model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from NASA's Goddard Earth Observing System (GEOS). This model was run for 2001 with a grid resolution of 2 degrees x 2.5 degrees (latitude-longitude) and 20 vertical layers.

The CMAQ modeling domain encompasses all the lower 48 states and extends from 126 degrees west longitude to 66 degrees west longitude and from 24 degrees north latitude to 52 degrees north latitude. The modeling domain is segmented into rectangular blocks referred to as grid squares. The model predicts pollutant concentrations and depositions for each grid cell. For this application the horizontal domain consisted of 16,576 grid cells that are roughly 36 km by 36 km. The modeling domain contains 14 vertical layers, with the top of the modeling domain at about 16,200 meters, or 100 millibar. The height of the surface layer is 38 meters.

A CMAQ modeling run was performed to estimate the impact of global sources on U.S. deposition estimates. For this analysis, all non-U.S. mercury input species to the model were set to zero. By comparing the results of this analysis with the 2001 Clean Air Mercury Rule (CAMR) base case run, which included all U.S. and global mercury species, the percent of total mercury deposition attributable to global sources can be

estimated.[32] The model estimated that over 80 percent on average of total mercury deposition in the United States is attributable to global sources.

Due to the evolving nature of mercury modeling science, such deposition estimates have associated uncertainties. For example, it remains difficult to distinguish between the natural emissions of mercury and the re-emission of previously deposited anthropogenic mercury and there remains uncertainty in the scientific community concerning the atmospheric processes that control the oxidation state of atmospheric mercury. Thus, further advances in the current understanding of mercury chemistry could potentially lead to changes in the modeling parameters and assumptions governing the mercury chemistry in the models and therefore, changes in the estimate of the fraction deposited in the U.S. attributable to global sources.

For more information on CMAQ, see http://www.epa.gov/asmdnerl/CMAQ.

D-MCM (Dynamic Mercury Cycling Model)

D-MCM is a food web simulation of mercury accumulation in lakes. It predicts the cycling and fate of major forms of mercury in lakes, including methylmercury, Hg (II), elemental mercury, and total mercury. It is a time-dependent mechanistic model which considers the most important physical, chemical, and biological factors affecting fish mercury concentrations in lakes. D-MCM is meant for lotic (lake) systems, and is not meant to be used for lentic (streams, rivers, etc.) systems.

D-MCM can be used to develop and test hypotheses, scope field studies, improve understanding of cause and effect relationships, predict responses to changes in loading, and support design and evaluation of mitigation options. It was used in the development of mercury TMDLs for McPhee and Narraguinnep Reservoirs in Colorado and for the TMDLs for Arivaca and Pena Blanca Lakes in Arizona. The Everglades Mercury Cycling Model (E-MCM) was developed off of D-MCM and added vegetation processes and the ability to simulate multiple sediment layers for wetlands.

Information on D-MCM can be found at: http://rd.tetratech.com/DraftHgBrochurev2.pdf.

EXAMS2 (Exposure Analysis Modeling System)

EXAMS2 is a model for creating aquatic ecosystem models which can evaluate the fate, transport, and exposure concentrations of chemicals. Chemicals include synthetic organic chemicals like pesticides, industrial materials, and leachates from disposal sites. EXAMS2 core is a set of modules that link chemical properties to limnological characteristics that control the fate and transport of chemicals in aquatic systems. This model allows for both long-term analysis of chronic chemical discharges at constant release and varying release over time, and short-term analysis of chemical releases.

EXAMS2 has commonly been used to predict pesticide fate in water and soil. This model has been used to evaluate the role of hydroxyl radicals in degrading pesticides by

[32] On February 8, 2008, the D.C. Circuit Court of Appeals vacated the Clean Air Mercury Rule and remanded portions of it to EPA, for reasons unrelated to the technical analyses cited in this guidance.

researchers at the University of Georgia. EXAMS2 was also used to simulate mercury fate in the Withlacoochee River watershed and the Ohoopee River watershed in Georgia.

Information on EXAMS2 can be found at: http://www.epa.gov/ceampubl/swater/exams/.

GBMM (Grid Based Watershed Mercury Model)

EPA's Grid Based Watershed Mercury Model (GBMM) is a continuous grid-based watershed mercury loading model using the latest ArcGIS platform. It simulates the spatial and temporal dynamics of mercury from both point and non-point sources on a daily basis. The model calculates the water balance, sediment generation and transport, and mercury dynamics within a watershed. The mercury transport and transformation module simulates the following key processes:

- Mercury input from atmospheric deposition.
- Mercury assimilation and accumulation in forest canopy and release from forest litter.
- Mercury input from bedrock weathering.
- Mercury transformation in soils.
- Mercury transformation in lakes and wetlands including reduction and net methylation.
- Mercury transport through sediment and runoff.
- Mercury transport in stream channels.

GBMM accepts input data from atmospheric deposition, point sources, and natural background in time series or in digital spatial maps. By using the grid-based technology, flow and mercury dynamics can be examined at any of several points in the watershed.

The software has been peer reviewed and tested on two watersheds in Georgia, where it was used to calculate mercury TMDLs. GBMM has been used to investigate the mercury fate and transport in Brier Creek watershed located in the coastal plain of Georgia. GBMM was used to investigate detailed watershed mercury processes. The findings of this study were presented in Eighth International Conference on Mercury as a Global Pollutant (August 2006), Madison, Wisconsin, USA.

For more information on GBMM please visit: http://www.epa.gov/athens/research/modeling/mercury/gbmm.html.

GEOS-CHEM Model

The Global GEOS-CHEM model simulates physical and chemical atmospheric processes driven by observations by NASA's Goddard Earth Observing System (GEOS). This model is managed and supported by the atmospheric chemistry modeling group at Harvard University. This model is used as a tool for atmospheric composition problems.

This model was run for the 2001 CMAQ model with a grid resolution of 2 degree x 2.5 degree (latitude-longitude) and 20 vertical layers. GEOS–Chem is a major contributor to

the NASA Global Model Initiative (GMI). GEOS–Chem has been interfaced with the NASA/GISS general circulation model to investigate the effects of climate change. This work contributes to the multi-institutional Global Change and Air Pollution (GCAP) project. GEOS–Chem provides chemical modules for data assimilation of tropospheric composition at the NASA GMAO.

For more information on GEOS-CHEM please visit: http://www-as.harvard.edu/chemistry/trop/geos/geos_overview.html.

GWLF (Generalized Watershed Loading Function)

GWLF simulates mixed land use watersheds to evaluate the effect of land use practices on downstream loads of sediment and nutrients (N, P). As a loading function model, it simulates runoff and sediment transport using the curve number (CN) and Universal Soil Loss Equation (USLE), combined with average nutrient concentration, based on land use. Recently, a GIS-interface has been integrated which can use national land use and soil GIS data. Also GWLF models in-stream routing using the Muskingum-Cunge method and simulates three particle classes of sediment transport.

GWLF has been used in studies and TMDL development nationally. It is suitable for application to generalized watershed loading, source assessment, and seasonal and interannual variability. It has been extensively used in northeast and mid-Atlantic regions. It has been adopted by Pennsylvania as state system for TMDL development and agricultural land management. GWLF was used to calculate mercury load from the watershed to a lake in several TMDLs in Arizona (e.g., TMDL for Pena Blanca Lake, Arizona). GWLF is also applied in West Virginia TMDL projects by Tetra Tech, Inc.

Information on GWLF can be found at: http://www.epa.gov/nrmrl/pubs/600r05149/600r05149gwlf.pdf and http://www.vims.edu/bio/models/basinsim.html.

Mercury Maps screening analysis

A simple screening-level analysis of the mercury sources affecting a waterbody or waterbodies can assist in determining what type of approach to TMDLs is most appropriate. EPA's Mercury Maps (USEPA 2001b) is a geographic information system (GIS)-based analysis using national data coverage for watersheds, fish tissue concentrations, and non-air deposition source locations.

Mercury Maps uses a simplified form of the IEM-2M model applied in EPA's *Mercury Study Report to Congress* (USEPA 1997a). By simplifying the assumptions inherent in the freshwater ecosystem models described in the report to Congress, Mercury Maps showed that these models converge at a steady state solution for methylmercury concentrations in fish that are proportional to changes in mercury inputs from atmospheric deposition (e.g., over the long term, fish concentrations are expected to decline proportionally to declines in atmospheric loading to a waterbody). This analytical approach applies only to situations where air deposition is the only significant source of mercury to a waterbody and the physical, chemical, and biological characteristics of the ecosystem remain constant over time. To predict reductions in fish concentrations, Mercury Maps requires estimates of percent air deposition reductions by watershed, as

generated from a regional air deposition model, and georeferenced measurements of mercury concentrations in fish.

A state or authorized tribe can apply Mercury Maps on a state or watershed scale. For example, it could apply Mercury Maps on a statewide scale, using state- or tribe-defined watershed boundaries. The state might have its own data on point source effluent loads and more detailed information on other significant sources of mercury in the state, e.g., erosion of mine tailings or natural geology.

Because Mercury Maps is a simplified approach, it has several limitations.

1. The Mercury Maps approach is based on the assumption of a linear, steady state relationship between concentrations of methylmercury in fish and present-day air deposition mercury input. This condition might not be met in many waterbodies because of recent changes in mercury inputs and other environmental variables that affect mercury bioaccumulation. For example, the United States has recently reduced human-caused emissions, and international emissions have increased.

2. Environmental conditions might not remain constant over the time required to reach steady state inherent in the Mercury Maps methodology, particularly in systems that respond slowly to changes in mercury inputs.

3. Many waterbodies, particularly in areas of historical gold and mercury mining in western states, contain significant non-air sources of mercury. Mercury Maps' methodology should not be applied to such waterbodies.

4. Finally, Mercury Maps does not provide for a calculation of the time lag between a reduction in mercury deposition and a reduction in the methylmercury concentrations in fish.

Despite the limitations of Mercury Maps, for those watersheds where mercury comes almost exclusively from air deposition, Mercury Maps can be used as a simple screening tool to show the watersheds across a region where the current fish tissue concentration on average exceeds the new methylmercury fish tissue criterion and, thus, to estimate the atmospheric load reductions needed to meet the new criterion. Further information on Mercury Maps is at http://www.epa.gov/waterscience/maps and from the Office of Air Quality Planning and Standards at http://www.epa.gov/ttn/atw/utility/ria_final.pdf.

MOBILE

MOBILE is an EPA model for estimating air pollution from highway vehicles. MOBILE predicts emissions (grams/mile) of air pollutants from cars, trucks, and motorcycles under various conditions. MOBILE models emissions of several air toxics, hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), carbon dioxide (CO_2), and particulate matter (PM). MOBILE is based on emissions testing of tens of thousands of vehicles. The model accounts for the impact on emissions of factors such as legislative changes in vehicle emission standards, variation in local conditions such as temperature, humidity, and fuel quality, and changes in the types and use of the vehicles being driven.

MOBILE has been used to calculate national and local inventories of current and future levels of highway vehicle emissions. The inventories are used to inform decision-making

about air pollution policy and programs at the national, state and local level. Inventories based on MOBILE are also used to meet requirement of federal statutes like the Clean Air Act (CAA) and the National Environmental Protection Act (NEPA). MOBILE contributed to the creation of the National Emissions Inventory (NEI).

Information on MOBILE can be found at: http://www.epa.gov/otaq/mobile.htm.

NDMMF (National Descriptive Model of Mercury in Fish Tissue)

NDMMF is a statistical model which simulates mercury accumulation in varying species of fish. It simulates factors representing differences in species, size, and sampling method. This model has the ability to control for site factors specific to a location that influence mercury concentrations in fish tissue. For example, all fish tissue samples can be scaled to a standardized 14" bass for a specific location. The model works in association with a national dataset of over 30,000 samples of fish tissue for calibration.

NDMMF could be useful for evaluating spatial and temporal trends in fish mercury concentrations and developing fish-consumption advisories. The U.S. Geological Survey recently applied this model to study spatial variation in fish-tissue mercury concentrations in the St. Croix River Basin, Minnesota and Wisconsin.

Information on NDMMF can be found at: http://emmma.usgs.gov/fishHgAbout.aspx.

NONROAD

NONROAD is an EPA model for estimating air pollution from all engines, equipment, and vehicles that is considered "nonroad". This includes recreational vehicles, agricultural equipment, industrial equipment, residential equipment, and construction equipment. The NONROAD model is used to predict past, present, and future emissions of air pollutants like hydrocarbons (HC), oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), sulfur oxides (SO_x), and particulate matter (PM). It has been shown that "nonroad" sources contribute a significant amount of air pollutants to the environment.

Used in complement to MOBILE, NONROAD has been used to calculate national and local inventories of current and future levels of "nonroad" emissions. This model has become critical over the past several years in providing state and local pollution control agencies the ability to create accurate and consistent inventories of "nonroad" emissions to satisfy the requirements of the Clean Air Act Amendments of 1990. NONROAD contributed to the creation of the National Emissions Inventory (NEI). The Lake Michigan Air Directors Consortium (LADCO) used NONROAD to forecast emissions in their region and make appropriate policy recommendations.

Information on NONROAD can be found at: http://www.epa.gov/otaq/nonrdmdl.htm.

QEAFDCHN (Quantitative Environmental Analysis Food Chain) Model

The QEAFDCHN model is a tool for predicting chemical residues in aquatic organisms given the concentrations of chemicals in water and sediment. To predict chemical residues, the model requires information on the individual species (bioenergetic and physiological) and their diets. The model is designed to determine chemical residue in

aquatic organisms given varying chemical concentrations in both water and sediment over time.

The QEAFDCHN model can be used in a steady-state or dynamic application. The model allows the specification of complex food webs, e.g., fish preying on multiple species including smaller fish, and even age classes of fishes. The model treats individual segments of the greater ecosystem as individual ecosystems and the model has an aquatic organism migration feature. QEAFDCHN has been applied to the Lavaca Bay, Texas, chlor-alkali facility mercury contamination study by Quantitative Analysis, LLC.

Information on QEADFCHN can be found at: http://www.epa.gov/superfund//health/conmedia/sediment/pdfs/bsafissue.pdf.

Regional Modeling System for Aerosols and Deposition (REMSAD)

REMSAD is a three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations (ICF International 2006). REMSAD has been peer-reviewed and is designed to support an understanding of the distributions, sources, and removal processes relevant to fine particles and other airborne pollutants, including soluble acidic components and several toxic species (mercury, cadmium, dioxin, polycyclic organic matter [POM], atrazine, and lead).

Mercury can be present in the atmosphere in both the gas and particulate phases. The mercury species included in REMSAD are Hg^0 (elemental mercury vapor), Hg^{2+} (divalent mercury compounds in gas phase), and Hg_P (divalent mercury compounds in particulate phase). These species represent the oxidation state of mercury, and the gas and particulate phases. The reactions in REMSAD, which are based on the studies of Lin and Pehkonen (1999) and other recently published studies, simulate the transfer of mercury mass from one of these states to another. REMSAD Version 8 uses the full Carbon Bond-V mechanism to simulate gas-phase photochemical processes in the atmosphere (micro-CB is still available as an option), and it also includes a chemical mechanism to calculate the transformations of mercury.

REMSAD simulates both wet and dry deposition of mercury. Wet deposition occurs as a result of precipitation scavenging. Dry deposition is calculated for each species based on land-use characteristics and meteorological parameters. REMSAD also includes algorithms for the reemission of previously deposited mercury (originating from anthropogenic and natural sources) into the atmosphere from land and water surfaces due to naturally occurring (e.g., microbial) processes.

REMSAD provides estimates of the concentrations and deposition of mercury and all other simulated pollutants at each grid location in the modeling domain. Post-processing can provide concentration averages and deposition totals for any subset of the time span of the simulation for any location within the domain.

The mercury treatment in REMSAD can be expanded to include additional, tagged mercury species. The Particle and Precursor Tagging Methodology (PPTM) feature allows the user to tag or track emissions from selected sources or groups of sources and

to quantify their contribution to mercury deposition throughout the modeling domain and simulation period.

The REMSAD model is capable of "nesting" one or more finer-scale subgrids within a coarser overall grid. This feature uses a fully interactive two-way nesting capability that permits high resolution over selected source and/or receptor regions of interest. The modeling system can be applied at scales ranging from a single metropolitan area to a continent containing multiple urban areas.

REMSAD has been used in identifying the sources contributing mercury deposition to a waterbody. In an EPA Wisconsin pilot project, REMSAD was used to input the air pollutant deposition results to aquatic models like the Mercury Cycling Model, to examine how mercury levels in fish might respond to potential changes in deposition. REMSAD has been used to develop TMDLs and determine strategies for addressing mercury and other air pollutant deposition. REMSAD was used in developing the mercury TMDL for the Coastal Bays and Gulf Waters of Louisiana (approved in 2005) and the mercury TMDLs for middle and south Georgia (approved in 2002).

Information on REMSAD can be found at: http://remsad.saintl.com/.

SERAFM (Spreadsheet-based Ecological Risk Assessment for the Fate of Mercury)

The SERAFM model is a spreadsheet-based risk assessment tool specifically designed for mercury contaminated ecosystems. SERAFM uses a steady-state simplifying assumption and includes a series of sequentially linked modules presented on separate spreadsheets. These modules include:

- Atmospheric deposition
- Watershed soil erosion
- Watershed mercury loading
- Waterbody solids balance
- Equilibrium partitioning (DOC complexation, solids partitioning)
- Mercury speciation
- Waterbody mercury calculations (historic sediment contamination, background, and remedial goal)
- Fish tissue concentrations
- Wildlife hazard quotients

The SERAFM model incorporates more recent advances in scientific understanding and implements an updated set of the IEM-2M solids and mercury fate algorithms that were described in the 1997 *Mercury Study Report to Congress* (USEPA 1997c).

For more information on SERAFM please visit: http://www.epa.gov/athens/research/modeling/mercury/serafm.html and http://www.epa.gov/nerl/news/forum2005/knightes.pdf.

TOXI5

TOXI5 is one of two submodels of WASP (Water Quality Analysis Simulation Model), the other being EUTRO5, which deals with eutrophication. TOXI5 is a sediment transport model which can also simulate the transport and transformation of chemicals. The transport of up to three types of sediment and up to three chemicals can be simulated. The chemicals may react independently or they may be linked with reaction yields which predict the fate of the interaction. Dissolved and sorbed chemical concentrations in the waterbody bed and overlying waters can be predicted using TOXI5.

TOXI5 was used to simulate the fate of mercury in the Ochlockonee Watershed in Georgia, to help develop mercury TMDLs for the Southeast U.S., and to evaluate the feasibility of dam release of water on the Nakdong River in Korea to mitigate frequent accidental spills of toxic chemicals.

For more information on TOXI5 please visit: http://smig.usgs.gov/cgi-bin/SMIC/model_home_pages/model_home?selection=wasp.

WASP (Water Quality Analysis Simulation Program)

The Water Quality Analysis Simulation Program (WASP) is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. It has detailed mercury transformation processes for the water column and benthic sediments. The mercury module simulates the following key processes:

- Volatilization of Hg^0 (aq) to Hg^0 (air)
- Oxidation of Hg^0 → Hg^{II}
- Reduction of Hg^{II} → Hg^0
- Methylation of HgII → MeHg
- Demethylation of MeHg → Hg^{II}
- Photoreduction of MeHg → Hg^0

WASP has been used to examine eutrophication of Tampa Bay, Florida; phosphorus loading to Lake Okeechobee, Florida; eutrophication of the Neuse River Estuary, North Carolina; eutrophication of the Coosa River and Reservoirs, Alabama; PCB pollution of the Great Lakes; eutrophication of the Potomac Estuary; kepone pollution of the James River Estuary; volatile organic pollution of the Delaware Estuary; heavy metal pollution of the Deep River, North Carolina; and mercury in the Savannah River, Georgia.

Information on WASP can be found at: http://www.epa.gov/athens/research/modeling/wasp.html.

WCS (Watershed Characterization System) Mercury Loading Model

The WCS Mercury Loading model is a GIS-based (ArcView 3.x) extension of the WCS model based on a soil-mercury mass balance model (IEM v 2.05). The soil-mercury mass balance model calculates surface soil concentrations in dissolved, sorbed, and gas phases.

The model accounts for three routes of contaminant entry into the soil:

- Deposition of particle-bound contaminant through dry fall
- Deposition through wet fall
- Diffusion of gas phase contaminant into the soil surface

The model also accounts for four dissipation processes that remove mercury from the surface soils:

- Volatilization (movement of gas phase out of the soil surface)
- Runoff of dissolved phase from the soil surface
- Leaching of dissolved phase through the soil horizon
- Erosion of particulate phase from the soil surface

The model assumes that the diffusion and volatilization processes are roughly balanced on an annual basis. The WCS Mercury Loading model was used to develop many TMDLs in EPA Region 4 including a mercury TMDL for the Middle and Lower Savannah River.

Information on the WCS model can be found at: http://www.epa.gov/athens/wwqtsc/WCS-toolbox.pdf.

Example of Linking Models

Since there is no single model that can simulate all processes involved in TMDLs, some TMDLs for mercury have linked together models of atmospheric deposition, watershed loading, and mercury cycling with bioaccumulation. For example, a watershed mercury model such as GBMM, or the watershed module within SERAFM could be linked to a receiving water mercury model such as WASP, and a bioaccumulation model such as BASS.

GBMM is a spatially discrete, dynamic watershed mercury loading model which was designed for direct linkage to the EPA receiving waterbody model, WASP. GBMM can simulate mercury fate and transport within the watershed landscape and transport mercury and soils to the receiving waters through the tributaries. WASP can in turn simulate mercury dynamics in the receiving water. To predict bioaccumulation of the resulting mercury concentrations into fish tissues, WASP can then be linked to BASS. SERAFM is a more simplified approach and captures the processes from watershed to waterbody to fish bioaccumulation; however, it makes simplifying assumptions such as the waterbodies are steady state and it uses the national BAFs presented by EPA for trophic level fish.

Linkage of such models may be a workable solution in some situations. One of the limitations of the GBMM-WASP-BASS approach is that it is not an "off-the-shelf" model and a high level of expertise might be required to link the models together.

Appendix F. Examples of National Deposition Monitoring Networks

A number of national deposition monitoring networks might be useful for developing TMDLs. The networks include the National Atmospheric Deposition Program–National Trends Network (NADP/NTN) and the Mercury Deposition Network (MDN, a subset of the NADP network). The NADP/NTN is a nationwide network of precipitation monitoring stations. Operating since 1978, it collects data on the chemistry of precipitation for monitoring of geographic patterns and temporal long-term trends. NADP/NTN measures weekly average concentrations of sulfate, nitrate, ammonium, base cations, and acidity at approximately 230 monitoring stations across the United States. The MDN measures concentrations of total mercury in precipitation at approximately 45 monitoring stations across the United States and Canada. NADP/NTN results for 2003 are shown in figure F-1. For more information about NADP, see http://nadp.sws.uiuc.edu.

Used in conjunction with NADP/NTN, the Clean Air Status and Trends Network (CASTNET) is the nation's primary source of atmospheric data on the dry deposition component of total acid deposition, ground-level ozone, and other forms of atmospheric pollution that enters the environment as particles and gases. CASTNET measures weekly average atmospheric concentrations of sulfate, nitrate, ammonium, sulfur dioxide, and nitric acid, as well as hourly concentrations of ambient ozone levels in rural areas. Dry deposition rates are calculated using the measured atmospheric concentrations, meteorological data, and information on land use, surface conditions, and vegetation. Seventy-nine monitoring stations operate across the United States. For more information about CASTNET, see http://www.epa.gov/castnet and http://nadp.sws.uiuc.edu.

Note that these national monitoring networks generally provide only estimates of wet deposition; estimates of dry deposition can be obtained from the literature. For more information on deposition monitoring networks, see *Deposition of Air Pollutants to the Great Waters: Third Report to Congress* (USEPA 2000h) (http://www.epa.gov/oar/oaqps/gr8water/3rdrpt) and the Air-Water Interface Plan (http://www.epa.gov/ttn/caaa/t3/reports/combined.pdf).

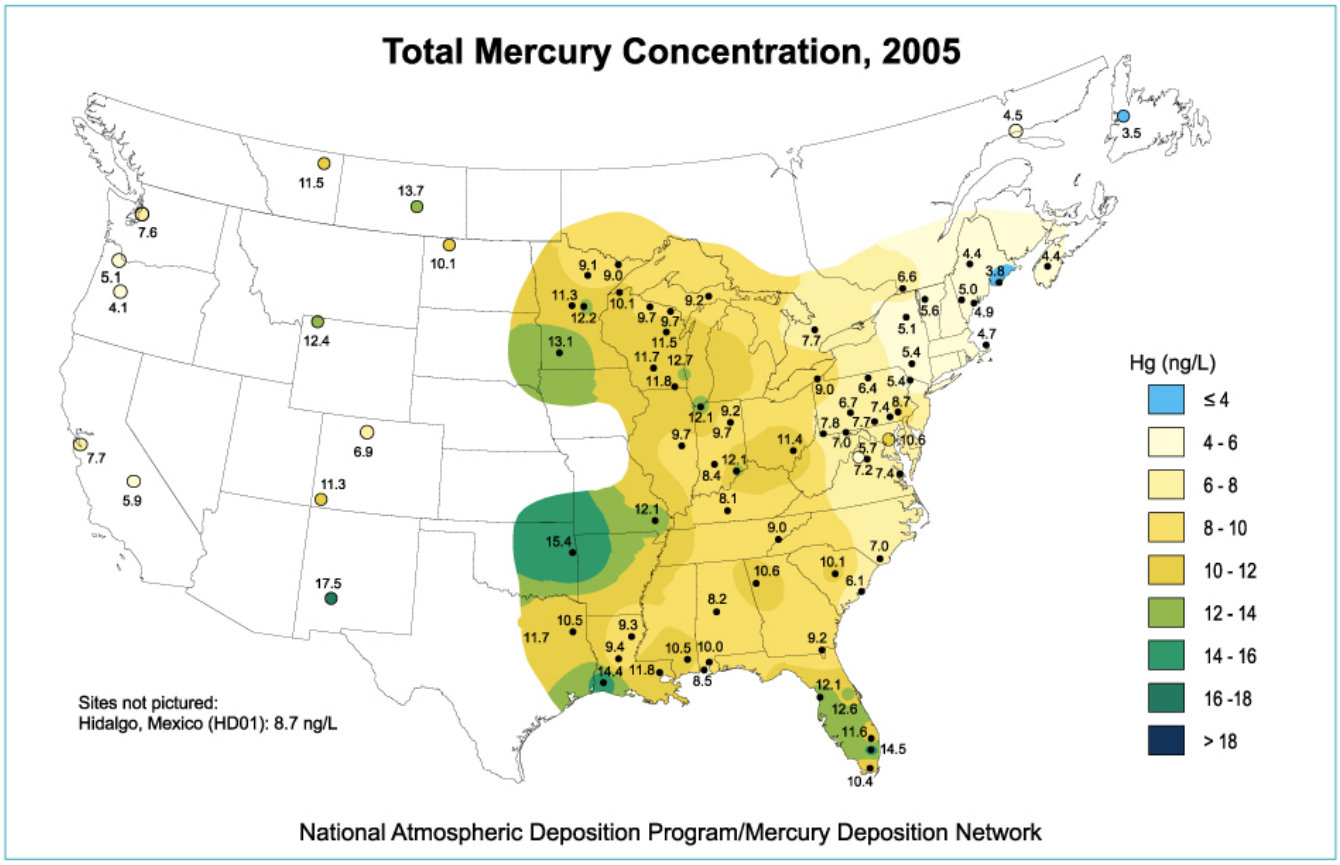

Figure F-1. MDN data for 2005.

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Note: Bold numbers indicate where the term is defined (if applicable). If the term has been broken into subcategories, this is noted with a *defined* entry.

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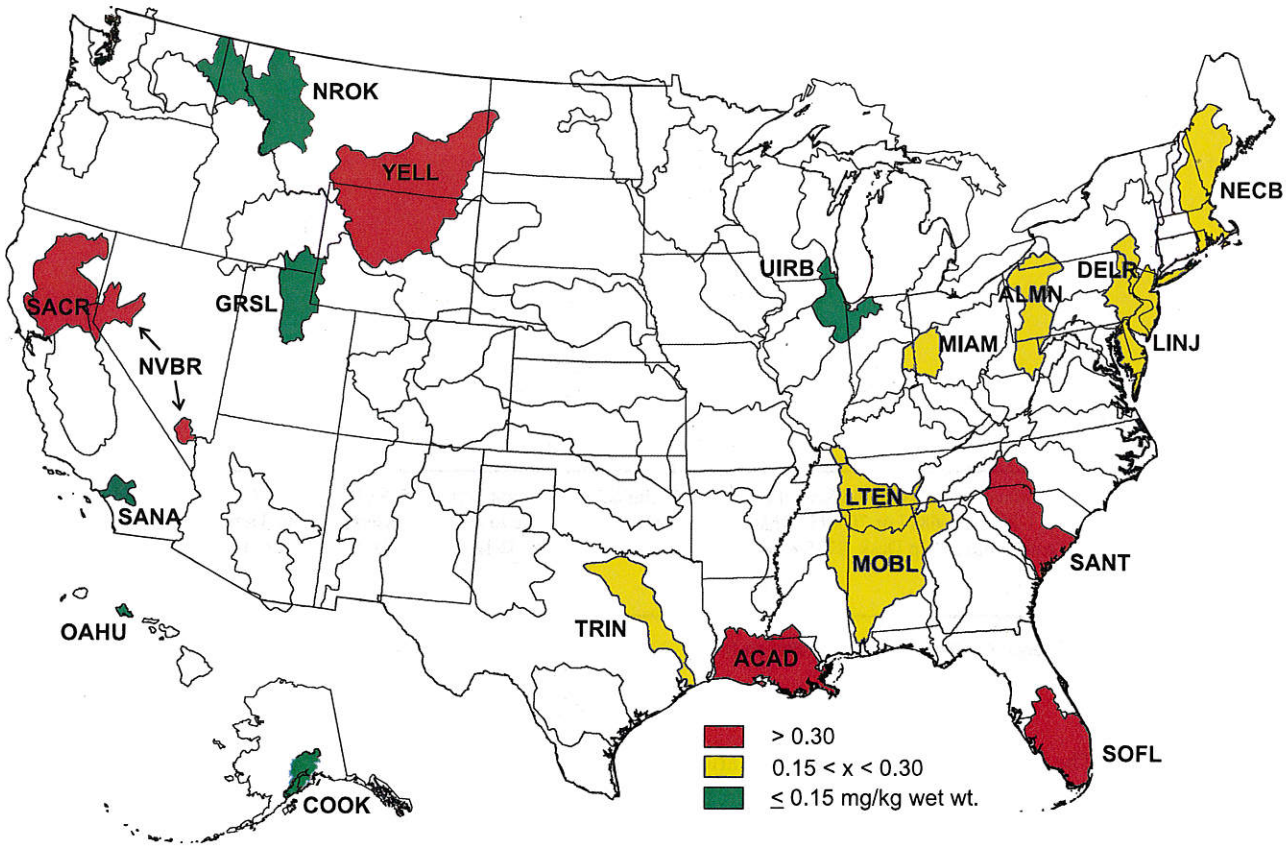
A National Pilot Study of Mercury Contamination of Aquatic Ecosystems Along Multiple Gradients: Bioaccumulation in Fish

Biological Science Report
USGS/BRD/BSR–2001-0009



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Front cover: The U.S. map shows 20 USGS National Water Quality Assessment (NAWQA) basins sampled in this study, categorized by geometric mean of mercury concentration in fish fillet samples. Basins shaded in gray delineate NAWQA study units not sampled.

A National Pilot Study of Mercury Contamination of Aquatic Ecosystems Along Multiple Gradients: Bioaccumulation in Fish

Biological Science Report
USGS/BRD/BSR–2001-0009
September 2001

by

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A National Pilot Study of Mercury Contamination of Aquatic Ecosystems Along Multiple Gradients: Bioaccumulation in Fish

Abstract: Water, sediment, and fish were sampled in the summer and fall of 1998 at 106 sites from 20 U.S. watershed basins to examine relations of mercury (Hg) and methylmercury (MeHg) in aquatic ecosystems. Bioaccumulation of Hg in fish from these basins was evaluated in relation to species, Hg and MeHg in surficial sediment and water, and watershed characteristics. Bioaccumulation was strongly (positively) correlated with MeHg in water ($r = 0.63$, $\rho < 0.001$) but only moderately with the MeHg in sediment ($r = 0.33$, $\rho < 0.001$) or total Hg in water ($r = 0.28$, $\rho < 0.01$). Of the other measured parameters, pH, DOC, sulfate, sediment LOI, and the percent wetlands of each basin were also significantly correlated with Hg bioaccumulation in fish. The best model for predicting Hg bioaccumulation included MeHg in water, pH of the water, % wetlands in the basin, and the AVS content of the sediment. These four variables accounted for 45% of the variability of the fish fillet Hg concentration normalized (divided) by total length; however, the majority was described by MeHg in water. A MeHg water concentration of 0.12 ng/L was on average, associated with a fish fillet Hg concentration of 0.3 mg/kg wet weight for an age-3 fish when all species were considered. For age-3 largemouth bass, a MeHg water concentration of 0.058 ng/L was associated with the 0.3 mg/kg fillet concentration. Based on rankings for Hg in sediment, water, and fish, sampling sites from the following five study basins had the greatest Hg contamination: Nevada Basin and Range, South Florida Basin, Sacramento River Basin (California), Santee River Basin and Coastal Drainages (South Carolina), and the Long Island and New Jersey Coastal Drainages. A sampling and analysis strategy based on this pilot study is planned for all USGS NAWQA study units over the next decade.

Key Words: Mercury, methylmercury, bioaccumulation, fish, water, sediment

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INTRODUCTION

Methylmercury (MeHg) is a potent neurotoxin that is among the most widespread contaminants affecting our Nation's aquatic ecosystems. Human fish-consumption advisories for Hg in fish have been issued in more than 40 states and account for more than eighty percent of all such advisories in the Nation (USEPA, 1998). While the threat to humans is very real, there is potentially a more serious threat to piscivorous wildlife, which consume relatively large quanitities of fish (Wiener and Spry, 1995). In Part One of this study (Krabbenhoft and others, 1999), Hg methylation efficiency was evaluated in sediment and water from watersheds that were sampled concurrently with the fish described by this report. Among other findings, MeHg production efficiency was highest in Eastern coastal basins containing high wetland densities. Nationwide, MeHg production was highest in sub-basins characterized as mixed agriculture and forested. In this report, relationships among Hg and MeHg in sediment and water are compared with bioaccumulation in fish axial muscle (the dominant repository for MeHg in fish) for 20 basins nationwide. The importance of total Hg load, methylation efficiency, MeHg in sediments and water, and selected watershed characteristics in determining the bioaccumulation of Hg in fish is assessed.

The USGS National Mercury Pilot Study

This study was conducted jointly by the National Water Quality Assessment (NAWQA) program, Toxic Substances Hydrology program, Wisconsin District Mercury Laboratory (WDML), and Columbia Environmental Research Center (CERC) of the U.S. Geological Survey. The overall objective was to identify ecosystem characteristics that favor the production and bioaccumulation of MeHg and to compare bioaccumulation rates on a national basis. Bioaccumulation of Hg in fish is a complex function of total Hg load, methylation efficiency, fish size, and the food chain dynamics in a given water body (Kidd and others, 1995). Consequently, aquatic ecosystems with high loads may have only moderate bioaccumulation in fish if methylation efficiency is low and conversely, significant bioaccumulation may result when loading is low if methylation efficiency is high. Regional- and national-scale fish surveys have been conducted in the past for Hg and other bioaccumulative contaminants. However, this is the first national-scale study in which water, sediment, and fish were sampled together with low-level Hg speciation analysis.

EXPERIMENTAL SECTION

Study Design

The major design characterics of this study were (1) national scope, (2) sampling of water, sediment, and predator fish muscle, (3) consistent use of ultra-trace clean sampling methods, (4) ultra-trace total and methyl-mercury analytical procedures, and (5) analysis of all routine water and sediment quality parameters. Sampling was conducted from June to October, 1998 at 3 to 8 sites from 20 of the 59 study units (front cover and Table 1) of the USGS NAWQA program (http://water.usgs.gov/nawqa). Nationally, these basins span the dominant east-to-west mercury deposition gradient (USEPA, 1997) and represent a wide range of environmental settings. Individual study basin teams were asked to choose sites within a basin which spanned gradients of wetland density, surface water pH, sulfate, total organic carbon, and suspected or known Hg loading. Most sampling sites were on streams. Some of the sites had high Hg loading from known Hg point sources.

Field crews were asked to focus on largemouth bass (*Micropterus salmoides*) or other black bass (*Micropterus sp.*) of age 3 years (estimated from regional growth rate data, when available) and to collect five individuals per site for compositing. Although collection objectives were not always met, all fish samples submitted were analyzed. In some cases, fish were analyzed individually to avoid creating composites of multiple species or ages. Axial muscle (fillet) was targeted for Hg analysis because it is generally the dominant and most stable repository in fish (Goldstein and others, 1996). Only total Hg was determined in the fish because virtually all of the Hg in the fillet is present as MeHg (Bloom, 1992). Black bass were targeted as ubiquitous predator fish which could facilitate inter-basin comparisons. Also, they might be expected to correlate well with localized sediment and water conditions because they normally inhabit relatively small ranges as compared to nomadic predators such as walleye (*Stizostedion vitreum*) or white bass (*Morone chrysops*), (Carlander, 1977). However, if black bass species were expected to be absent at one or more sites within a basin, samplers were advised to collect a predator species common to the entire basin so that gradients within each basin could be examined.

Age-3 fish were targeted because: (1) they should be relatively plentiful and of reasonable size for sampling fillets, (2) differences in Hg accumulation between males and females of the same size should be small, i.e., sexual growth dimorphism for largemouth bass is reportedly minimal up to this age (Lange and

Table 1. Basins, number of sites, and number of fish samples analyzed.

Abbrev.	Study Basin Name	no. sites	no. samples[a]
ACAD	Acadian-Ponchartrain Basin	5	5
ALMN	Allegheny and Monongahela River Basins	5	6
COOK	Cook Inlet Basin (Alaska)	4	6
DELR	Delaware River Basin	9	12
GRSL	Great Salt Lake Basins	2	4
LINJ	Long Island and N.J. Coast Drainages	4	13
LTEN	Lower Tennessee River Basin	3	8
MIAM	Miami River Basin (Ohio)	7	13
MOBL	Mobile River and Tributaries	7	15
NECB	New England Coastal Basin	5	5
NROK	Northern Rockies Intermontane Basins	2	2
NVBR	Nevada Basin and Range	1	8
OAHU	Oahu Island	6	6
SACR	Sacramento River Basin	5	11
SANA	Santa Ana River Basin	4	4
SANT	Santee River Basin and Coastal Drainages	5	5
SOFL	South Florida Basin	2	6
TRIN	Trinity River Basin	5	18
UIRB	Upper Illinois River Basin	5	6
YELL	Yellowstone River Basin	5	6

[a] Samples per basin, each consisting of either a homogenized composite or an individual depending on size and species submitted.

others, 1994) and (3) age-3 fish should be old enough to exhibit significant bioaccumulation of Hg. Older fish generally bioaccumulate higher concentrations of Hg but would be more difficult to capture in a consistent age class. Also, concentrations of Hg in older fish might be less representative of recent conditions contributing to the observed concentrations of Hg in the sediment and water.

Sample Collection and Preparation

Sampling and analysis of sediment and water was described in Part One of this study (Krabbenhoft and others, 1999). Of note, surface water was not filtered and sediments were taken from the top 2 to 4 cm. Ultra-trace protocols were followed for the sampling of water for Hg. Fish samples were collected by the most efficient means available, usually by electroshocking or gill-netting. Each fish was rinsed in stream water, measured for length and weight, double bagged in zip-seal plastic, and placed on dry ice as soon as possible. Samples from the ACAD and SANT basins were filleted by field crews, who also determined the ages of their specimens. Most samples were shipped within 48 hours of collection, but some were stored frozen for 1 to 2 weeks before shipment. Once received by CERC, they were stored at –20 °C for 3 to 6 months before the fillets were prepared for analysis.

Before removing fillets, individual fish from each site were thawed at room temperature for 1 to 2 hours, depending on size. Several scales were removed from behind the gill cover for aging. Each fish was then rinsed with laboratory-grade deionized (DI) water (> 10 Mohm-cm) and placed on a polypropylene cutting board situated in a polypropylene bin. Fillet knives with either ceramic (ZrO) or titanium-aluminum alloy (for larger fish) blades were used to remove a skinless, boneless (belly flap removed) fillet from the left side of each specimen. Each fillet (including those removed by field crews) was chopped into 2-cm square sections, placed in a heavy-duty polyethylene zip-seal freezer bag, rinsed twice with ultra-pure (UP) water (18 Mohm-cm), drained thoroughly and returned to the freezer. Between samples, the knife and cutting board were scrubbed with tap water and detergent, then rinsed with DI water, 1% (v/v) ultra-pure nitric acid, and HPLC-grade methanol. Equipment and cleaning procedures used for the few samples filleted by field crews were not necessarily as described above. However, we assume that potential surface contamination of all fillets was minimized by rinsing twice with UP water before

analysis.

For each site, fillets of the same species were composited for all fish of a similar size (assumed to be of similar age). However, for many sites the sampled fish varied greatly in size and apparent age, consequently some individuals were analyzed separately to avoid compositing fish of differing ages. For a few sites, the fish collected were too small (< 50 g) to conveniently remove a fillet; these specimens were chopped and processed either whole or whole, less heads. After all samples were filleted, the frozen muscle sections were placed into an acid-washed borosilicate glass jar and lyophilized (freeze-dried) to a constant dry weight at -5°C with a vacuum of about 100 mtorr. Lyophilization facilitates sample manipulation and storage but does not cause loss of biologically-incorporated Hg from tissue (LaFleur, 1973; Lasorsa and Allen-Gil, 1995). The dry product was briefly blended with a hand-held high-speed bio-homogenizer having a polystyrene bowl fitted with a stainless steel cutting blade. The base and blade assembly were washed between samples with detergent and hot water, rinsed with UP water, and dried with filtered compressed air. A representative portion of each homogenate was immediately transferred to a borosilicate glass vial fitted with a telfon-lined cap for storage in a desiccator.

Hg Determination

Tissue samples were digested before determination of Hg with microwave heating in sealable tetra-fluorinated ethylene (TFE) pressure vessels. Five mL of HNO_3 and 0.5 mL of HCl (each sub-boiled in quartz and stored in a TFE bottle) were added to a 0.5-g dry tissue sample and the vessel was sealed and placed overnight in a water bath at 70°C. The vessel was cooled, vented, then heated with a 3-step microwave program. After cooling, 1 mL of ultra-pure 30% H_20_2 was added, the vessel was sealed, and the 3-step heating program was repeated. The vessel was again cooled and the liquid contents were quantitatively transferred and diluted to 100 mL with 1% (v/v) HCl in an acid-cleaned polyethylene bottle. After briefly mixing, a 30-mL portion of the digestate was immediately transferred to a borosilicate glass tube and capped until analysis.

Analysis for Hg was conducted by cold-vapor atomic absorption spectrophotometry with flow injection sample introduction and stannous chloride reduction. Standards used for calibration included solutions containing 0.0, 5.0, 10.0, and 20.0 ng Hg/mL. Quality assurance samples analyzed included method (digestion) blanks, reference tissues, replicate samples, pre-digestion spikes (MeHg), post-digestion spikes (Hg^{2+}), and calibration and blank verification solutions. Sample results were blank-corrected based on the mean of three method blanks processed with each digestion set.

Age Determination

Age was estimated by scale analysis (Jearld, 1983) except for fish from SOFL and ACAD study units, for which sagittal otiliths were analysed (Porak and others, 1988). Scales were soaked in 70% ethanol to clean debris, increase transparency and soften them for flattening. Annuli were determined by two separate readers with the aid of a microfiche reader. A third reader was used in the case of discrepancies. All scale samples (about 10 per fish) were examined for each fish; the scale with the clearest markings was then used by all readers. Because samples were collected in late summer and fall, numerical ages of individuals that were spring spawners were assigned increments of 0.5 yr, whereas fall spawners (e.g., Salmonidae) were assigned increments of whole years. For example, a largemouth bass determined to be age-0 or age-1 was assigned a value of 0.5 or 1.5 yr, respectively. Due to resource limitations, not all individuals for composite samples were aged. Rather, the average for two representative individuals was used to estimate the age for each composite. Consequently, the age assigned for each composite was either a whole number or an increment of 0.5.

Statistical Analysis and Modelling

Linear regression and correlation analysis was conducted using the following variables: Hg concentration (µg/g wet wt.) in fish (Hg_{fish}), fish age (yr), fish length (m), fish weight (kg), methylmercury concentration (ng/g dry wt.) in sediment ($MeHg_{sed}$), total mercury concentration (ng/g dry wt.) in sediment ($HgTot_{sed}$), methylmercury concentration (ng/L) in water ($MeHg_{water}$), total mercury concentration (ng/L) in water ($HgTot_{water}$), percent methyl mercury in sediment, acid-volatile sulfide (AVS) in sediment (µmol/g dry wt.), sediment percent loss on ignition (LOI - an estimate of organic matter), dissolved organic carbon (DOC) in water (mg/L), sulfate concentration in water (wat_{sulf}), water pH (wat_{pH}), and % wetlands (of basin). We examined both Hg_{fish} and Hg_{fish} divided by weight, length, or age, as the dependent variable. Statistical analysis did not include results for fish determined to be less than one year of age, nor the results from the NBVR basin because of the extraordinarily high concentrations. For the multiple regression, residuals and partial plots were used to determine whether transformations were needed to meet the assumptions

of a good regression model (Helsel and Hirsch, 1992). The natural logarithm was used for Hg_{fish}, $MeHg_{water}$, $HgTot_{water}$, $HgTot_{sed}$, and $MeHg_{sed}$, and a cube root transformation for AVS, to obtain approximately normally-distributed residuals with constant variance. Several reasonable candidate regression models were selected using the adjusted R^2 (coefficient of determination) statistic. From this list, the one with the best predictive power (lowest PRESS statistic) was chosen. For principal components analysis (PCA), all data were processed using SIMCA-P (ver 8.0, Umetrics AB). The models and principal components were evaluated using pattern recognition of score (sample) plots and loading (variable) plots. As with the regression models, NVBR data was excluded from the analysis. Additionally, a subset consisting of sites where largemouth bass (LMB) were collected was modeled and evaluated in the same manner as the complete data set. For PCA only, the full data set and the LMB subset were also analyzed with the three size variables (age, length, weight) excluded so that influences of the remaining independent variables on Hg_{fish} could be more clearly examined.

Quality Assurance

Quality control results for the fish determinations of Hg were as follows: recovery of pre-digestion spikes of MeHg averaged 102.3 % (s.d. 4.2, n = 16); mean recovery for post digestion spikes of Hg^{2+} was 98.5 % (s.d. 5.1, n = 25). The measured values for three reference fish samples were in good agreement with certified or control ranges (Table 2). Precision for triplicate determinations (including digestion and analysis) averaged 2.6 % relative standard deviation (RSD) and ranged from 0.6 to 7.5% RSD (n = 8). The method detection limit, calculated for each of the three digestion blocks based on three times the pooled standard deviation of the method blanks (three per block) and a low-level sample analyzed in triplicate, ranged from 0.004 to 0.020 µg/g wet wt. Overall, eight of the nine method blanks were near or below the instrument detection limit (about 0.05 µg/L). The one elevated blank (0.3 µg/L) resulted in a higher reporting method detection limit (0.020 µg/g wet wt.) for samples determined in the same digestion block. However, virtually all sample concentrations were considerably above this highest blank. Consequently, the potential error associated with this worst-case blank was relatively small and it would affect the accuracy of only the very lowest sample concentrations. Overall, the results for quality assurance samples indicated good accuracy and precision for the study samples.

RESULTS AND DISCUSSION

Complete sample site information, species, weights, lengths, ages, and mercury concentrations in fish samples are listed in the Appendix; summary statistics are given in Table 3. For fish greater than 0.5 yr in age, the arithmetic means for total length, weight, and age were as follows: all species – 260 mm, 324 g, 3.2 yr; largemouth bass – 280 mm, 420 g, 3.2 yr; smallmouth bass – 261 mm, 299 g, 3.2 yr. For all fish samples (n = 159) the following statistics for Hg concentration (µg/g wet wt.) were obtained: arithmetic mean, 0.478; geometric mean, 0.218; median, 0.206; minimum, 0.018; maximum, 5.84. For largemouth bass (n = 50) these same statistics were 0.510, 0.329, 0.292, 0.045 and 4.22; for smallmouth bass (n = 37) the values were 0.244, 0.195, 0.205, 0.042 and 1.05, respectively. In comparison, the nationwide geometric mean for 27 largemouth bass composites sampled as part of the 1984 National Contaminant Biomonitoring Program (NCBP, Schmitt and Brumbaugh, 1990) is estimated at 0.31 µg/g wet weight for the fillet based on a conversion equation from whole fish (Goldstein and others, 1996). Thus, in general the national mean concentration of Hg in largemouth bass from our study (0.33) is similar to samples collected 15 years previously for the NCBP. Of course, this comparison does not account for possible differences in age or size of the samples, or differences in watershed coverage.

Table 2. Measured mercury concentrations (µg/g dry wt.) for fish reference tissues (n =3 for each).

MATERIAL I.D.	FishMatrix (CommonName)	Measured Mean(std.dev.)	Certifiedor ControlRange
CERCSTB	WholeStripedBass	2.21(0.01)	2.26+_ 0.51
NISTRM-50	AlbacoreTunaFillet	0.99(0.04)	0.95+_ 0.10
NRCCDorm-1	DogfishFillet	0.90(0.06)	0.80+_ 0.07

Table 3. Summary statistics for mercury concentrations (µg/g wet wt.) in fish fillet samples.

Statistic	AllSamples (n=159)	LargemouthBass (n=50)	SmallmouthBass (n=37)
Mean	0.478	0.510	0.244
Median	0.206	0.292	0.205
GeometricMean	0.218	0.329	0.194
Minimum	0.018	0.045	0.042
Maximum	5.84	4.22	1.05

Mean Fish Concentration by Basin

The geometric means of fish Hg concentrations for each of the 20 study unit basins are presented in Figure 1. Because Hg concentrations in fish from a given body of water are usually a function of size or age (Wiener and others, 1990, Lange and others, 1994) and various sizes and species of fish were collected, the geometric means for the Hg concentrations normalized (divided) by weight, length, and age are also presented in Table 4. All age-0 fish (n = 7) were excluded for this comparison due to the high relative uncertainty associated with the assignment of a fractional age of less than one. For comparing Hg in fish between waterbodies, it would be preferable to conduct an analysis of covariance between concentration and size and adjust each treatment (site) mean to a uniform size variable (Sorenson and others, 1990; Lange and others, 1993). However, for most of our sites we had insufficient observations for this approach. As indicated in Table 4, NVBR, SOFL, SANT, and SACR basins consistently ranked high by any of four measures of Hg bioaccumulation in fish. The YELL, ACAD, NECB, and LINJ basins also ranked high or moderately high by these measures. The extraordinarily high concentration for NVBR fish compared with the other basins (Figure 1) is striking. Indeed, sections of the Carson River Basin are reported to be among the most severely Hg-contaminated in the world (Bonzongo and others, 1996). However, our data from this basin as a whole are greatly skewed relative to the other basins because all samples came from one severely contaminated site (Lahontan Reservoir). Similarly, fish samples from the SOFL unit were limited to two rather contaminated sites, which probably yielded a somewhat elevated mean for that study unit basin, although Hg contamination there is widespread. Means among the other 18 basins varied by a factor of about 20. The wide variety of fish species that were sampled probably factored into this range. Whereas over 65% of our samples were either largemouth-, smallmouth-, spotted-, or white bass, at least 16 other species were also represented. Also, sampling sites were selected to represent a gradient of environmental conditions and Hg levels, but they do not necessarily represent a systematic coverage of each entire basin. Nevertheless, the rankings listed in Table 4 give a reasonable guide as to the relative Hg contamination in fish among the basins sampled.

Ranking of basins for fish concentrations normalized by either length or age tended to mirror the rankings for non-adjusted concentrations. However, normalization by weight yielded some differences in rankings when compared to rankings by other means. For example, fish from the NECB and COOK study units ranked much higher for weight-normalized data as compared to length- or age-normalized data. However, samples from each of these two study units were quite small in size and were of a species that was uncommon for the data set (mixed sunfish and dolly varden, respectively). Also, the fillet data for some of the samples from these two study units were actually estimated from whole-body analysis based on a conversion equation derived from larger species (Goldstein and others, 1996). In the case of length-adjusted data, the largest specimens might have been favored due to the fact that as most fish age they have diminished increases in length relative to weight (Carlander, 1977). On the other hand, normalization by weight may have favored fish samples that were very small because regression equations for Hg concentration with fish weight tend to have a higher positive y-intercept for Hg contaminated systems relative to length-normalized data (Lange and others, 1994). These combined factors might explain why small sunfish from the NECB ranked highest by the weight-normalized criteria, but ranked fourth or lower by other measures (Table 4). Regardless of the fish ranking method chosen, the MeHg concentrations

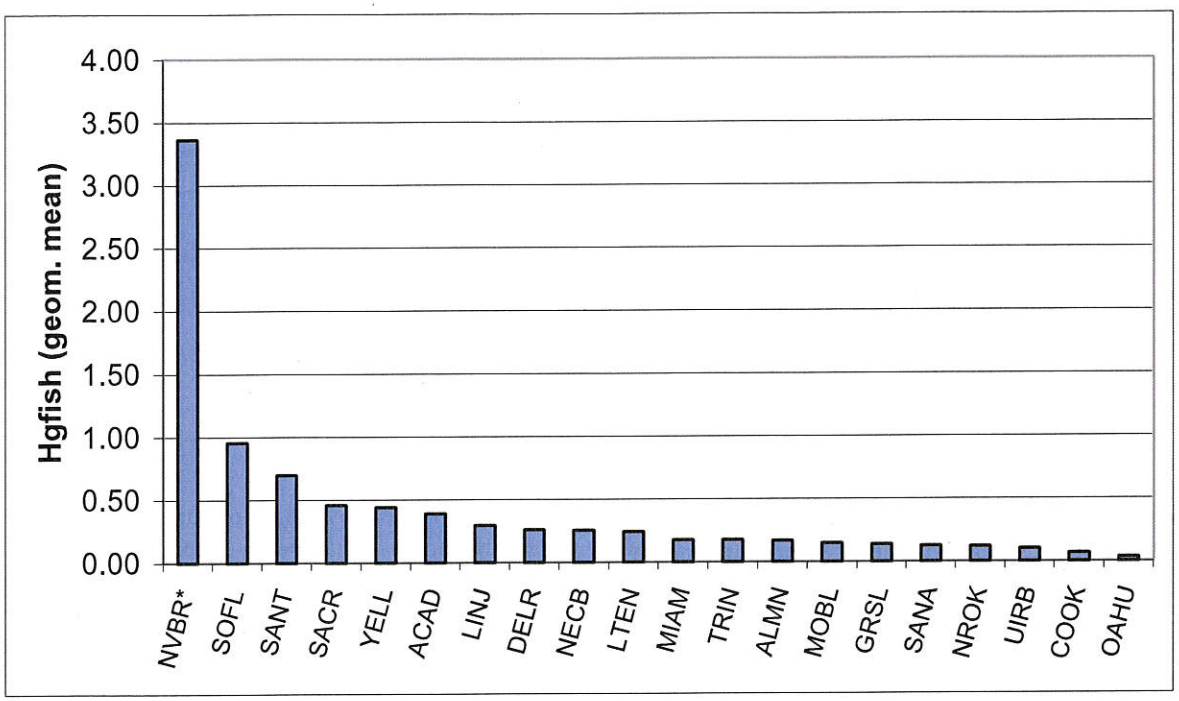


Figure 1. Geometric mean of Hg concentration in fish fillet samples collected for each of the 20 basins. *Samples from NVBR represent only one site (Lahontan Reservoir).

in both the sediment and water from the NECB basin were relatively high (Krabbenhoft and others, 1999), therefore, a high ranking for the fish is not surprising. But the comparison of bioaccumulation for NECB samples with the other basins must be viewed with caution because sunfish do not bioaccumulate Hg as rapidly as larger predator species and the fillet concentrations were estimated from the whole body measurements. In any event, a statewide Hg advisory is presently in effect for Massachusetts (where all of the NECB samples were collected).

Basins of Concern for Human Health

Our study was not designed to address the safety of consuming fish from the various participating study units, or to assess Hg exposure risks to fish and wildlife. Most, if not all of the basins of concern have already been identified by state and other federal agencies. Assessing the toxicological significance of Hg concentrations in fish with respect to populations of fish and fish-consuming wildlife is a complex matter that would be difficult to address from our data considering the the limited number of samples collected for each basin. Sensitivity to MeHg exposure can vary greatly among species and the rate of accumulation in fish apparently affects the toxicity (Wiener and Spry, 1996). Furthermore, the concentration of Hg in tissues other than the axial muscle, such as the brain or in the eggs, would generally be more useful for assessing potential impacts on fish (Wiener and Spry, 1996), whereas whole-body concentrations might be more meaningful for assessing impacts to piscivorous waterfowl and mammals (Wolfe and others, 1998). In order to address human health risks from fish consumption, we would have targeted fish older than 3 years, which typically contain higher concentrations of Hg and are more commonly sought by anglers. But because human health issues invariably arise when nation-wide fish residue data is examined, this aspect is briefly addressed.

Fish from our study that had Hg concentrations above 0.50 µg/g wet weight are listed in Table 5. Historically, 0.50 µg/g was a commonly reported human health advisory Hg fish concentration applicable to consumers of "high risk" categories, e.g., children, expectant mothers, and sub-populations whose diets include large percentages of fish (U.S. EPA, 1998). Recently, the U.S. EPA reduced the human health Hg fish criteria to 0.30 µg/g wet weight (U.S. EPA, 2001). Our results document that Hg contamination in U.S. freshwater fish is a widespread problem. One or more samples from nine of the 20 basins exceeded the 0.50 ug/g wet weight criteria and 15 of the basins had at least one sample above the 0.30 criteria. State fish

Table 4. Ranking of basins by geometric mean mercury concentration of fish fillet (µg/g wet wt) : unadjusted, or normalized by age, length, and weight.

Rank	Basin and geometric mean concentration (µg/g wet)[a]			
	unadjusted	÷ age (yr)[b]	÷ length (m)	÷ weight (kg)
1	NVBR[c] (3.34)	NVBR[c] (0.86)	NVBR[c] (9.2)	NECB[d] (8.7)
2	SOFL (0.95)	SOFL (0.30)	SOFL (3.1)	NVBR (4.8)
3	SANT (0.70)	SACR (0.15)	SANT (2.6)	SOFL (2.6)
4	SACR (0.46)	NECB[d] (0.12)	NECB[d] (2.3)	LINJ (2.5)
5	YELL (0.44)	YELL (0.12)	SACR (1.5)	SANT (2.2)
6	ACAD (0.39)	ACAD (0.12)	ACAD (1.5)	COOK[e] (2.1)
7	LINJ (0.29)	LINJ (0.12)	LINJ (1.3)	LTEN (1.7)
8	DELR (0.26)	LTEN (0.10)	YELL (1.2)	ACAD (1.5)
9	NECB[d] (0.25)	DELR (0.08)	LTEN (1.1)	SANA (1.2)
10	LTEN (0.24)	ALMN (0.06)	DELR (0.9)	SACR (1.1)
11	MIAM (0.17)	SANA (0.06)	COOK[e] (0.8)	DELR (0.9)
12	TRIN (0.17)	MIAM (0.05)	MIAM (0.7)	MOBL (0.9)
13	ALMN (0.17)	TRIN (0.05)	SANA (0.7)	YELL (0.8)
14	MOBL (0.15)	MOBL (0.05)	TRIN (0.6)	MIAM (0.8)
15	GRSL (0.13)	GRSL (0.04)	ALMN (0.6)	UIRB (0.8)
16	SANA (0.12)	UIRB (0.04)	MOBL (0.6)	TRIN (0.6)
17	NROK (0.12)	NROK (0.03)	UIRB (0.5)	ALMN (0.6)
18	UIRB (0.10)	COOK[e] (0.03)	GRSL (0.4)	GRSL (0.4)
19	COOK[e] (0.07)	OAHU (0.01)	NROK (0.4)	NROK (0.3)
20	OAHU (0.03)	-----	OAHU (0.2)	OAHU (0.2)

[a] Excludes age-0 fish.
[b] No age data available for SANT.
[c] All samples from one site (Lahanton Reservoir).
[d] Estimate for fillet based on log [muscle] = 0.35 + 0.92*log[whole body] (Goldstein and others, 1996).
[e] Dolly varden only; fillet concentration estimated for 2 of 3 samples.

consumption advisories for Hg are currently in effect for most sites in the nine basins that exceeded the 0.50 criteria; exceptions include the SACR, MIAM, and MOBL basins. In addition, five states not included in our study (VT, MI, NH, IN, MO) currently have statewide advisories in effect for consumption of one or more species of freshwater fish due to Hg. Two other states not covered (MN and WI) have Hg advisories on a large number of water bodies.

Sources and Factors Enhancing Bioaccumulation of Hg in Fish

Among the primary basins of concern, the geographic and land-use categories varied greatly for the sub-basins from which fish above advisory concentrations were sampled. However, fish from our study with concentrations above 0.50 µg/g were most commonly from coastal or lowland primary basins, e.g. SOFL, SANT, LINJ, ACAD, SACR, MOBL. Presumably, the relatively high percentages of wetlands in these lowland basins enhance methylation rates and in turn, bioaccumulation rates of Hg in fish (St. Louis and others, 1994; Hurley, 1995: Krabbenhoft and others, 1999). The sources of Hg among these basins varies widely.

In the NVBR and SACR basins, nearby cinnabar (HgS) deposits and elemental Hg in streambeds resulting from past gold mining amalgamation practices continue to contribute to elevated Hg concentrations in fish (Bonzango and others, 1996; Domagalski, 1998). In the YELL basin, elevated Hg concentrations in reservoir fish have been associated with coal and phosphate deposits of Wyoming and Montana (May and McKinney, 1981). In a detailed study of that basin, it was concluded that elevated Hg in reservoir fish resulted primarily from weathering of soils and rocks upstream and that reservoirs furthest upstream

Table 5. Fish samples with Hg fillet concentrations greater than 0.50 µg/g wet wt (-- = no data).

Study Unit	Site Name	Species (no. of indiv.)	Mean Wet Weight (g)	Hg conc. µg/g wet wt.	Advisory[a] In Effect?
NVBR	Lahontan Reservoir, NV	White Bass (8)	694	3.36	Yes
SACR	Sacramento Slough nr. Knights Landing, CA	Largemouth Bass (1)	1471	2.17	No[b]
SOFL	Water Conservation District 3A15, FL	Largemouth Bass (3)	788	2.15	Yes
SANT	N. Fork Edisto R. nr. Fairview Crossroad, SC	Largemouth Bass (1)	907	1.82	Yes
SACR	Bear River @ Hwy 70, CA	Largemouth Bass (1)	518	1.21	No[b]
SACR	Bear River @ Hwy 70, CA	Smallmouth Bass (1)	467	1.10	No[b]
LINJ	Great Egg Harbor @ Sicklerville, NJ	Chain Pickerel (2)	172	0.91	Yes[c]
ACAD	Bogue Falaya R. @ Covington, LA	Largemouth Bass (8)	--	0.83	Yes[d]
ACAD	Tangipahoa R. @ Robert, LA	Largemouth Bass (8)	--	0.77	Yes[d]
YELL	Shoshone River, @ mouth nr. Kane, WY	Walleye (5)	817	0.70	Yes
YELL	Bighorn Lake @ Hwy14A, WY	Walleye (5)	896	0.68	Yes[e]
YELL	Bighorn River nr. Kane, WY	Walleye (5)	452	0.66	No
YELL	Shoshone River @ mouth nr. Kane, WY	Walleye (1)	1444	0.66	No
SACR	Sacramento Slough nr. Knights Landing, CA	Largemouth Bass (1)	1156	0.65	No
MOBL	Satilpa Creek nr. Coffeeville, AL	Spotted Bass (2)	140	0.65	No
LINJ	Great Egg Harbor @ Sicklerville, NJ	Largemouth Bass (1)	49	0.65	Yes
SANT	N. Fork Edisto River nr. Branchville, SC	Largemouth Bass (1)	--	0.63	Yes
MOBL	Satilpa Creek nr. Coffeeville, AL	Largemouth Bass (1)	92	0.62	No
LINJ	Great Egg Harbor @ Sicklerville, NJ	Chain Pickerel (5)	84	0.59	Yes
SANT	S. Fork Edisto River @ Springfield, SC	Largemouth Bass (1)	--	0.58	Yes
SANT	S. Fork Edisto River nr. Canaan, SC	Largemouth Bass (1)	--	0.55	Yes
SOFL	Water Conservation District U3	Largemouth Bass (3)	254	0.55	Yes
SACR	Bear River @ Hwy 70, CA	Smallmouth Bass (1)	150	0.54	No[b]
MIAM	E. Fork L. Miami R. nr Williamsburg, OH	Smallmouth Bass (1)	608	0.51	No

[a]Source: USEPA, 1998
[b]Advisory by state of California pending (J. Domagalaski, pers. commun., April 1999)
[c]Statewide advisory for bass and pickerel in New Jersey.
[d] Statewide monitoring program for Hg in fish currently in progress.
[e]Advisory in effect for state of Montana but not Wyoming (April 1999).

exhibited higher bioaccumulation rates because of greater susceptibility to flood events (Phillips and others, 1984). Flooding results in greater scouring of Hg from soils but more importantly methylation of waterborne Hg is enhanced when terrestial vegetation is inundated for extended periods of time (which increases the dissolved organic carbon in the water) as is the case when new reservoirs are filled (Bodaly and others, 1997).

There may be localized point sources of Hg in the ACAD basin associated with Hg-charged manometers used with natural gas wells; however, this is primarily a problem in northeast Louisiana (Facemire and others, 1995). The state of Louisiana and the USGS have been engaged in a statewide assessment of Hg contamination in fish since 1993 (Louisiana Department of Environmental Quality, 1999). Selected water bodies in the SANT and MOBL basins may still be impacted by past uses of mercury in the chloralkali and paper mill industries (May and McKinney, 1981). However, widespread elevation of Hg in fish from the SANT basin has generally not been traceable to specific industrial or wastewater discharges (South Carolina Department of Health and Environmental Control, 1999).

Overlaying the numerous point sources is a broader contribution from atmospheric deposition of mercury originating primarily from emissions associated with waste incineration and coal combustion (Hanisch, 1998). Atmospheric deposition rates of mercury are generally greatest in Florida and the northeastern U.S. (USEPA, 1997). However, many lakes in the upper Midwest have also apparently been affected by atmospheric deposition and those with low buffering capacity (and depressed pH) are likely to have high Hg accumulations in fish (Sorenson and others, 1990; Wiener and others, 1990). There is currently debate as to how localized the effects of atmospheric deposition of Hg are with respect to the emission sources and ultimately, if proposed U.S. atmospheric emission controls for Hg would be effective in reducing Hg burdens in fish (Hanisch, 1998). An index of atmospheric Hg accumulation (AHA) developed in part one of this study indicated that among the study units examined, the NVBR, NROK, GRSL, COOK, and SACR basins are most influenced by ground-based Hg sources, whereas the ALMN, DELR, LINJ, SANT, and SOFL basins are most influenced by atmospheric sources of Hg.

Ranking of Basins by Hg in Fish, Sediment, and Water

The six basins with the greatest contamination, as determined by ranking of individual sites for selected fish, sediment, and water Hg measures, are presented in Table 6. Only the highest ranking site from each study unit was considered for this comparison, i.e., for some criteria multiple sites from one study unit may have ranked above sites from other study units, but only one site from each study unit is presented. The seven Hg criteria evaluated included 1) concentration (µg/g wet) of Hg in fish (Hg_{fish}), 2) Hg_{fish} divided by fish age (yr), 3) Hg_{fish} divided by fish length (m), 4) methylmercury concentration (ng/g dry wt.) in sediment ($MeHg_{sed}$), 5) total mercury concentration (ng/g dry wt.) in sediment ($HgTot_{sed}$), 6) methylmercury concentration (ng/L) in water ($MeHg_{water}$), and 7) total mercury concentration (ng/L) in water ($HgTot_{water}$). For the ranking of sites based on Hg_{fish} normalized by age, age-0 fish (n = 7) were excluded due to the large relative error in asssigning a fractional age.

Based on the three fish criteria the following study units had samples that ranked at least twice in the top six: NVBR, SOFL, SACR, LINJ, and SANT (Table 6). Basins with sites ranking once in the top six included ACAD, YELL, MOBL, and NECB. Study unit basins having a site that ranked in the top six for both sediment and fish criteria included NVBR, SOFL, NECB, SANT, and LINJ. Conversely, basins with a site in the top six for sediment criteria but not for fish included: GRSL, COOK, and OAHU. The NROK basin contained a sampling site that was among the highest for HgTot and MeHg in sediment (S. Fork Coeur d'Alene R), but fish were not collected there because impacts of mining activity has made them scarce. Despite relatively high HgTot and MeHg in sediments at the Weber R. (GRSL) site, mountain whitefish (*Prosopium williamsoni*) collected there were below the median Hg concentration (0.206) for all samples in this study. However, this species feeds primarily on aquatic insects (Carlander, 1977) and therefore may not bioaccumulate Hg as rapidly as piscivorous fishes. The Deshka R. (COOK) and Lake Wilson (OAHU) sites were notable because despite having elevated concentrations of Hg in the sediments, each was among the very lowest for the concentration of Hg in fish (albeit for sculpin and tilapia, respectively). The Deshka R. site had an unusually high concentration of MeHg in the sediment (5.1 ng/g) considering the HgTot was only 21 ng/g, whereas sediment from the Lake Wilson site was relatively high in HgTot but only moderate in MeHg.

Basins having a site ranking high for Hg in water as well as for fish included NVBR, SOFL, SANT, SACR, and LINJ. Essentially all of the highest ranking sites for $MeHg_{water}$ also ranked high for Hg_{fish}. However,

Table 6. Top six study units based on ranking of individual sites according to various Hg criteria. Values for fish are means of up to 7 individuals; sediment and water data are single samples from each site. Only the highest site from each study unit was considered in the overall rankings for each criteria.

Criteria	#1	#2	#3	#4	#5	#6
1. Hg_{fish}	NVBR	SOFL	SACR	SANT	LINJ	ACAD
(ug/g wet wt.)	3.36	2.15	1.80	1.80	0.82	0.79
Site	Lahontan Res.	WC3-A15	Sacramento Sl.	N.Fk. Edisto R.	Gr. Egg Hbr.	Bogue Falaya R.
2. Hg_{fish}/ age[a]	NVBR	SOFL	SACR	LINJ	YELL	MOBL
(ug/g wet / yr)	0.86	0.66	0.40	0.38	0.25	0.22
Site	Lahontan Res.	WC3-A15	Sacramento Sl.	Gr. Egg Hbr.	Big Horn R.	Satilpa Cr.
3. Hg_{fish}/ length	NVBR	SOFL	SANT	LINJ	SACR	NECB
(ug/g wet / m)	9.2	6.0	4.4	3.9	3.6	3.1
Site	Lahontan Res.	WC3-A15	N. Fk. Edisto R.	Gr. Egg Hbr.	Sacramento Sl.	Ipswich R.
4. $MeHg_{sed}$	LINJ	NECB	NROK	SOFL	SANT	COOK
(ng/g)	10.9	9.9	8.2	7.8	6.8	5.1
Site	Swan R.	Ipswich R.	Coeur d' Alene R.	WC3-A15	N. Fk. Edisto R.	Deshka R.
5. $HgTot_{sed}$	NROK	NVBR	NECB	GRSL	OAHU	SOFL
(ng/g)	4520	4130[b]	2480	1040	300	288
Site	Coeur d' Alene R.	Carson R.	Neponset R.	Weber R.	Lake Wilson	WC3-A15
6. $MeHg_{water}$	SANT	NVBR	SOFL	ACAD	NECB	LINJ
(ng/L)	1.5	1.3[b]	0.61	0.46	0.44	0.34
Site	N. Fk. Edisto R.	Carson R.	WC2-U3	Bayou Lacassine	Ipswich R.	Gr. Egg Hbr.
7. $HgTot_{water}$	NVBR	OAHU	GRSL	SACR	SANA	LINJ
(ng/L)	656[b]	24	22	18	15	12
Site	Carson R.	Nuuanu Res.	Weber R.	Bear R.	Santa Ana R.	Gr. Egg Hbr.

[a]excludes age-0 fish due to high relative error in assigning fractional age. No age data available for SANT unit.
[b]based on average of sites immediately above and below Lahontan Reservoir.

three basins had sites that ranked high for $HgTot_{water}$ but not for Hg_{fish}. These included OAHU (Nuunanu Res.), SANA (Santa Ana R.), and GRSL (Weber R.).

Correlation of Water and Sediment Parameters with Hg Bioaccumulation

A summary of the correlation of each measured variable (transformed as necessary to meet linearity requirements) with length-normalized mercury concentrations in fish is given in Table 7. Based on the initial analysis of our data, weight and length were about equally correlated with Hg_{fish} concentrations. But because of possible anomalies previously mentioned for rankings normalized by weight, we normalized by length for the correlation analysis. The correlation for age was significantly lower than for either length or weight, perhaps because the sample age was by design confined to a relatively narrow range and the resolution was limited to 0.5 units. Had our dataset consisted of samples of more widely varying ages, perhaps age would have been more useful. As indicated in Table 7, all of the measured parameters except $HgTot_{sed}$ and AVS_{sed} were significantly correlated with Hg bioaccumulation. The relative strength for correlation of bioaccumulation in fish with measures of Hg in water and

Table 7. Correlation of measured parameters with bioaccumulation of Hg in fish.

		correlation (r) with $log_e(Hg_{fish}/length)$	
parameter	transformation	all species	largemouth bass
$MeHg_{water}$	log_e	0.623 ***	0.712***
$MeHg_{sed}$	None	0.332***	0.596***
$HgTot_{water}$	log_e	0.277**	0.453**
$HgTot_{sed}$	log_e	ns	ns
DOC_{water}	log_e	0.331***	ns
pH_{water}	None	-0.371***	-0.496**
$sulfate_{water}$	log_e	-0.339***	-0.685***
LOI_{sed}	None	0.250**	0.420**
AVS_{sed}	cube root	ns	ns
% wetland	None	0.413***	0.523***

*** = $p < 0.001$; ** = $p < 0.01$; ns = no significant correlation ($p > 0.05$)

sediment was: $MeHg_{water} > MeHg_{sed} > HgTot_{water} >> HgTot_{sed}$ (no significant correlation). The correlation between $MeHg_{water}$ and $MeHg_{sed}$ was significant but relatively weak ($r = 0.306$, $\rho = .0009$). With the exception of DOC, all variables that were correlated with bioaccumulation exhibited stronger relationships for largemouth bass than for all species combined.

The positive relationship of Hg bioaccumulation with % wetlands, DOC, and sediment LOI (a proxy for organic matter) is widely documented (St. Louis and others, 1994, McMurtry and others, 1989, Mason and Lawrence, 1999). Higher MeHg production is generally associated with increases in organic matter in either the water column or in sediments because of enhanced microbial activity. But whereas low to moderate levels of DOC usually correlate with enhanced methylation rates of Hg (especially if the DOC is from terrestrial sources), high levels may act to reduce methylation and bioaccumulation (Winfrey and Rudd, 1990, Grieb and others, 1990, Driscoll and others, 1995). For reasons that are unclear, our Hg_{fish} data exhibited a significant positive correlation with DOC for all species combined, but not for largemouth bass. The bioacumulation of mercury in fish usually increases in waters of low pH (Wiener and others, 1990, Cope and others, 1990, Grieb and others, 1990, McMurtry and others, 1990) and the results from our nationwide sampling was no exception. In addition to other factors, lower water pH enhances Hg methylation and reduces loss of volatile Hg species from the water column by evasion (Winfrey and Rudd, 1990). Our data also exhibited a highly significant, negative correlation of Hg bioaccumulation with sulfate. The relationship was similar when either sites affected by mining, agriculture, or both were excluded from the analysis (ag and mining activity are often associated with elevated concentrations of sulfate in nearby drainges). At this time, the reason for the inverse relationship is unclear. Elevated levels of sulfate might be expected to correlate positively with Hg bioaccumulation rates because of the presence of sulfate in acidic precipitation (which has been associated with increased Hg bioaccumulation) and because of the role of sulfate-reducing bacteria that are directly involved in the methylation of mercury in water.

However, others have reported both positive and negative correlations of bioaccumulation with sulfate, depending on the watershed type (Grieb and others, 1990) and in general, most studies suggest that sulfate is not a determinant variable in the production of MeHg (Winfrey and Rudd, 1990).

Principal Components Analysis (PCA)

Factor loadings from the two most significant principal components of the PCA are presented graphically as vectors in Figures 2 (all species) and 3 (largemouth bass). Principal components 1 and 2 accounted for 44% and 54% of the variability for all species and for largemouth bass, respectively. From these plots, it is clear that a measure of fish size was the dominant variable influencing factor 2 (vectors in the positive y-direction) whereas the variables associated with the presence of organic matter (DOC, $MeHg_{water}$, LOI, % wetland, and $MeHg_{sed}$) each had a similar level of influence on factor 1 (vectors in positive x-direction). For largemouth bass only, there was a third statistically significant factor (not plotted in Figure 3) that accounted for an additional 14% of the variability. Therefore, a second PCA was conducted for largemouth bass only, but with the measures of length, weight, and age excluded, to allow for convenient examination of the first and third principal components. We expect that the exclusion of size factors may only be useful for data of a single fish species that are of relatively uniform size/age, as was the case for the largemouth bass in this study. With this plot (Figure 4), the importance of MeHg, especially in the water, on the fish Hg concentration is readily apparent because the Hg_{fish} and $MeHg_{water}$ appear as nearly identical vectors. In agreement with the simple regression analysis for largemouth bass (Table 7), DOC appears to correlate less strongly with the Hg_{fish} than many of the other parameters. It also appears that along with pH, sulfate, and AVS, DOC "counteracts" the influence of $TotHg_{water}$ on Hg_{fish} (vectors are opposite in the y-direction). However, the influence of DOC for the largemouth bass subset was probably greatly affected by the sites in the SOFL basin, which had the highest DOC values. And in fact, data for the SOFL sites fall near or outside the 95% confidence ellipse (interval) for PCA site score plots, indicating the SOFL sites were unique with respect to the variables analyzed in comparison to the other basins sampled.

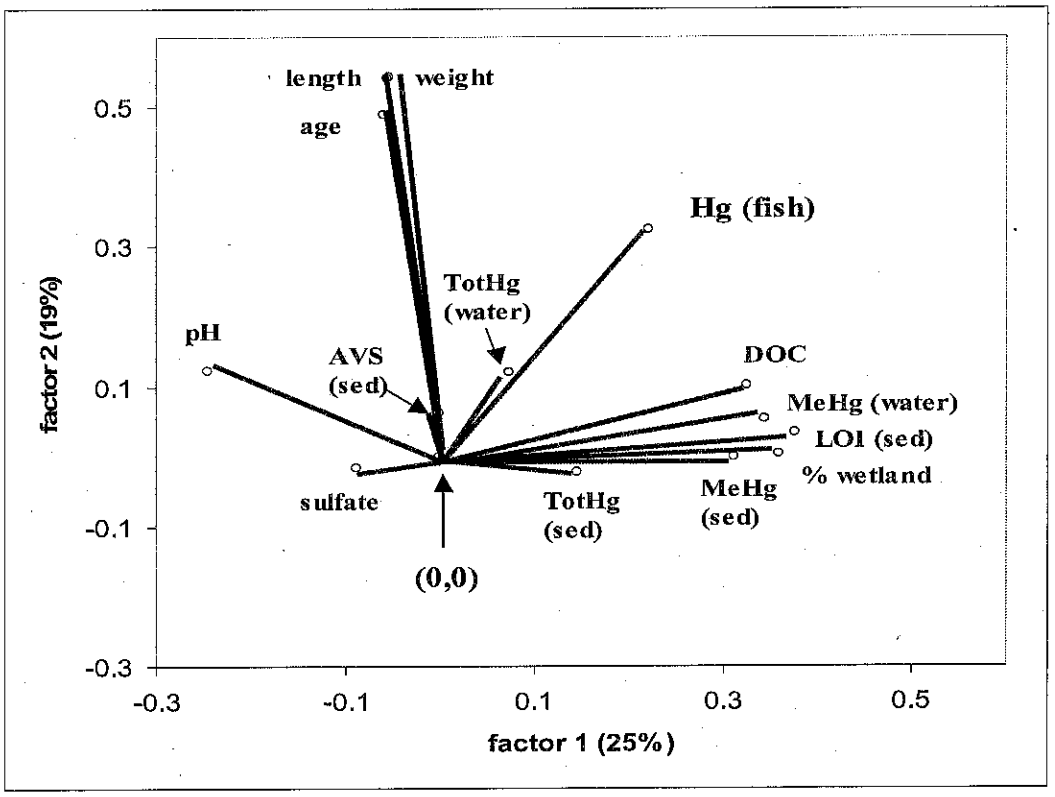


Figure 2. Principal Components Analysis - Factor Loadings for Hg Concentration in Fish (all species).

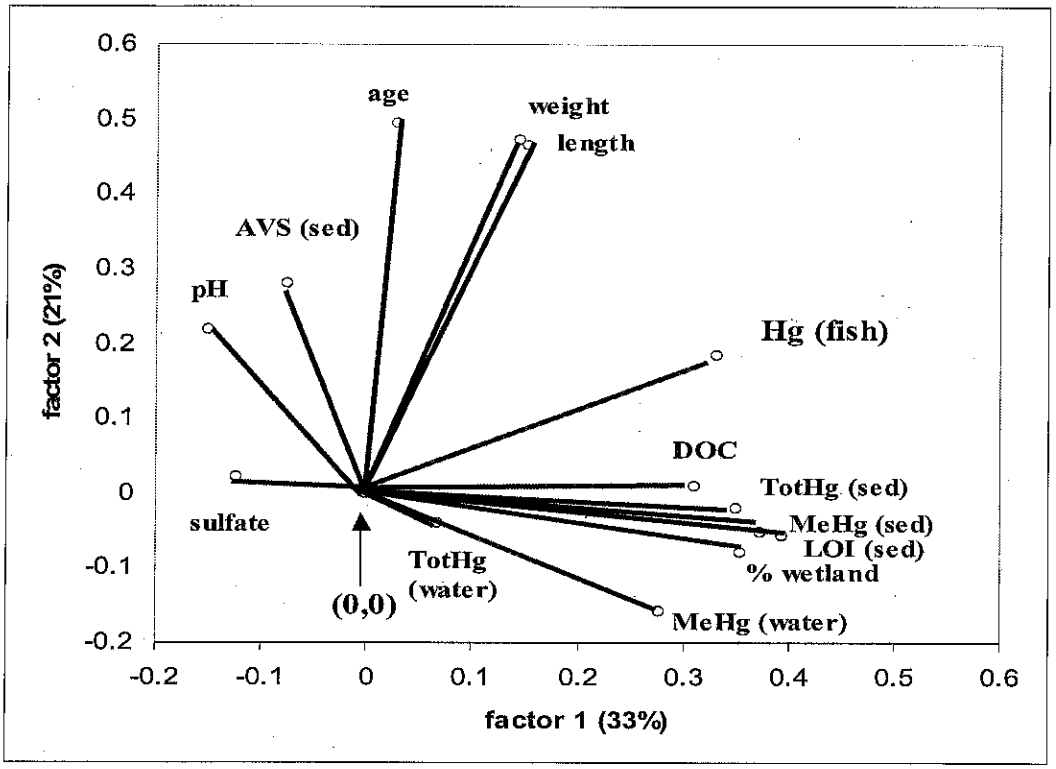


Figure 3. Principal Components Analysis - Factor Loadings for Hg Concentration in Largemouth Bass.

Model for the Bioaccumulation of Hg in Fish

An overall regression model for the bioaccumulation of Hg in fish was developed with the following candidate variables: fish weight (kg), fish total length (mm), fish age (yr), $MeHg_{water}$ (ng/L) , $HgTot_{water}$ (ng/L), $MeHg_{sed}$ (ng/g dry) $HgTot_{sed}$ (ng/g dry), DOC (mg/L), LOI (% dry wt), sediment AVS (µmol/g dry), water pH, and percent wetlands of each basin. Variables were transformed when necessary to meet the assumptions of linear regression. We also determined stable isotope ratios (C and N) in the fillets as a potential measure of trophic position (Kendall and others, 2000). However, the results were difficult to interpret (e.g., stable isotope ratios for the sediments would have been useful for adjusting for basin source differences) and consequently that data is not included in this report. For all fish combined, the following 4-variable model was deemed most useful based on the highest adjusted R^2 (44.6%) and lowest PRESS statistic (48.6):

$$\log_e(\text{Hg/length}) = -3.55 + 0.408 \log_e(MeHg_{water}) + 0.021\ (\%\text{wetland}) - 0.269\ pH - 0.121\ (AVS)^{1/3}$$

For our samples the $MeHg_{water}$ was by far the most useful predictor of Hg bioaccumulation "rate" (assuming fish length increases approximately linearly with time); it accounted for 30 of the 45% of the variability described by the model. Essentially, all of the other non-mercury parameters were measured because they were expected to influence the production MeHg. As it was correlated with several other of the explanatory variables, $MeHg_{sed}$ added no new explanatory power to the above regression equation. Many of our sampling sites were flowing (non-stratifying) waters in which the sediment-water boundary might be expected to be the most important Hg-methylation zone for the water body (Krabbenhoft and Gilmour, 1998). Also, because sediments act as a sink for most contaminants, the MeHg load in the sediment might be expected to provide a better indicator of the long term exposure for the age-3 fish that were targeted in our study. Poor correlation of Hg in fish with HgTot in sediments has been widely documented (Wiener and others, 1984; Harrison and Klaverkamp, 1990; Sorensen and others, 1990). However, relatively few studies have been conducted that directly compared MeHg in sediments with Hg in

fish. Our results suggest that on a national basis, MeHg in water is a much better predictor of concentrations in fish than is MeHg in the sediment, and that other sediment-related variables (e.g., AVS, %wetlands) probably replicate any ability of MeHg in sediment to predict Hg in fish. However, limnologic sampling conditions may greatly affect this relationship.

Presumably, fish tend to bioaccumulate a large percentage of their Hg burden during warmer months when rates of feeding and microbial methylation of Hg are highest. In waters that stratify, mixing of anoxic hypolimnetic water during fall "turnover" can result in rapid increases of mercury accumulation in zooplankton and young-of-year fishes (Slotten and others, 1995). Also, hypolimnetic tailrace water below stratified reservoirs may become enriched in MeHg during early fall (Canavan and others, 2000). We collected samples when water levels were generally at low flow - a condition that tends to favor an increase in concentrations of MeHg in the water. Because of these seasonal factors, our samples might have exhibited improved correlations with methylmercury concentrations in water relative to that in the sediment. Calculations presented by Mason and Lawrence (1999) suggest that both the sediment and water column can be significant contributors of MeHg to fish via food chain pathways. However, the greater importance of MeHg in the water relative to the sediment for our model indicates that MeHg production in surficial sediments may be of minimal consequence in some water bodies, perhaps because it is not effectively transported to the water column. Fluxes of MeHg from sediments to the water column are reported to be considerable only under anoxic conditions (Gill and others, 1999) because apparently, MeHg generated at the redox boundary is effectively trapped by sorption to solids in oxic sediment surface layers (Gagnon, and others, 1996). Therefore, for flowing, non-stratifying waters like most that were sampled in our study, effective transfer of MeHg to the water column from sediments might only occur for sediments that are prone to resuspension from wind or other factors (Bloom, and others, 1999).

The positive coefficient for % wetlands and the negative coefficient for pH with our model is in agreement with most other studies. Wetlands can be significant sources of MeHg and their presence can promote

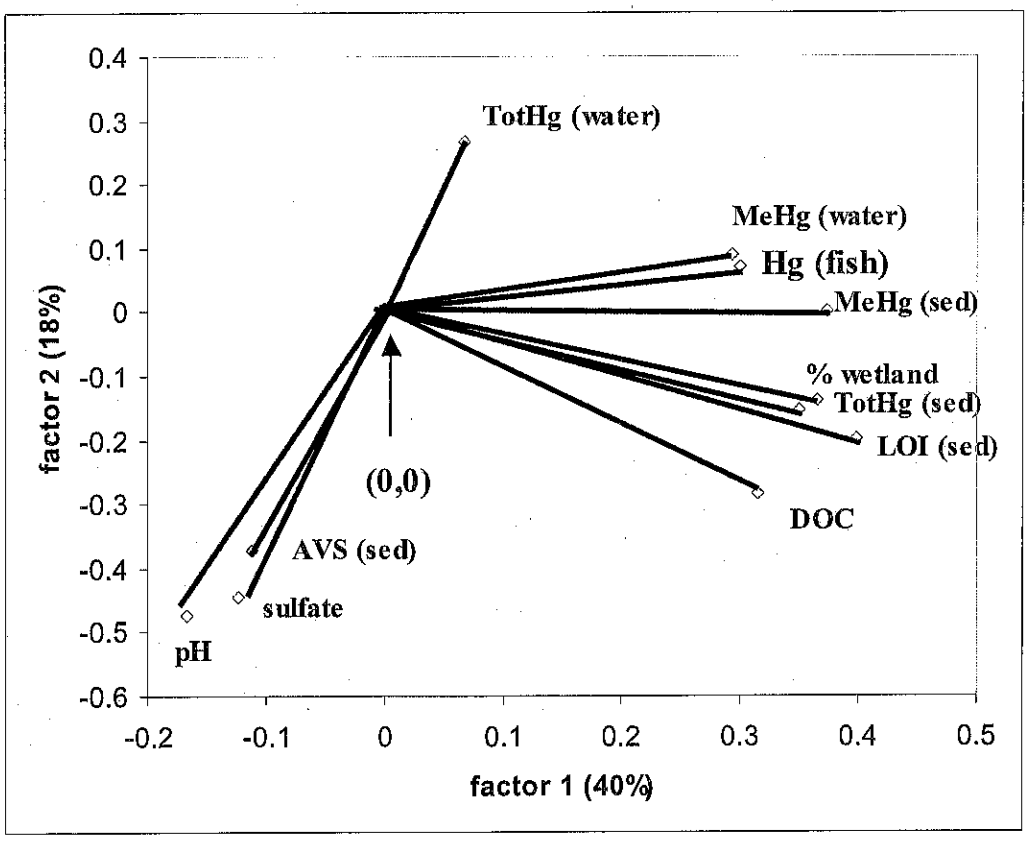


Figure 4. Principal Components Analysis - Factor Loadings for Hg Concentration in Largemouth Bass, excluding weight, length, and age.

MeHg production because, in addition to other factors, they provide DOC (and enhance microbial activity) to the watershed (Rudd, 1995). Bioaccumulation of Hg in fish usually increases in waters of low pH, primarily because the water column retains more Hg under acidic conditions (Winfrey and Rudd, 1990). A minor, but statistically significant factor with our bioaccumulation model, was the sediment acid-volatile sulfide (AVS), which exhibited a negative coefficient. Such a result might seem contradictory, because wetland sediments usually contain considerable AVS, yet Hg bioaccumulation rates are positively correlated with the presence of wetlands. It may be that highly anaeorbic wetlands, which typically contain very high AVS in the sediments, do not contribute to increased bioaccumulation of Hg in fish in the same way that more aerobic wetlands do. Also, it is possible that some of the MeHg in the water originated considerably upstream from our sampling sites. As discussed in Part One of this report, the methylation efficiency of Hg was found to decrease in sediments containing very high AVS, presumably because of the strong affinity of sulfides for Hg, which make it less available. Perhaps the small, but negative coefficient of AVS (as the cube root) for our model accounts for decreased methylation efficiency, or a net removal of MeHg from water, at very high AVS concentrations.

Regression plots of length-normalized fish concentrations for all species and for largemouth bass versus MeHg concentration in water are indicated in Figures 5 and 6, respectively. Based on these data, a water MeHg concentration of 0.12 ng/L was associated with a fish fillet Hg concentration of 0.30 µg/g for an age-3 fish when all species are considered. For age-3 largemouth bass a water MeHg concentration of 0.058 ng/L was, on average, associated with the 0.30 µg/g fillet concentration. In addition to fish species and age, other factors that might affect this relationship include seasonal and hydrologic conditions during water sampling, and prey availability and dietary pathways for the sampled fish. Although the diet is generally the dominant vector for bioaccumulation of MeHg in predator fish, the strong correlation with MeHg in water indicates that the water column was the primary source (at the base of the food chain) for the majority of our sites. It is important to note that our water samples were not filtered for the determination of Hg, although most were collected during low flow and consequently were relatively low in suspended solids. Additional studies are needed to define the limitations in estimating fish concentrations from MeHg concentrations in water, and to determine the sampling conditions that maximize the predictive power of water analyses.

Relation of Hg in Fish, Sediment, and Water to Land Use Patterns

All of the study basins were heterogeneous with respect to land cover and use. For the purposes of this

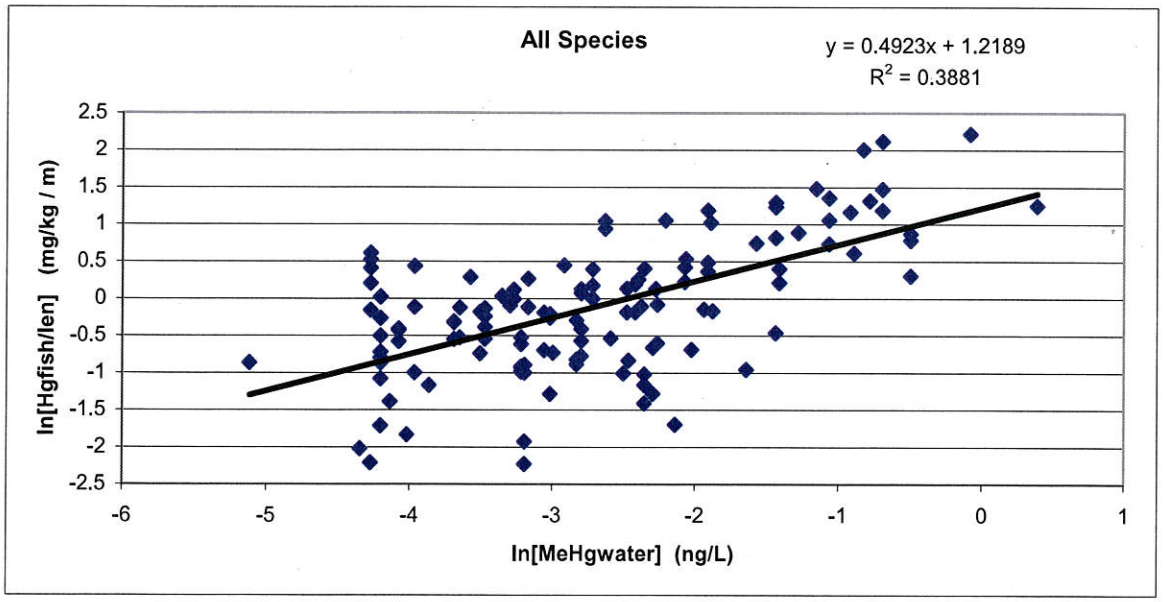


Figure 5. Length-normalized concentration of Hg in fish (all species) as a function of MeHg concentration in water. Excludes NVBR basin.

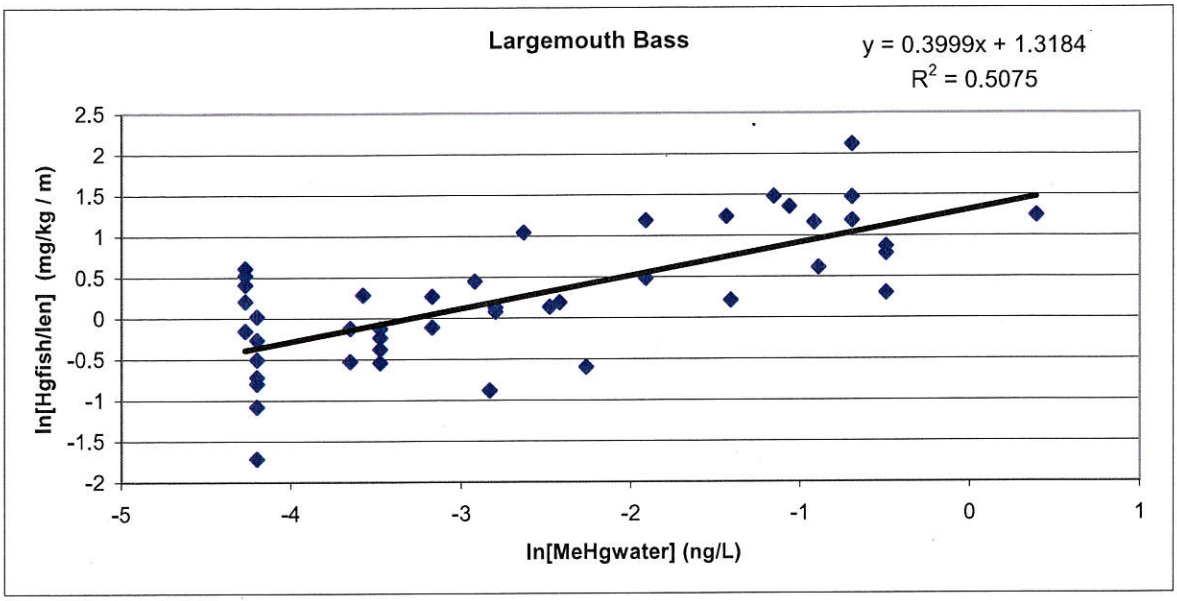


Figure 6. Length-normalized concentration of Hg in largemouth bass as a function of MeHg concentration in water.

analysis, the sub-basins above each of the sampling sites were categorized into one of the five following broad classes: agriculture dominant (Ag.); mixed agriculture and forest (A/F); background or reference site (Bkg.); current or abandonded mining activities near site (Mine); and urban or industrial activity near sampling site (Urb.). The land-use categories assigned to individual sites are listed in Part One of this report. The geometric means for each of the five Hg parameters and five land use catogories are depicted in Figure 7. Rankings for concentrations of Hg in fish were as follows: A/F >> Mine >Ag > Urb.≃ Bkd. Forested watersheds have been previously identified with high Hg methylation rates (Hurley and others, 1995). Also, A/F basins from our study often contained higher percentages of wetlands, which overall, contribute to higher methylation efficiency. Sub-basins characterized as mining-impacted ranked highest for HgTot in both sediment and water, and second in MeHg in water. As previously discussed, several of the mining basins sampled had past gold-mining operations where Hg amalgamation practices were used. Thus, although the methylation rates are not necessarily high in many of these basins, the overwhelming loads of HgTot in the watershed can yield relatively high concentrations of MeHg in the water and Hg in fish. Surprisingly, sub-basins categorized as urban had a comparatively low mean for Hg_{fish} but ranked fairly high for the HgTot and MeHg in sediment. At first glance, one might suspect that this discrepancy was due to a species bias, i.e., fewer top predators present in urban areas. But in fact, most of the fish sampled from urban sub-basins were either largemouth- or smallmouth bass. Interestingly, the correlation between $MeHg_{water}$ and $MeHg_{sed}$ was highly significant for urban sites ($r = 0.606$, $\rho = .0002$) but it was not significant for any other land-use category. The factors affecting the bioaccumulation of Hg in fish from urban settings deserves additional research.

The bioaccumulation factor (BAF) for MeHg in water to Hg in fish muscle (assumed to be all MeHg) is plotted in Figure 8 for each land-use category (and the SOFL basin) for either largemouth bass or all species combined. The SOFL unit was considered separately because of its unique character and because most other sites were flowing streams. There are no clear differences for BAFs among land-uses for all species combined. However, a trend opposite of that observed for fish concentrations (Figure 7) is apparent for BAFs for largemouth bass alone, i.e., the land-use categories with the highest fish and water concentrations (A/F and Mine) have the lowest BAFs, and vice-versa. Perhaps most striking is the comparatively low BAF for SOFL, where MeHg concentrations in water are generally high. A similar trend was observed for BAFs normalized by fish length, which indicates that overall, there was not a remarkable bias due to size differences of fish collected among land-use categories. The inverse relationship of BAF with the concentration of MeHg in water suggests that lower concentrations of MeHg in water are more efficiently biotransferred than are higher

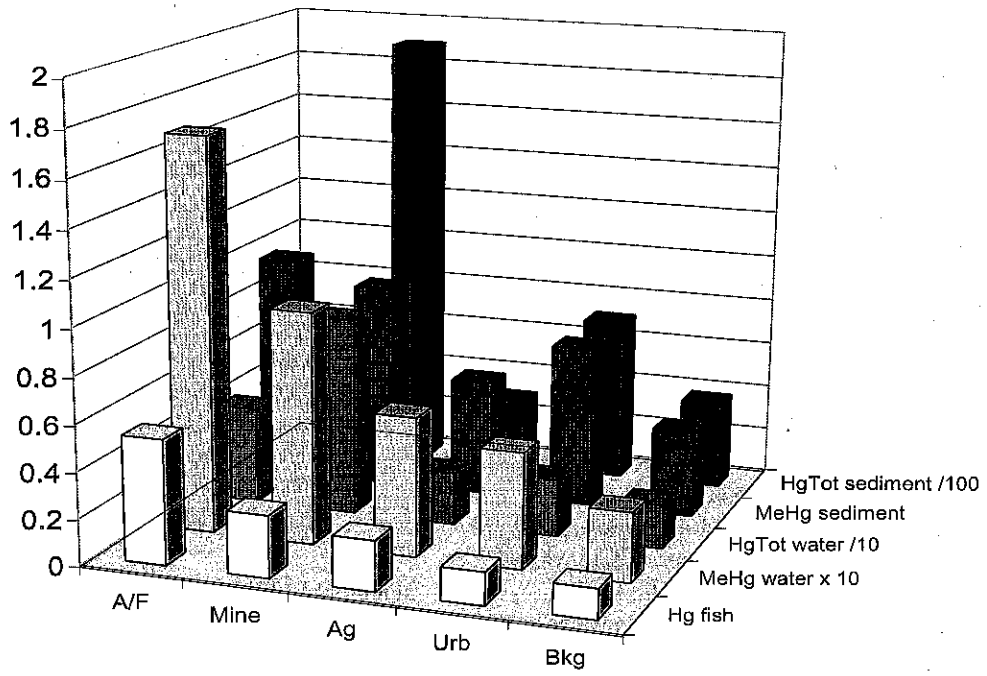
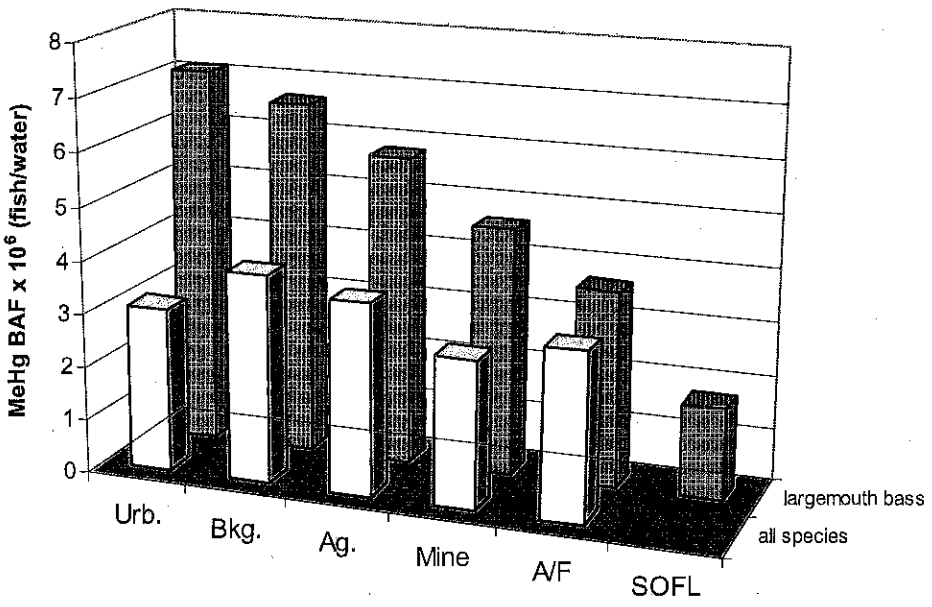


Figure 7. Geometric mean of Hg or MeHg in fish, water, and sediment for each land use category (see text for land use definitions). Number of observations = 13, 42, 23, 15, and 34, for A/F, Mine, Ag., Bkg, and Urb, respectively. Excludes South Florida basin.



concentrations. This might result from lower assimilation (or greater elimination) by fish at higher MeHg concentrations. Or perhaps water quality factors that increase the MeHg production rate (like high DOC) also serve to reduce the relative bioavailablity and ultimately the BAF because of increased complexation of MeHg. These results warrant further investigation. But regardless of the water quality or type, high concentrations of MeHg in water will generally produce high concentrations in fish.

SUMMARY

Mercury contamination of waterways is a widespread problem and sources and accumulation rates in fish vary among basins. One or more fish fillet samples from nine of 20 basins examined in this pilot study had Hg concentrations above the historical advisory level of 0.50 µg/g wet weight and 15 of the basins had at least one sample above EPA's 2001 criteria of 0.30 µg/g wet weight. Based on rankings of selected water, sediment, and fish criteria, sampling sites from the following five basins exhibited the greatest Hg contamination: Nevada Basin and Range, South Florida, Sacramento Basin, Santee Basin and Coastal Drainages, and the Long Island and New Jersey Coast Drainages. The concentrations of Hg in fish were correlated strongly with MeHg in water, but only moderately with MeHg in sediment or HgTot in water. There was no correlation between Hg in fish and total Hg in sediment. The concentration of MeHg in water was by far the most useful variable for predicting the Hg bioaccumulation in fish. However, percent wetlands (+), pH of water (-) , and sediment AVS (-) also contributed significantly to the model. Based on our data, a MeHg water concentration of 0.12 ng/L was on average, associated with a fish fillet Hg concentration of 0.30 µg/g wet weight for an age-3 fish when all species were considered. For age-3 largemouth bass a MeHg water concentration of 0.058 ng/L was associated with the 0.30 µg/g fillet concentration. Additional studies are needed to define the limitations in estimating fish concentrations from MeHg concentrations in water, and to determine the sampling conditions that maximize the predictive power of water analyses.

Based on ranking criteria, sub-basins categorized as mixed agriculture/forest and mining-impacted had the most consistent contamination of Hg in all three sample matrices (water, sediment, and fish). The greatest discrepancy for rankings of Hg in fish and in sediments was for urban watersheds, where sediments often ranked high but fish usually ranked low. The bioaccumulation factor ($MeHg_{fish}$ / $MeHg_{water}$) was lowest for land-use categories having the highest concentrations of MeHg in water, which indicates that low concentrations of MeHg in water are more efficiently biotransferred than higher concentrations. Nevertheless, high concentrations of MeHg in water will generally produce high concentrations in fish. A sampling and analysis strategy based on this pilot study is planned for all USGS NAWQA study units over the next decade. We expect those results to provide a comprehensive national characterization of mercury contamination and bioaccumulation in our aquatic ecosystems.

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Appendix. Concentrations of mercury in fish collected from USGS NAWQA Hg-Pilot Study basins, June through October, 1998. No. fish indicates number of fish in each composite sample. Sample species with [a] superscript were analyzed as whole-body less head; those with [b] superscript were analyzed as whole body. All others are fillet tissue. See text for assignment of age.. CERC = Columbia Environmental Research Center; -- = no data.

CERC #	S.U.	*Site*	*Species*	No. Fish	Mean Weight (g)	Mean Total Length (mm)	Mean Age (yr)	µg Hg / g dry	µg Hg / g wet
18221-1	ALMN	Clarion R. @ Ridgeway, PA	Smallmouth Bass	2	745	363	4.5	1.495	0.327
18222-1	ALMN	Dunkard Cr. @ Shannopin, PA	Smallmouth Bass	4	130	223	3.0	1.102	0.204
18223-1	ALMN	Youghiogheny R. @ Sutersville, PA	Smallmouth Bass	1	292	290	2.5	0.439	0.072
18224-1	ALMN	Allegheny R. @ New Kensington, PA	Smallmouth Bass	3	108	206	1.5	0.449	0.087
18225-1	ALMN	Tenmile Cr. nr. Amity, PA	Smallmouth Bass	2	430	312	4.0	1.517	0.288
18226-1	ALMN	Tenmile Cr. nr. Amity, PA	Largemouth Bass	1	592	329	3.5	0.941	0.181
18227-1	LINJ	Muddy Run @ Centerton, NJ	Chain Pickerel	2	307	345	4.0	0.781	0.159
18227-2	LINJ	Muddy Run @ Centerton, NJ	Chain Pickerel	4	10	120	0.5	0.475	0.100
18228-1	LINJ	Muddy Run @ Centerton, NJ	Largemouth Bass	2	362	295	3.0	1.760	0.334
18228-2	LINJ	Muddy Run @ Centerton, NJ	Largemouth Bass	2	110	192	3.0	1.088	0.207
18228-3	LINJ	Muddy Run @ Centerton, NJ	Largemouth Bass[a]	1	21	119	0.5	0.567	0.132
18229-1	LINJ	Passaic R. @ Millington, NJ	Redfin Pickerel	2	81	229	2.5	1.811	0.340
18230-0	LINJ	Passaic R. @ Millington, NJ	Redfin Pickerel[b]	4	12	112	0.5	0.624	0.125
18231-1	LINJ	Passaic R. @ Millington, NJ	Largemouth Bass	2	179	212	2.5	1.286	0.262
18232-1	LINJ	Passaic R. @ Millington, NJ	Smallmouth Bass	1	25	118	0.5	1.522	0.276
18233-1	LINJ	Swan R. @ E. Patchague, NY	Redfin Pickerel	7	36	166	2.0	0.460	0.073
18234-1	LINJ	Great Egg Harbor @ Sicklerville, NJ	Chain Pickerel	2	172	284	3.0	4.511	0.816
18234-2	LINJ	Great Egg Harbor @ Sicklerville, NJ	Chain Pickerel	5	84	237	1.5	2.911	0.495
18235-1	LINJ	Great Egg Harbor @ Sicklerville, NJ	Largemouth Bass	1	49	148	1.5	3.212	0.575
18236-1	UIRB	Des Plains R. @ Russell, IL	Bowfin	1	617	337	3.5	1.014	0.174
18237-1	UIRB	Nippersink Cr. Abv. Wonder Lake, IL	Smallmouth Bass	2	84	180	1.5	0.330	0.066
18238-1	UIRB	Salt Cr. @ Western Springs, IL	Smallmouth Bass	3	70	175	2.0	0.489	0.088
18239-1	UIRB	Pitner Ditch nr. LaCrosse, IN	Largemouth Bass	3	154	219	3.0	0.707	0.129
18240-1	UIRB	Mukwanago R. @ Mukwanago, WI	Rock Bass	4	62	143	2.0	0.575	0.107
18241-1	UIRB	Mukwanago R. @ Mukwanago, WI	Largemouth Bass	1	114	182	2.5	0.412	0.075
18242-1	LTEN	Sequatchie R. nr. Whitwell, TN	Largemouth Bass	1	228	250	3.5	2.275	0.421
18242-2	LTEN	Sequatchie R. nr. Whitwell, TN	Largemouth Bass	3	114	214	2.5	1.449	0.262
18243-1	LTEN	Buffalo R. nr. Flatwoods, TN	Largemouth Bass	1	351	282	3.5	1.256	0.241
18244-1	LTEN	Buffalo R. nr. Flatwoods, TN	Largemouth Bass	1	132	212	2.5	2.143	0.390
18245-1	LTEN	Buffalo R. nr. Flatwoods, TN	Largemouth Bass	1	35	144	1.5	1.398	0.217
18246-1	LTEN	Indian Cr. nr. Madison, AL	Largemouth Bass	2	288	280	2.5	0.871	0.163
18247-1	LTEN	Indian Cr. nr. Madison, AL	Largemouth Bass	1	470	324	3.5	1.325	0.256
18248-1	LTEN	Indian Cr. nr. Madison, AL	Largemouth Bass	2	38	148	1.5	0.720	0.130
18249-0	COOK	S. Fk. Campbell Cr. nr. Anchorage, AK	Slimy Sculpin[b]	5	23	--	--	0.292	0.069
18250-1	COOK	S. Fk. Campbell Cr. nr. Anchorage, AK	Dolly Varden	5	141	233	--	0.429	0.086
18251-0	COOK	Chester Cr @ Artic Blvd, Anchorage, AK	Slimy Sculpin[b]	5	20	--	--	0.152	0.036
18252-1	COOK	Costello Cr. nr. Colorado & Denali, AK	Dolly Varden[b]	1	35	158	--	0.164	0.036
18252-2	COOK	Costello Cr. nr. Colorado & Denali, AK	Dolly Varden[b]	4	11	114	--	0.101	0.021
18253-0	COOK	Deshka R. NR. Willow, AK	Slimy Sculpin[b]	10	35	--	--	0.246	0.060
18254-0	NECB	Stillwater R. NR. Sterling, MA	Mixed Sunfish[b]	5	12	84	--	0.796	0.173
18255-0	NECB	Neponset R. @ Norwood, MA	Mixed Sunfish[b]	4	50	127	3.5	0.457	0.116

CERC #	S.U.	*Site*	*Species*	No. Fish	Mean Weight (g)	Mean Total Length (mm)	Mean age (yr)	µg Hg / g dry	µg Hg / g wet
18256-0	NECB	Aberjona R. @ Winchester, MA	Mixed Sunfish[b]	5	23	94	--	0.236	0.055
18257-0	NECB	Saugus R. @ Ironworks@ Saugus, MA	Mixed Sunfish[b]	4	19	100	--	0.486	0.107
18258-0	NECB	Ipswich R. @ S. Middleton, MA	Mixed Sunfish[b]	5	33	114	2.5	1.423	0.349
18259-0	DELR	Schuylkill R. @ Philadelphia, PA	Smallmouth Bass	5	317	308	4.1	1.616	0.323
18260-0	DELR	Delaware R. @ Trenton, NJ	Smallmouth Bass	5	749	371	4.3	1.439	0.288
18261-0	DELR	Delaware R. @ Port Jervis, NY	Smallmouth Bass	4	294	276	3.5	1.654	0.331
18262-0	DELR	Lehigh R. @ Glendon, PA	Smallmouth Bass	5	338	297	3.5	0.648	0.130
18263-1	DELR	Racoon Cr. @ Swedesboro, NJ	Chain Pickerel	1	330	372	3.5	1.521	0.287
18263-2	DELR	Racoon Cr. @ Swedesboro, NJ	Chain Pickerel	1	105	254	0.5	0.687	0.126
18264-1	DELR	Little Lehigh Cr. @ E. Texas, PA	Brown Trout	3	141	233	--	0.148	0.031
18265-1	DELR	Hay Cr. nr. Birdsboro, PA	Smallmouth Bass	1	557	335	3.5	1.587	0.333
18265-2	DELR	Hay Cr. nr. Birdsboro, PA	Smallmouth Bass	2	221	258	2.5	1.457	0.290
18266-1	DELR	Manatawny Cr. nr. Pottstown, PA	Smallmouth Bass	3	206	253	3.5	0.883	0.169
18267-1	DELR	Tulpehocken Cr. nr. Bernville, PA	Smallmouth Bass	1	354	283	3.5	1.113	0.236
18268-1	DELR	L. Neshaminy Cr. nr. Neshaminy, PA	Smallmouth Bass	2	180	236	3.0	1.398	0.268
18269-1	SACR	Colusa Basin Drain , CA	Largemouth Bass	4	644	343	4.8	1.945	0.393
18270-1	SACR	Sacramento Slough nr. Knights Landing	Largemouth Bass	1	1471	550	4.5	10.734	1.803
18270-2	SACR	Sacramento Slough nr. Knights Landing	Largemouth Bass	1	1156	390	5.5	3.214	0.633
18270-3	SACR	Sacramento Slough nr. Knights Landing	Smallmouth Bass	1	675	324	4.5	2.220	0.466
18271-1	SACR	Cottonwood Cr. nr. Cottonwood, CA	Smallmouth Bass	1	401	315	3.5	1.264	0.264
18271-2	SACR	Cottonwood Cr. nr. Cottonwood, CA	Smallmouth Bass	5	115	193	1.5	0.438	0.092
18272-1	SACR	Bear River @ Hwy 70 nr. Rio Oso, CA	Largemouth Bass	1	518	325	3.5	5.983	1.119
18272-2	SACR	Bear River @ Hwy 70 nr. Rio Oso, CA	Smallmouth Bass	1	467	288	3.5	5.442	1.050
18273-1	SACR	Bear River @ Hwy 70 nr. Rio Oso, CA	Smallmouth Bass	1	150	220	2.5	2.695	0.499
18274-1	SACR	Bear River @ Hwy 70 nr. Rio Oso, CA	Mountain Whitefish	1	549	390	2.0	1.376	0.246
18275-1	SACR	Putah Cr. nr. Davis, CA	Largemouth Bass	5	62	158	1.5	1.320	0.247
18276-1	SANA	South Fork Santa Ana River, CA	Brown Trout	6	90	194	1.5	0.743	0.127
18277-1	SANA	Santa Ana R. @ Hammer Rd.	Largemouth Bass	2	54	158	2.0	0.743	0.140
18278-1	SANA	Santa Ana R. blw. Prado Dam	Mixed Sunfish	10	53	136	2.0	0.685	0.118
18279-1	SANA	Mill Cr. @ Chino - Corona Rd.	Common Carp	5	393	311	3.0	0.694	0.114
18280-1	NVBR	Lahontan Res., NV	White Bass	1	435	310	3.5	9.381	1.895
18280-2	NVBR	Lahontan Res., NV	White Bass	1	435	325	2.5	29.06	5.696
18280-3	NVBR	Lahontan Res., NV	White Bass	1	490	334	3.5	32.61	5.837
18280-4	NVBR	Lahontan Res., NV	White Bass	1	615	350	3.5	7.387	1.418
18280-5	NVBR	Lahontan Res., NV	White Bass	1	437	335	3.5	16.42	3.219
18280-6	NVBR	Lahontan Res., NV	White Bass	1	883	380	4.5	13.34	2.881
18280-7	NVBR	Lahontan Res., NV	White Bass	1	879	392	4.5	16.01	3.634
18280-8	NVBR	Lahontan Res., NV	White Bass	1	1171	472	5.5	24.90	5.154
18281-1	YELL	Bighorn R. @ Kane, WY	Walleye	5	452	373	2.5	3.289	0.635
18282-1	YELL	Tongue R. @ State Line nr. Decker	Smallmouth Bass	1	299	270	3.5	0.743	0.153
18283-1	YELL	Yellowstone R. @ Sidney, MT	Sauger	2	176	294	3.0	1.287	0.250
18284-1	YELL	Bighorn Lake @ Hwy 14A Causeway	Walleye	5	896	453	4.0	3.382	0.676
18285-1	YELL	Shoshone R. @ Mouth nr. Kane, WY	Walleye	1	1444	535	5.5	3.249	0.669
18285-2	YELL	Shoshone R. @ Mouth nr. Kane, WY	Walleye	5	817	437	4.5	3.452	0.666
18286-1	ACAD	Tangipahoa R. @ Robert, LA	Largemouth Bass	8	562	335	4.2	3.789	0.743
18287-1	ACAD	Turtle Bayou nr. Bayou Penchant, LA	Largemouth Bass	8	387	292	2.5	0.999	0.206
18288-1	ACAD	Bayou Teche nr. St. Martinville, LA	Largemouth Bass	8	334	298	3.1	1.320	0.260

CERC #	S.U.	*Site*	*Species*	No. Fish	Mean Weight (g)	Mean Total Length (mm)	Mean age (yr)	µg Hg / g dry	µg Hg / g wet
18289-1	ACAD	Bogue Falaya R. @ Covington, LA	Largemouth Bass	8	392	306	3.5	4.098	0.791
18290-1	ACAD	Bayou Segnette nr. Barataria, LA	Largemouth Bass	8	487	326	2.8	1.027	0.209
18291-1	GRSL	Cub R. nr. Richmond, UT	Largemouth Bass	2	136	204	4.5	1.369	0.271
18292-1	GRSL	Weber R. nr. Coalville, UT	Mountain Whitefish	1	833	391	4.0	0.628	0.141
18292-2	GRSL	Weber R. nr. Coalville, UT	Mountain Whitefish	2	545	374	4.0	0.535	0.117
18292-3	GRSL	Weber R. nr. Coalville, UT	Mountain Whitefish	2	317	300	3.0	0.364	0.073
18293-1	TRIN	Trinity R. below Dallas, TX	Bluegill Sunfish[b]	2	19	95	1.5	0.412	0.064
18294-1	TRIN	Trinity R. below Dallas, TX	Bluegill Sunfish[b]	1	38	120	2.5	0.494	0.079
18295-1	TRIN	Trinity R. below Dallas, TX	Mixed Sunfish	2	77	162	2.5	0.431	0.064
18296-1	TRIN	Trinity R. below Dallas, TX	Flathead Catfish	1	1087	470	--	0.910	0.159
18297-1	TRIN	White Rock Lake Dallas TX	Largemouth Bass	1	91	186	0.5	0.270	0.045
18298-1	TRIN	White Rock Lake Dallas TX	Largemouth Bass	2	341	282	3.5	0.252	0.051
18299-1	TRIN	White Rock Lake Dallas TX	Largemouth Bass	1	663	345	3.5	0.586	0.117
18300-1	TRIN	Lake Livingston, TX	Largemouth Bass	1	1305	412	4.5	1.179	0.249
18300-2	TRIN	Lake Livingston, TX	Largemouth Bass	1	849	366	4.5	1.876	0.373
18300-3	TRIN	Lake Livingston, TX	Largemouth Bass	2	526	324	5.0	1.226	0.249
18300-4	TRIN	Lake Livingston, TX	Largemouth Bass	2	306	278	4.0	0.645	0.125
18301-1	TRIN	Clear Cr. nr. Sanger, TX	Spotted Bass	1	40	150	0.5	1.411	0.258
18302-1	TRIN	Clear Cr. nr. Sanger, TX	Spotted Bass	1	87	180	0.5	0.861	0.157
18303-1	TRIN	Clear Cr. nr. Sanger, TX	Spotted Bass	1	142	228	3.5	1.450	0.299
18304-1	TRIN	Clear Cr. nr. Sanger, TX	Channel Catfish	1	372	380	--	2.245	0.341
18304-2	TRIN	Clear Cr. nr. Sanger, TX	Channel Catfish	2	114	248	--	0.841	0.133
18305-1	TRIN	Trintity R. nr. Crockett, TX	Largemouth Bass	1	311	260	3.5	0.631	0.127
18306-1	TRIN	Trintity R. nr. Crockett, TX	Flathead Catfish	3	191	262	--	0.716	0.110
18307-1	NROK	Clark Fork at Turah, MT	Mountain Whitefish	5	551	356	4.5	0.641	0.155
18308-1	NROK	Clark Fork at St. Regis, MT	Mountain Whitefish	5	264	294	3.5	0.436	0.092
18309-1	MIAM	Little Miami R. @ Milford, OH	Smallmouth Bass	3	55	153	1.5	0.244	0.042
18310-1	MIAM	Little Miami R. @ Milford, OH	Smallmouth Bass	1	698	340	5.5	1.393	0.276
18311-1	MIAM	Whitewater R. nr. Nultown, IN	Smallmouth Bass	1	80	187	2.5	0.792	0.135
18312-1	MIAM	Whitewater R. nr. Nultown , IN	Smallmouth Bass	1	129	220	2.5	0.701	0.128
18313-1	MIAM	Whitewater R. nr. Nultown, IN	Smallmouth Bass	2	257	270	4.0	1.038	0.198
18314-1	MIAM	E. Fork, L. Miami R. Williamsburg, OH	Smallmouth Bass	1	107	205	2.5	1.108	0.205
18315-1	MIAM	E. Fork, L. Miami R. Williamsburg, OH	Smallmouth Bass	2	386	302	3.5	1.859	0.359
18316-1	MIAM	E. Fork, L. Miami R. Williamsburg, OH	Smallmouth Bass	1	608	350	4.5	2.524	0.520
18317-1	MIAM	Stillwater R. @ Union, OH	Smallmouth Bass	3	130	217	2.5	1.074	0.180
18318-1	MIAM	Stillwater R. @ Union, OH	Smallmouth Bass	1	284	275	3.5	0.706	0.138
18319-1	MIAM	Great Miami R. nr. Tipp City, OH	Smallmouth Bass	4	178	242	3.5	0.649	0.117
00012-1	MIAM	Mad R. @ Hwy 41	Smallmouth Bass	1	518	325	5.5	1.355	0.271
00013-1	MIAM	Great Miami R. @ Hamilton	Smallmouth Bass	2	345	292	3.5	0.565	0.113
18523-1	OAHU	Kawainui Canal, HI	Tilapia	5	127	188	4.0	0.157	0.030
18524-1	OAHU	Ala Wai Canal, HI	Tilapia	5	124	179	2.0	0.115	0.020
18525-1	OAHU	Hoomaluhia Reservoir, HI	Tilapia	5	49	133	3.0	0.116	0.018
18526-1	OAHU	Nuuanu Reservoir, HI	Tilapia	5	249	226	4.0	0.317	0.063
18527-1	OAHU	Waikele Stream, HI	Smallmouth Bass[a]	1	32	135	0.5	0.189	0.050
18528-1	OAHU	S. Fork Lake Wilson, HI	Tilapia	5	302	250	4.5	0.237	0.046
18529-1	MOBL	Shades Cr., AL	Longear Sunfish	8	29	118	3.0	0.718	0.122
18530-1	MOBL	Alabama R. @ Claiborne, AL	Black Crappie	2	210	245	3.0	0.810	0.146
18530-2	MOBL	Alabama R. @ Claiborne, AL	Black Crappie	1	94	180	2.5	0.411	0.067

CERC #	S.U.	Site	Species	No. Fish	Mean Weight (g)	Mean Total Length (mm)	Mean age (yr)	µg Hg / g dry	µg Hg / g wet
18531-1	MOBL	Alabama R. @ Claiborne, AL	Spotted Bass	2	754	365	3.5	0.837	0.147
18531-2	MOBL	Alabama R. @ Claiborne, AL	Spotted Bass	2	262	275	3.5	0.789	0.149
18531-3	MOBL	Alabama R. @ Claiborne, AL	Spotted Bass	2	158	240	2.5	0.486	0.094
18532-1	MOBL	Satilpa Cr near Coffeeville, AL	Largemouth Bass	1	92	194	2.5	3.078	0.551
18532-2	MOBL	Satilpa Cr near Coffeeville, AL	Spotted Bass	1	140	235	3.5	3.213	0.601
18533-1	MOBL	Town Cr at Tupelo, MS	Channel Catfish[a]	10	32	160	--	0.359	0.073
18534-1	MOBL	Tombigbee R. nr. Coffeeville Lock, AL	Largemouth Bass	2	588	350	4.5	1.572	0.313
18534-2	MOBL	Tombigbee R. nr. Coffeeville Lock, AL	Largemouth Bass	4	252	269	3.0	1.761	0.351
18535-1	MOBL	Coosa River at Rome, GA	Black Crappie	1	453	304	3.5	0.653	0.125
18535-2	MOBL	Coosa River at Rome, GA	Black Crappie	1	266	249	2.5	0.153	0.027
18535-3	MOBL	Coosa River at Rome, GA	Black Crappie	1	140	204	2.5	0.163	0.030
18536-1	MOBL	Chickasaw Cr., AL	Bluegill Sunfish[a]	2	31	118	--	1.108	0.248
00001-1	SANT	N. Fork Edisto R, nr. Fairview crossroad	Largemouth Bass	1	907	410	--	9.015	1.803
00002-1	SANT	N. Fork Edisto R. nr. Branchville, SC	Largemouth Bass	1	84	180	--	3.130	0.626
00003-1	SANT	South Edisto R. nr Springfield, SC	Largemouth Bass	1	517	310	--	2.860	0.572
00004-1	SANT	S. Fork Edisto R. nr Canaan, SC	Largemouth Bass	1	83	170	--	2.725	0.545
00005-1	SANT	Saluda R., SC	Largemouth Bass	1	900	390	--	2.355	0.471
00006-1	SOFL	Water Conservation 3A15, FL	Largemouth Bass	1	1694	507	4.8	21.1	4.22
00007-1	SOFL	Water Conservation 3A15, FL	Largemouth Bass	1	205	250	1.8	4.10	0.82
00008-1	SOFL	Water Conservation 3A15, FL	Largemouth Bass	1	466	325	2.8	7.10	1.42
00009-1	SOFL	Water Conservation U3, FL	Largemouth Bass	1	307	301	3.8	3.30	0.66
00010-1	SOFL	Water Conservation U3, FL	Largemouth Bass	1	227	273	2.8	1.85	0.37
00011-1	SOFL	Water Conservation U3, FL	Largemouth Bass	1	229	264	3.8	3.15	0.63

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13. ABSTRACT (*Maximum 200 words*) Bioaccumulation of mercury (Hg) in fish sampled at 106 sites from 20 U.S. watershed basins was evaluated in relation to species, Hg and methylmercury (MeHg) in surficial sediment and water, and watershed characteristics. Bioaccumulation of Hg was strongly (positively) correlated with MeHg in water but only moderately with the MeHg in sediment or total Hg in water. The best model for predicting Hg bioaccumulation included MeHg in water, pH of the water, % wetlands in the basin, and the AVS content of the sediment; however, MeHg in water explained most of the model variability. Based on our data, a MeHg water concentration of 0.12 ng/L was on average, associated with a fish fillet Hg concentration of 0.3 mg/kg wet weight for an age-3 fish when all species were considered. For age-3 largemouth bass, a MeHg water concentration of 0.058 ng/L was associated with the 0.3 mg/kg fillet concentration. Based on rankings for Hg in sediment, water, and fish, sampling sites from the following five study basins had the greatest Hg contamination: Nevada Basin and Range, South Florida Basin, Sacramento River Basin (California), Santee River Basin and Coastal Drainages (South Carolina), and the Long Island and New Jersey Coastal Drainages.

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Methyl-Mercury Degradation Pathways: A Comparison among Three Mercury-Impacted Ecosystems

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We examined microbial methylmercury (MeHg) degradation in sediment of the Florida Everglades, Carson River (NV), and San Carlos Creek (CA), three freshwater environments that differ in the extent and type of mercury contamination and sediment biogeochemistry. Degradation rate constant (k_{deg}) values increased with total mercury (Hg_t) contamination both among and within ecosystems. The highest k_{deg}'s (2.8−5.8 d^{-1}) were observed in San Carlos Creek, at acid mine drainage impacted sites immediately downstream of the former New Idria mercury mine, where Hg_t ranged from 4.5 to 21.3 ppm (dry wt). A reductive degradation pathway (presumably *mer*-detoxification) dominated degradation at these sites, as indicated by the nearly exclusive production of $^{14}CH_4$ from ^{14}C-MeHg, under both aerobic and anaerobic conditions. At the upstream control site, and in the less contaminated ecosystems (e.g. the Everglades), k_{deg}'s were low ($\leq$0.2 d^{-1}) and oxidative demethylation (OD) dominated degradation, as evident from $^{14}CO_2$ production. k_{deg} increased with microbial CH_4 production, organic content, and reduced sulfur in the Carson River system and increased with decreasing pH in San Carlos Creek. OD associated CO_2 production increased with pore-water SO_4^{2-} in Everglades samples but was not attributable to anaerobic methane oxidation, as has been previously proposed. This ecosystem comparison indicates that severely contaminated sediments tend to have microbial populations that actively degrade MeHg via *mer*-detoxification, whereas OD occurs in heavily contaminated sediments as well but dominates in those less contaminated.

Introduction

Methylmercury (MeHg) is a heavy metal organo-toxin formed primarily by sulfate reducing bacteria in anoxic sediments (*1, 2*). Due to concerns regarding its bioaccumulation in aquatic food chains, much attention has been focused on factors controlling MeHg production under various environmental conditions (*3*−*8*). The balance of MeHg production and degradation ultimately controls MeHg concentration, yet comparatively little attention has been given to the degradation process (*9*), which may proceed by a number of abiotic and biotic pathways in the natural environment. Abiotic pathways include photodegradation (*10*) and the reaction with sulfide to form dimethylmercury (Me_2Hg) and HgS (*11*).

Biotic degradation also takes a number of forms. The most thoroughly researched involves mercury resistance in bacteria possessing genes of the *mer*-operon ((*12*−*14*) and references therein). This capacity appears widespread in nature and has been found for both gram negative and gram-positive bacteria and under aerobic and anaerobic conditions (*15*−*17*). The *mer*-operon can be carried on plasmids and other transposable elements and transferred among different bacteria species. "Broad-spectrum" resistance refers to the ability of bacteria to detoxify both inorganic Hg(II) and organomercurials, including MeHg. This contrasts with "narrow-spectrum" resistance, in which only Hg(II) detoxification occurs. The transcription of the specific detoxification and transport proteins is regulated by an organomercurial-responsive MerR protein in the first case and by a Hg(II) responsive regulatory MerR in the second case. Unique to broad-spectrum resistance is the *mer*-B gene that encodes for the organomercurial-lyase enzyme, which cleaves MeHg, forming CH_4 and Hg(II) as end-products. The associated *mer*-A gene, common in both resistance types, produces the enzyme mercuric reductase, which further reduces Hg(II) to volatile elemental Hg^0 (*18*). In this way, broad-spectrum mercury resistant microbes are able to detoxify MeHg by converting it to a form that may readily evade from the immediate environment.

An alternative anaerobic, non-*mer*-mediated, degradation pathway has been demonstrated for the sulfate reducing bacteria *Desulfovibrio desulfuricans* (*19*), where 2 mol of MeHg react with microbially produced sulfide to form an unstable dimethylmercury sulfide $(MeHg)_2S$ intermediate, which decomposes to Me_2Hg and HgS, as in the abiotic pathway above. Me_2Hg is then degraded to MeHg and CH_4. Thus, the production of CH_4 from MeHg is common to both of the above reductive demethylation (RD) pathways. It is unknown if the non-*mer* RD pathway is induced or regulated by ambient MeHg concentrations, as is *mer*-detoxification. However, genes regulating the production of sulfide and the degradation of MeHg were shown to be located on the same plasmid in *Clostridium cochlearium* T-2 (*20*), and it has been proposed that the MeHg degradation pathway in *C. cochlearium* and *D. desulfuricans* is one and the same (*21*).

Reports of CO_2 as a major bacterial end-product of MeHg degradation in anaerobic sediments led to the proposal of an oxidative demethylation (OD) pathway, which has since been demonstrated in freshwater, estuarine, and alkaline-hypersaline sediments (*22*−*24*). OD is thought to represent a cometabolism of MeHg analogous to the metabolism of other small organic substrates (e.g. C_1 compounds) by heterotrophic bacteria and as such does not represent an active detoxification response. Sulfate reducing, methanogenic, and aerobic bacteria have all been implicated in this pathway. While the production of CO_2 from MeHg is what defines OD, the production of both CO_2 and CH_4 via OD is also possible and would be analogous to the production of both end-products in the degradation of methanol or

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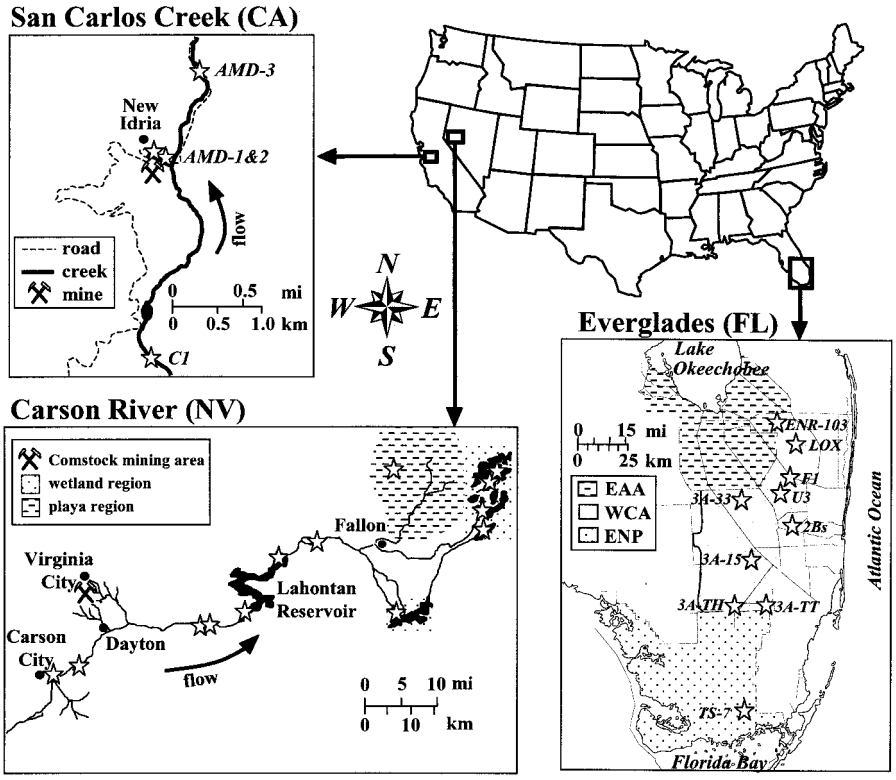

FIGURE 1. Maps of the San Carlos Creek (CA) [a], Carson River (NV) [b], and Everglades (FL) [c] ecosystems, with sampling sites given as (☆) and towns/cities as (●). Part [c] includes the Everglades Agricultural Area (EAA), Water Conservation Areas (WCA), and Everglades National Park (ENP).

monomethylamine by methanogens (*23*, *24*). In contrast, no CO_2 is formed from MeHg by either of the two RD pathways. Recently however, the evidence for OD has come into question. It has been suggested that the formation of $^{14}CO_2$ from ^{14}C-MeHg degradation experiments may simply reflect *mer*-detoxification followed by anaerobic $^{14}CH_4$ oxidation to $^{14}CO_2$ (*25*).

The specific environmental factors that control the relative importance of these biotic pathways in a particular system are largely unknown, although MeHg and/or Hg(II) concentration are likely important. Since *mer*-detoxification of MeHg is induced by the presence of the substrate, some threshold concentration is needed to induce transcription (*26*). A similar threshold concentration might not be necessary for OD to occur if this pathway represents a cometabolism of MeHg. We hypothesize that OD dominates at low in-situ MeHg concentrations, when induction of *mer*-degradation is minimal. It is also unknown if Hg(II) reduction to Hg^0 occurs under conditions favoring OD. If this capacity is lacking, an extended residence time for Hg might be predicted in systems where OD dominates. Thus, our limited understanding of the OD pathway and its potential importance in the global Hg cycle has led us to further investigate this process in various ecosystems throughout the past decade. We have observed OD in all systems investigated to date and focus here on the three most intensively studied. The Florida Everglades represents a moderately contaminated system with a nonpoint-source atmospheric Hg input, whereas San Carlos Creek (CA) and Carson River (NV) exhibit significantly higher Hg levels owing to ongoing point-source and historic regional contamination, respectively. Here we attempt to decipher the relative importance of these various microbial pathways under different environmental conditions by comparing MeHg degradation dynamics, in terms of CH_4 and CO_2 end-products, both within and among these three very different ecosystems. We also directly test the hypothesis that anaerobic CH_4 oxidation can account for the current and previous reports of OD.

Methods

Sites and Field Sampling. Mercury loading to the Florida Everglades is primarily in the form of atmospheric deposition (*27*), with sediment total mercury (Hg_t) concentrations typically 0.1−0.5 ppm (dry wt) (*28*). Surface sediment was collected from ten Everglades wetland sites (Figure 1) during December 1996, July 1997, January 1998, and June 1998, as part of the South Florida Aquatic Cycling of Mercury in the Everglades (ACME) project (*29*, *30*). Sample depth varied from the top 0−4 cm (July 1997 and June 1998) to the complete unconsolidated surface floc layer (top 4−10 cm; Dec 1996 and Jan 1998). These sites represent a 130-km north−south transect along an eutrophication gradient, stemming from high phosphate inputs from the Everglades Agricultural Area (EAA) (*31*). Sites were located in the Water Conservation Areas (WCA), the experimental Everglades Nutrient Removal (ENR) zone, and the more pristine Everglades National Park (ENP). Specific site descriptions have been given elsewhere (*24*, *32*, *33*).

The Carson River U.S. EPA Superfund site, in western Nevada, was originally contaminated during the mid- to late 1800s with elemental Hg^0 used in the processing of gold and silver ores associated with the Comstock load. The river flows northeast and drains into a desert/wetland evaporation basin at the terminus. Historic Hg inputs are from smaller tributaries originating near Virginia City and from a major amalgamation facility near Dayton. Due to the reworking and mobilization of these sediments over the past century, downstream locations currently have benthic Hg_t concentrations as high as several hundred ppm (*34*). Sediment samples (0−4 cm) were collected during October 1998 at 13 sites, over a 100-km stretch from Carson City to the wetlands

TABLE 1. Conditions Used for Methylmercury (MeHg) Degradation Measurement via $^{14}CH_3HgI$ Incubation and CT-LSC Detection of Gaseous ^{14}C End-Products

sample set	date	holding time prior to assay (d)	incubation duration (h)	^{14}C-MeHg added (nCi*cc sed^{-1})	total MeHg added (ng Hg*cc sed $^{-1}$)
Carson R. (NV)	Oct 1998	93−95	24	14	52
Everglades (FL)	Dec 1996	<0.3	22−28	0.5	2
Everglades (FL)	July 1997	<0.3	7−8	2−4	7−15
Everglades (FL)	Jan 1998	<0.3	6−12	2−3	7−11
Everglades (FL)	June 1998	<0.3	6−8	3	11
San Carlos Creek (CA)	Oct 1997	14	20	3	11
San Carlos Creek (CA)	Jan 1999	30	23	2−3	7−11

region. Sites were categorized into five types depending on location and major features (*n* given in [ ]): river [5], Lahontan reservoir [2], agricultural drain [2], wetland [3], and playa [1]. Descriptions of the Carson River and associated wetlands are given elsewhere (*35*, *36*).

San Carlos Creek (SCC), located in the Diablo Mountain range of central California, intersects the former New Idria mercury mine, which operated for 118 years (1854−1972) and was the second largest producer of elemental Hg^0 in North America (*37*). The creek is impacted both by acid mine drainage (AMD) and mercury contamination from unprocessed cinnabar (HgS) ore and roasted-ore waste. Surface sediment (0−4 cm) was initially sampled in October 1997 at a non-AMD control site (C-1) located 3.2 km upstream of the mine and at an AMD site (AMD-3) located 1.2 km downstream of the mine. A second sampling in January 1999 included the two previous sites plus two additional sites associated with a short (<0.2 km) feeder stream from the New Idria mine flowing into SCC. AMD-1 was located directly in front of the mine, where subsurface AMD emerges as surface flow. AMD-2 was 0.1 km downstream, adjacent to a settling pond at the base of large roasted-ore waste pile. Detailed site descriptions are given elsewhere (*37*, *38*).

Sediment collection for microbial assays was conducted by hand with acid cleaned polycarbonate core tubes in all ecosystems. Holding times prior to the initiation of ^{14}C-MeHg incubations varied from <0.3 to 95 days (Table 1). When incubations were not initiated within a few hours of sample collection, sediment was stored at 5 °C in completely filled acid-cleaned mason jars until further analysis.

Sediment Assays. Sediment was subsampled (3 cm^3) into 13 cm^3 serum vials, which were crimp sealed and flushed with O_2-free N_2 gas. Radiolabeled MeHg (as $^{14}CH_3HgI$) was added (2−42 nCi*100 μL^{-1}) to each. The final ^{14}C-MeHg amendment levels (2−52 ng Hg*cm^{-3} wet sed or 15−2400 ppb dry wt, median = 134 ppb) were higher than in-situ MeHg (<10 ppb dry wt) for these systems (*28*, *39*). Samples were vortexed (30 s) and incubated in the dark at room temperature (17−22 °C) for 6 to 28 h (Table 1). Incubations were arrested with the addition of 1 mL of NaOH (3 N). Each site/depth sample set was replicated ($n = 2-3$) and included one autoclaved killed control. A high specific activity ^{14}C-MeHg stock (54 mCi*$mmol^{-1}$, Amersham Corp., Arlington Heights, IL) was used in all investigations, and ^{14}C-end-products were quantified by a CH_4 combustion and CO_2 trapping technique, followed by liquid scintillation counting (CT-LSC) (*24*). The serum bottle headspace was first flushed with commercial air (35−30 mL*min^{-1} for 15 min), while vortexing, to drive off $^{14}CH_4$. This end-product was combusted to $^{14}CO_2$ in an inline furnace (850 °C, using a CuO catalyst) and subsequently trapped in a solution of 8 mL of methanol and 3 mL of monoethanolamine. Nearly 100% $^{14}CH_4$ extraction efficiency achieved by twice amending the sample with 1 mL of pure unlabeled CH_4 during the flushing period. Samples were subsequently acidified with 1 mL of 6 M HCl to convert base-fixed aqueous $^{14}CO_3^{2-}$ to gaseous $^{14}CO_2$, which was then flushed from the bottle using N_2 and similarly trapped as above in a new CO_2-trap. Pure nonlabeled CO_2 was also twice added (1 mL) to samples during this second flushing step to facilitate the removal of $^{14}CO_2$ from the original sample. Scintillation cocktail (ScintiVerse II, Fisher Scientific) was added to all $^{14}CO_2$ traps, and samples were counted by LSC.

Pseudo-first-order MeHg degradation rate constant (k_{deg}) values were calculated as $k_{deg} = -\ln(1-f)*time^{-1}$, where f was the fraction of added ^{14}C-MeHg degraded to $^{14}CH_4 + {}^{14}CO_2$ (kill corrected). The relative amount of $^{14}CO_2$ produced was expressed as the percentage of total gaseous end-products recovered (henceforth called $\%^{14}CO_2$) and was calculated from kill-corrected data as $\%^{14}CO_2 = [{}^{14}CO_2/({}^{14}CH_4+{}^{14}CO_2)]*100$. While most ^{14}C-MeHg incubations consisted of only one time point (Table 1), multipoint time courses (20−120 h) were also conducted at selected sites from each ecosystem. In these cases, k_{deg} was calculated from the slope of the initial linear portion of each [%MeHg degraded versus time] curve. All determinations of statistically significant relationships were based on the $P < 0.05$ criteria for the slope of a linear model.

Methane ($^{14}CH_4$) oxidation was assessed in parallel with ^{14}C-MeHg degradation in all three ecosystems. Samples from SCC in 1997 were amended with $^{14}CH_4$ (5 nCi*250 μL^{-1}, sp. act. = 56 mCi*$mmol^{-1}$, purity = 97.5%, Amersham Corp.) and incubated 20 h, under both aerobic and anaerobic (static) conditions. Everglades (January 1998) sediment samples (3 cm^3) were amended with $^{14}CH_4$ (6 nCi*100 μL^{-1}, added to the gas phase of sealed vials) and incubated statically (no shaking) for 6−12 h, under both aerobic and anaerobic conditions. Carson River samples were slurried (3 cm^3 sediment plus 1 mL of anoxic DI water), amended with $^{14}CH_4$ (15 nCi*250 μL^{-1}), and incubated on a gyrating shaker table (150 rpm) under anaerobic conditions (only) for 45 h. Radiotracer $^{14}CH_4$ (sp. act. = 21.1 mCi*$mmol^{-1}$), used for Everglades and Carson River experiments, was obtained from and originally produced in the laboratory of B. Ward (UC Santa Cruz, CA) from methanogenic cultures incubated with $H^{14}CO_3^-$ (personal communication). $^{14}CH_4$ and $^{14}CO_2$ was subsequently quantified by the CT-LSC method in all cases.

Sediment Hg_t was quantified using acid digestion, Sn-reduction, gold trapping, and cold vapor atomic fluorescence spectrophotometry (CVAFS) detection (*40, 41*). MeHg was assayed by distillation (*42*), aqueous phase ethylation, G−C separation, and CVAFS detection (*43*). Assays were conducted at the following three institutions: Everglades samples—Academy of Natural Sciences (St. Leonard, MD), Carson River samples—USGS (Madison, WI), and New Idria samples—USGS (Menlo Park, CA). All institutions used similar equipment and assay conditions.

As measures of organic content, dry sediment samples were subject to weight loss on ignition (LOI) analysis (*44*) (all three systems) and to particulate carbon (PC) analysis (Carson River only) measured with a Carlo Erba elemental analyzer (Model 1500). Sediment pH was measured (Carson River and SCC only) by inserting a pH electrode (Cole-Parmer, model 59002-72) directly into homogenized sediment. Acid-volatile-

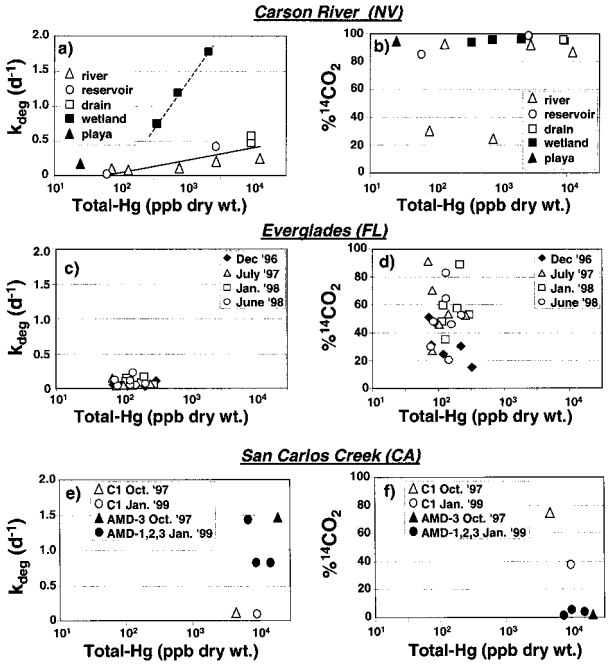

FIGURE 2. Log-linear plots of MeHg degradation rate constant (k_{deg}) [a,c,e] and $\%^{14}CO_2$ end-product [b,d,f] versus Hg_t concentrations in sediment from the Carson River (NV) 1998 [a,b], Everglades (FL) 1996−1998 [c,d], and San Carlos Creek (CA) 1997/1999 [e,f]. Carson River data is grouped by ecosystem zone, Everglades data by sampling date, and San Carlos Creek data by region and sampling date. Least-squares regression line and associated r^2 is given in [a] for data grouped by either wetlands or all other sites (excluding playa).

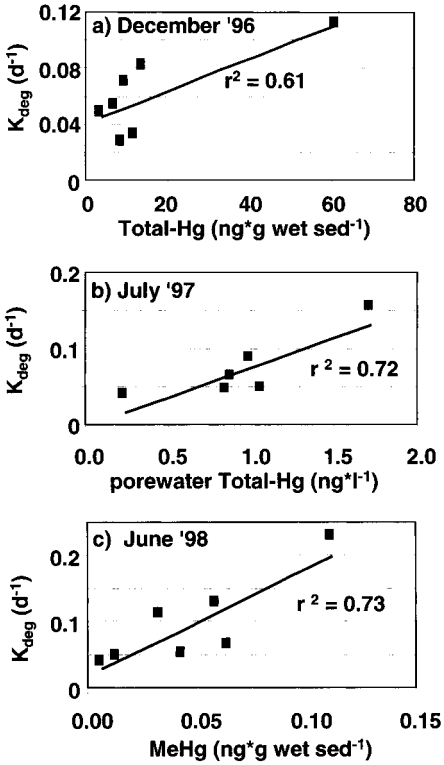

FIGURE 3. Significant linear regressions of MeHg degradation rate constant (k_{deg}) values versus various mercury pools in the Everglades data set. Depth intervals for k_{deg} data were variable (top 4 to 10 cm) during December 1996 and 0−4 cm during both July 1997 and June 1998. The corresponding mercury pool concentrations represent the 0−4 cm average depth interval in all cases.

sulfur (AVS) in Carson River samples was determined spectrophotometrically (*45*) after zinc-acetate trapping of H_2S from acidified whole sediment (*46*). AVS was determined similarly (*47*) in Everglades samples. Pore-water from Carson River sediment was collected under anaerobic conditions via centrifugation and was assayed for SO_4^{-2} via ion-chromatography (*48*) and for free sulfide (*45*). Everglades pore-water was collected by direct filtration of whole sediment or by using an in-situ interstitial pore-water sampler, with free sulfide analyzed using an ion-specific electrode (*28*). Methanogenesis in Carson River samples was measured as the net CH_4 production, over 7 days, quantified by gas chromatography with flame ionization detection. Methanogenesis in Everglades (1997) samples was measured as the conversion of radiolabeled $H^{14}CO_3^-$ (spec. act. = 54.4 mCi*mmol^{-1}; ICN Biomedicals, Irvine, CA) to $^{14}CH_4$, quantified via gas chromotography with gas proportional counting detection (*22*).

Results

Values of k_{deg} increased with increasing Hg_t (20−12 700 ppb dry wt) in the Carson River (Figure 2a). Two distinct regional groupings were observed, with the wetland sites exhibiting a stronger MeHg degradation response to Hg_t than river, reservoir, and agricultural drain sites (combined). All sites exhibited >80% $^{14}CO_2$, except two river sites which were 20−30% (Figure 2b). Everglades Hg_t concentrations (Figure 2c−d) fell into a low and narrow range (70−320 ppb dry wt) compared to the Carson River. Everglades k_{deg}'s were consistently low (0.03−0.23 d^{-1}) and similar to previously measured values (*24*). The $\%^{14}CO_2$ ranged from 15 to 92%. Neither k_{deg} nor $\%^{14}CO_2$ varied as a function of log[Hg_t] in the complete Everglades data set. However, significant relationships between k_{deg} and specific mercury fractions (e.g. bulk sediment Hg_t and MeHg, pore-water Hg_t) were found when individual sampling dates were analyzed (Figure 3a−c), although, specific results were not consistent among all dates.

SCC Hg_t levels were very high at both the control site (4800−9600 ppb dry wt) upstream and AMD sites (4500−21 300 ppb dry wt) downstream of the New Idria mercury mine (Figure 2e−f). A consistent spatial trend of low k_{deg} (≤0.1 d^{-1}) and high $\%^{14}CO_2$ (37−74%) upstream of the mine, and high k_{deg} (0.8−1.5 d^{-1}) and minimal $\%^{14}CO_2$ (1−4%) below the mine, was observed for both sampling dates.

Time course k_{deg}'s (Figure 4a−g) ranged from 0.017 d^{-1} for the modestly contaminated Everglades ENR-103 site, to 5.8 d^{-1} for the severely contaminated SCC AMD-3 site. This latter value was significantly larger than 1.5 d^{-1} depicted in Figure 2e for the same site and date. The lower value was calculated using the single 20-h data point so as to be comparable with the k_{deg} for January 1999 SCC, which was based on a single-point (22 h) incubation. The nonlinear time courses (Figure 4a,e,g) point out the potential for the underestimation of k_{deg} when calculated from a single time point, particularly from a prolonged incubation. MeHg degradation was slow (<0.1 d^{-1}) and increased linearly with time for both Everglades sites and SCC site C1. In contrast, after an initial rapid rate (0.45 d^{-1}), MeHg degradation slowed over time at Carson River site F1. A similar, but more pronounced, rapid initial degradation followed by a much slower rate was observed for SCC AMD-3 sediment, under both oxic and anoxic incubation conditions. The $\%^{14}CO_2$ was high (≥40%) and remained relatively constant over time for Carson River F1, Everglades ENR-103, and SCC C1 (anaerobic). There was a distinct decrease in $\%^{14}CO_2$ with time at both Everglades 3A-15 and SCC C1 (aerobic). Very little (<0.05%) $^{14}CO_2$ was produced in both aerobic and anaerobic SCC AMD-3 time courses.

Carson River k_{deg}'s increased with a number of biogeochemical parameters associated with the transition from

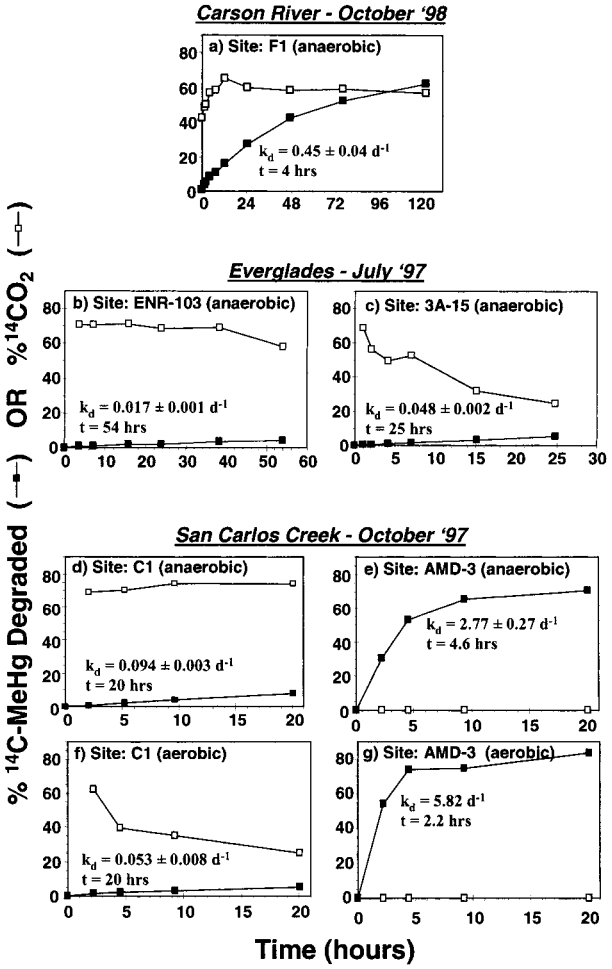

FIGURE 4. Time course experiments: percent MeHg degraded (closed square) and percent $^{14}CO_2$ end-product (open square) versus time for Carson River (NV), site F1 [a]; Everglades (FL), sites ENR-103 and 3A-15 [b,c]; and San Carlos Creek (CA), sites C1 and AMD-3 [d−g]. Degradation rate constants (k_{deg}'s) are calculated from the initial linear portion of each % degradation versus time plot. The maximum time point used for each regression is noted in each case, as are aerobic or anaerobic incubation conditions.

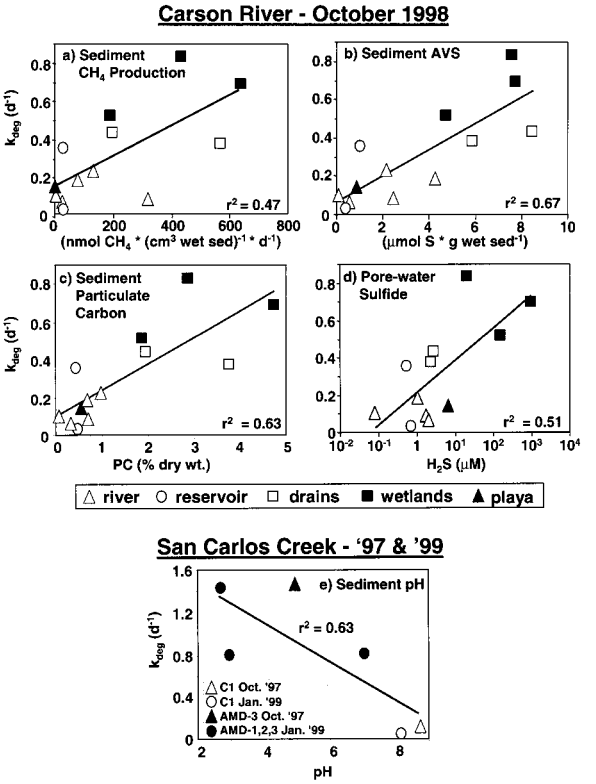

FIGURE 5. Significant linear regressions of biogeochemical variables (CH_4 production, acid-volatile-sulfur (AVS), particulate carbon (PC), pore-water sulfide (H_2S), and sediment pH) versus MeHg degradation rate constants (k_{deg}) for 0−4 cm depth interval sediment in the Carson River (NV) 1998 [a−d], and San Carlos Creek (NV) 1997/1999 [e].

low-organic river to comparatively high-organic wetland sediments, including methanogenesis rate, sediment PC and AVS, pore-water sulfide (Figure 5a−d), and LOI (not shown, similar to PC graph 5c). These parameters did not covary with Hg_t (data not shown). In contrast, no significant relationships were found between k_{deg} and methanogenesis, AVS, or sulfide in the Everglades data (no PC data). A weak negative relationship with LOI was seen for July 1997 but was heavily weighted by a single data point (not shown). No relationship between k_{deg} and LOI was seen for SCC (not shown), although degradation increased with decreasing sediment pH, which ranged from 8.1 to 8.7 at C1 and from to 2.6 to 7.1 at the AMD sites (Figure 5e). No significant relationship between pH and k_{deg} was observed for the Carson River data, where pH varied over a much narrower range (6.9−8.2).

Methane oxidation was investigated to determine if this microbial process could account for any of the $^{14}CO_2$ production routinely observed for ^{14}C-MeHg degradation experiments. In four Everglades sediments, 48−69% $^{14}CO_2$ was produced from ^{14}C-MeHg under anaerobic conditions, whereas only 0−4% $^{14}CO_2$ was produced from $^{14}CH_4$ during contemporaneous incubations (Table 2). In contrast, 9−23% $^{14}CH_4$ oxidation was observed in aerobic samples from the two sites. A corresponding increase in the $\%^{14}CO_2$ from ^{14}C-MeHg was also observed under aerobic conditions, although the total amount of MeHg degraded decreased slightly in both cases. In a similar set of parallel incubations (anaerobic only), no $^{14}CO_2$ was produced from $^{14}CH_4$ (detection limit ca. 0.1%) at any of 13 Carson River sites (not shown), while end-product $\%^{14}CO_2$ from ^{14}C-MeHg ranged from 24 to 98% (Figure 2b). Finally, no $^{14}CH_4$ oxidation was observed at either SCC (1998) site under either aerobic or anaerobic conditions, during a 20-h incubation (not shown). A positive relationship between $\%^{14}CO_2$ and pore-water SO_4^{2-} was observed in three of the four Everglades sampling dates (Figure 6), although, a similar relationship was not evident in the Carson River data.

TABLE 2. Parallel ^{14}C-MeHg Degradation and $^{14}CH_4$ Oxidation Experiments Conducted under Both Anaerobic and Aerobic Conditions with Florida Everglades Whole Sediment (Jan 1998)[a]

site	MeHg degradation k_{deg} (d^{-1})	MeHg end-product $\%^{14}CO_2$	$^{14}CH_4$ oxidation to $^{14}CO_2$ (%)
	Anaerobic Incubations		
LOX	0.06 (0.01)	53 (7)	0.8 (0.8)
TS-7	0.11 (0.01)	48 (5)	0.2 (0.1)
2Bs	0.09 (0.02)	57 (23)	4.1 (1.6)
ENR-103	0.07 (0.01)	69 (8)	0.0
	Aerobic Incubations		
LOX	0.04 (0.00)	75 (9)	23 (3)
TS-7	0.05 (0.01)	102 (14)	9 (1)

[a] Standard deviations are given in parentheses. Replication was n = 3 and n = 2 for ^{14}C-MeHg and $^{14}CH_4$ amended samples, respectively. Incubation time was 6−12 h.

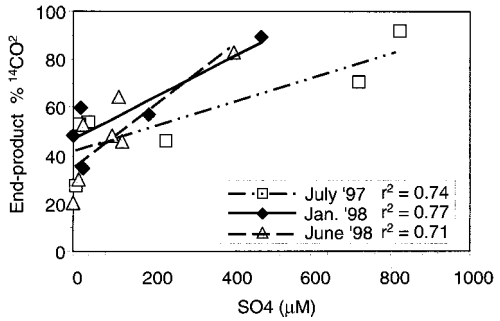

FIGURE 6. Significant linear regressions of the percent $^{14}CO_2$ end-product versus pore-water SO_4^{2-} concentrations (0−4 cm depth interval) from the Everglades data set.

Discussion

The positive relationship between k_{deg} and log[Hg_t] in the Carson River data set (Figure 2a) reconfirms earlier findings for this system in which the demethylation rate increased among three sites with increasing Hg contamination (*23*). The two distinct spatial groupings in the current data indicate that MeHg degrading bacteria in the wetlands were more responsive to Hg contamination than bacteria in other regions. This may reflect differences in the composition, abundance or activity of the respective microbial communities, and/or differences in the MeHg availability. The $\%^{14}CO_2$ data suggests that OD dominated MeHg degradation even at the most contaminated sites. This appears in contrast to results from the earlier investigation noted above, in which $\%^{14}CO_2$ decreased with increasing Hg contamination and demethylation rate. Such a trend would suggested a shift in microbial populations, from those invoking OD at low Hg levels to those invoking RD at higher contamination levels. The natural selection of bacteria, able to invoke *mer*-detoxification of both inorganic and organic mercury, has been shown in other Hg contaminated sediments (*18*, *49*). The lack of any clear relationship between $\%^{14}CO_2$ and Hg_t in the current study may indicate that the long sediment holding time (>90 days), prior to ^{14}C-MeHg incubation, impacted the original community composition so as to obscure this relationship. Alternatively, the apparent trend in the earlier report may have been spurious due to the limited number of observations ($n = 3$) or because *mer*-detoxification was inadvertently stimulated in contaminated sediments due to the high ^{14}C-MeHg amendment levels used (1800 ng Hg*cm^{-3}) compared to the current study (2−52 ng Hg*cm^{-3}).

The positive relationship between k_{deg} and various mercury pools evident in the Everglades data (Figure 3) further illustrates the potential for increased degradation with increasing contamination within an ecosystem. The inconsistency in the types of significant regressions observed among sampling dates partially reflects the fact that while sediment for both MeHg degradation assays and Hg-speciation analysis was collected at the same site and date, these samples were collected by two different groups of researchers, often tens of meters apart and not always at the same depth intervals (see Figure 3 legend). Thus, the analysis of k_{deg} and Hg-speciation relationships is less than optimal for this data set. However, since within-site variation in k_{deg} and Hg-species concentrations was presumably smaller than regional (among-site) variations (not directly tested), significant trends were detected in some cases. Further, since the range of Hg_t concentrations is much smaller in the Everglades compared to the Carson River, the expected response of the microbial community to increasing Hg contamination in the Everglades is expected to be more subtle and significant relationships more difficult to decipher. Finally, other geochemical factors assuredly influence k_{deg} values and thus partially obscure the direct influence of increased contamination in the Everglades.

Comparisons among systems further confirm the positive relationship between k_{deg} and Hg_t. In the Everglades, where Hg_t values were comparatively low, k_{deg}'s were likewise consistently low **(**Figure 2c**)**. In SCC, where Hg_t was very high both above and below the New Idria mine, k_{deg}'s were high at all AMD sites and low at the control site (Figure 2e). Mercury bioavailability likely accounted for this among-site difference within SCC. The source of Hg upstream is primarily recalcitrant and insoluble weathered cinnabar (HgS) abundant throughout the local area, whereas the downstream source includes particle-bound Hg(II) liberated by acidic conditions within the mine and the leaching of roasted-ore waste adjacent to the mine (*37*, *38*). Thus, the higher levels of bioavailable Hg_t at sites downstream of the mine would be more prone to select for bacterial populations that actively degrade MeHg.

As with the 1998 Carson River data, the lack of any clear relationship between $\%^{14}CO_2$ and log[Hg_t] in the Everglades (Figure 2d) indicates that something other than Hg_t alone influences MeHg degradation pathways or stoichiometric end-product ratios. The positive relationship between $\%^{14}CO_2$ and pore-water SO_4^{2-} (Figure 6) suggests that this anion plays a role in MeHg degradation pathway, although it is unclear if this role is biological (e.g. mediating sulfate reduction) or abiotic (e.g. affecting MeHg-complex formation). In either case, the consistent production of $^{14}CO_2$ at all sites demonstrates that OD was active, if not dominant. We infer that in-situ Hg was not high enough to induce a strong RD response in the Everglades sites. The situation appears altogether different in SCC sediments, where the lack of significant $^{14}CO_2$ production in AMD sites indicates that RD dominated degradation, as might be predicted under severely contaminated conditions. Abundant $^{14}CO_2$ production observed upstream of the mine (at C-1) supports the hypothesis that a strong RD response is invoked when Hg is not only very high in concentration but also bioavailable in form.

Time course experiment results (Figure 4) for Carson River site F1 and SCC site AMD-3 indicate that the ^{14}C-MeHg amendment was sequestered into at least two pools; one readily available to the resident microbial community and one less available. This was apparent from the initial rapid degradation rates followed by a slowing or cessation of degradation and was in contrast to the slow linear degradation seen in both Everglades sites and SCC site C1. Variations in substrate availability, due to refractory MeHg-complex formation with dissolved and/or particulate phases, may partially account for these spatial differences. Carson River site F1 had low organic content (4% LOI) compared to the two Everglades sites (80−91% LOI), suggesting that very organic-rich sediments may sequester a larger fraction of MeHg into slowly degrading refractory pools. We conclude that sediment organic content was not responsible for the large spatial differences in k_{deg} observed for SCC because LOI percentages were similar for SCC sites C1 and AMD-3 (11% and 17% LOI, respectively) and no significant relationship between k_{deg} and LOI was observed for SCC data. However, large differences in solid-phase composition were evident, with the AMD sites primarily composed of orange colored flocculent material, presumably iron(III)-oxy-hydroxy sulfate precipitate, typical of acid mine drainage (*50*). The distribution of ^{14}C-MeHg between organic and inoganic solid phases was not directly assessed. However, since 55−75% of the ^{14}C-MeHg amendment was readily degraded within 5 h at AMD-3 (Figure 4e,g), we speculate that much of the substrate was associated with the iron(III)-oxy-hydroxy sulfate fraction and that this portion was readily available to the MeHg degrading microbial population.

The nearly constant $\%^{14}CO_2$ produced in five of seven sites (Figure 4) indicates that one pathway dominated MeHg degradation in most cases. Specifically, OD is implicated in the case of Carson River F1, Everglades ENR-103, and SCC C1 (anaerobic), and *mer*-detoxification is implicated in the case of SCC AMD-3. We emphasize *mer*-detoxification in the latter case and not the alternative RD pathway (via reaction with H_2S), which would have been inhibited under aerobic conditions. Similarly for SCC C1, the change in the $\%^{14}CO_2$ trend, from constant and high under anaerobic conditions to decreasing with time under aerobic conditions, also suggests *mer*-detoxification may have been preferentially stimulated under aerobic conditions. The clear decrease in $\%^{14}CO_2$ with time at Everglades 3A-15 [anaerobic] and SCC C1 [aerobic] (Figure 4c,f) indicate that OD and RD were simultaneously active with RD dominating, since $\%^{14}CO_2$ would be expected to increase if OD dominated. An alternative explanation for decreasing $^{14}CO_2$ with time is that different microbial groups are capable of OD but with different stoichiometric end-product $^{14}CO_2/^{14}CH_4$ ratios and/or at different rates. It is important to emphasize that $\%^{14}CO_2$ end-product measurements alone do not indicate the relative importance of OD verses RD, particularly with single time point incubations, as some $^{14}CH_4$ may also be an OD end-product (*23, 24*). Only in cases where either $^{14}CH_4$ or $^{14}CO_2$ is the exclusive end-product can either RD or OD, respectively, be solely inferred. Then, only under aerobic conditions can the non-*mer* Me_2Hg intermediate pathway be ruled out and *mer*-detoxification surmised (e.g. SCC AMD-3).

Amendments with ^{14}C-MeHg, above ambient MeHg levels, may have stimulated RD to varying degrees at some sites (e.g. Figure 4c,f), which may partially account for the wide range of $\%^{14}CO_2$ values observed in Everglades samples (Figure 2d). It is noteworthy that when observed, the decrease in $\%^{14}CO_2$ was immediate and did not involve a lag time, suggesting that the bacterial community was preacclimated to MeHg (*18, 51*). Alternatively, the addition of ^{14}C-MeHg to organic-poor sediments may have stimulated heterotrophic bacteria capable of using MeHg as an organic substrate. If so, this would cause us to overestimate the importance of OD, as the rate of $^{14}CO_2$ produced would presumably be higher than that of nonlabeled CO_2 produced from in-situ MeHg levels. Previous experiments with Everglades sediment did show a significant increase in $\%^{14}CO_2$ produced with increasing ^{14}C-MeHg over a large amendment range (50−4000 ng MeHg*g dry sed^{-1}) but no significant increase in $\%^{14}CO_2$ over a much smaller range (2−18 ng MeHg*g dry sed^{-1}) (*24*). Amendment concentrations in the current work were varied over a wide range (in ng MeHg*g dry sed^{-1}: Everglades, 16-2600; Carson River, 68-270; SCC, 16-61), due to large variations in sediment porosity. While the corresponding amount of carbon added from ^{14}C-MeHg was small on a volumetric basis (0.01−0.25 nmol C*cm^{-3}), and only a fraction of the added radiolabel may be available for degradation, it is uncertain if the ^{14}C-MeHg amendment levels used in the current experiments resulted in a significant stimulation of heterotrophic activity. This possibility cannot be ruled, especially for some of the low organic sediments of the Carson River systems.

It is not surprising that a clear relationship between Hg_t and k_{deg} was not evident in all cases, as other environmental factors undoubtedly also impact observed MeHg degradation rates. The increase in k_{deg} with methanogenesis, sediment organic content (PC), and reduced S suggest that within-system regional differences in benthic microbiology and/or geochemistry are important in the Carson River (Figure 5a−d). It is difficult to assess the relative contribution and mechanism of each of these covarying parameters, as a control on microbial MeHg degradation, without conducting controlled experiments. Taken together, however, they depict a shift to higher k_{deg}'s going from organic-poor (river) to comparatively organic-rich and sulfidic (wetland and agricultural drain) sites with higher rates of anaerobic metabolism. These relationships were statistically independent ($P > 0.05$) of increases in k_{deg} due to increasing Hg_t. The increase in k_{deg} with increasing pore-water sulfide might suggest the non-*mer* RD pathway (via Me_2Hg formation), although the major end-product (>80%) was $^{14}CO_2$ and not $^{14}CH_4$ in most cases (Figure 3b). Thus, it would appear that it was OD, not RD, which dominated degradation. It is unknown if OD can also be carried out on $(MeHg)_2S$ or Me_2Hg, but such reactions could explain the spatial variation in the Carson River system.

The lack of positive relationships in the Everglades data set, similar to those noted above for the Carson River, may be due to the difficulty in detecting such relationships with such a comparatively low and narrow range of k_{deg}'s values. Alternatively, the relative influences of individual environmental controls on MeHg degradation may differ among systems. Specifically, the large difference in sediment organic content (as assessed by LOI) between the Everglades (33−91%, median = 80%, $n = 25$) and the Carson River (1−12%, median = 2%, $n = 13$) may partially account for the contrast in k_{deg} values among these ecosystems, for different reasons. The consistently low k_{deg} values in the organic-rich Everglades could reflect a high degree of MeHg-organic (or MeHg-reduced-S) complex formation, thereby decreasing MeHg availability to bacteria. While benthic anaerobic metabolism is presumably not carbon limited in the Everglades, organic substrate appears to limit microbial rates in the Carson River system, as evident from the increase in both methanogenesis and SR along a transect from organic-poor river sites to comparatively organic-rich wetland sites (data not shown). This increase in microbial rates parallels the increase in MeHg degradation for the Carson. Additional unpublished sequential extraction experiments conducted with ^{14}C-MeHg amended Carson River sediment indicates decreasing dissolved (water-extractable) and readily exchangeable (acid-extractable) MeHg pool size and an increase in MeHg-organic complex (base-extractable) pool size, with increasing organic content (data not shown). Assuming that the dissolved and readily exchangeable MeHg pools are more available for degradation than the MeHg-organic complex pool, then the increase in the overall activity of the MeHg degrading community more than compensates for the decrease in bioavailable MeHg pool size along the Carson River organic gradient.

The apparent increase in k_{deg} with decreasing pH in SCC sediments (Figure 5e) was not due to abiotic acid cleavage of the methyl group from MeHg, since the k_{deg}'s presented were kill corrected and represent microbial degradation only. Acidophilic bacteria were thus clearly involved in MeHg degradation at the AMD sites. To our knowledge, this is the first time that a significant MeHg degradation capacity has been suggested for this general bacterial group.

The lack of significant anaerobic $^{14}CH_4$ oxidation, in any of the three ecosystems, demonstrates that this process could not explain the $^{14}CO_2$ produced from anaerobic ^{14}C-MeHg degradation, as has been recently proposed (*25*). The fact that CH_4 oxidation was readily observed in Everglades samples incubated aerobically demonstrates our ability to detect this process. The corresponding increase in $\%^{14}CO_2$ from ^{14}C-MeHg, under aerobic conditions, indicates that some of this $^{14}CO_2$ could have been due to aerobic oxidation of $^{14}CH_4$ produced from either RD or OD.

A clear demonstration of OD in pure culture remains outstanding to date. The methylotrophic methanogen GS-16 (*22*), subsequently named *Methanolobus taylorii* sp. nov. (*52*), produced $^{14}CO_2$ from ^{14}C-MeHg ($\%^{14}CO_2$ = 29−46%) when grown on trimethylamine, although the total amount of ^{14}C-MeHg degraded was low (<3%). No anaerobic $^{14}CO_2$

production from ^{14}C-MeHg was detected for two sulfate reducing strains (*Desulfovibrio desulfuricans* LS and ND 132) and one methanogen (*Methanococcus maripaludis*), in a subsequent study (*25*). However, the high ^{14}C-MeHg amendment level used (500 ng/cm^3) was far in excess of typical environmental contamination levels and in excess of the levels used in the current study (2−52 ng/cm^3). Subsequently, *mer*-detoxification may have been induced, giving rise to detection of $^{14}CH_4$ only. It was not noted whether these bacteria were screened for the *mer*-operon. Further, previous work by Baldi et al. (*19*) demonstrated that *D. desulfuricans* degrades MeHg by the non-*mer* RD pathway (via reaction with H_2S), even under SO_4^{2-} limited conditions. While the above study (*25*) cites low SO_4^{2-} conditions for the culture media, it is also possible that low sulfide levels also existed in the sulfate reducing cultures and that the non-*mer* RD pathway was subsequently responsible for the detection of $^{14}CH_4$ as the sole gaseous end-product.

The current study demonstrates strong within-system and among-system differences in MeHg degradation rates and pathways. Systems or regions with low Hg contamination exhibited low k_{deg}'s and OD dominated the degradation pathway. A much wider range of k_{deg}'s was observed at higher contamination levels as other environmental factors become important, such as overall metabolic rates, sediment reduced S, organic matter concentrations, and substrate availability. The sequestering of MeHg by various solid phase fractions, as a key factor in mediating MeHg availability to bacteria, should be more fully investigated. Only under conditions of extreme contamination with bioavailable Hg was a strong RD pathway clearly dominant, and only then under aerobic conditions was *mer*-detoxification specifically implicated. While OD appears widespread in natural systems, its unambiguous demonstration in pure culture remains elusive, and the pathway specifics remain unknown. More work is needed to reconcile the results from the limited number of pure culture experiments with those from whole sediment field measurements.

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Mercury in the Aquatic Environment: A Review of Factors Affecting Methylation

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Mercury in the Aquatic Environment: A Review of Factors Affecting Methylation

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ABSTRACT: Mercury is one of the most hazardous contaminants that may be present in the aquatic environment, but its ecological and toxicological effects are strongly dependent on the chemical species present. Species distribution and transformation processes in natural aquatic systems are controlled by various physical, chemical, and biological factors. Depending on the prevailing environmental conditions, inorganic mercury species may be converted to many times more toxic methylated forms such as methylmercury, a potent neurotoxin that is readily accumulated by aquatic biota. Despite a considerable amount of literature on the subject, the behavior of mercury and many of the transformation and distribution mechanisms operating in the natural aquatic environment are still poorly understood. This review examines the current state of knowledge on the physicochemical behavior of mercury in the aquatic environment, and in particular the environmental factors influencing its transformation into highly toxic methylated forms.

KEY WORDS: methylmercury, speciation, environmental transformation, bioaccumulation.

I. INTRODUCTION

Mercury (Hg), a toxic element, is widely distributed in the environment and is naturally present in aquatic systems in very low concentrations. The extensive past industrial use of the metal and its compounds together with widespread agricultural application of organomercurials frequently has resulted in serious contamination of surface waters and sediments (e.g., Hosokawa;[147] Wilken and Wallschläger;[334] Heaven et al.[140]). Long-range atmospheric transport of Hg from fossil fuel combustion and other sources has led to increased concentrations in freshwater systems and biota even in remote areas that are free from direct anthropogenic influences (Rada et al.,[265]; Lindqvist[200]).

The chemistry of Hg is complex, making it difficult to predict the behavior of mercuric pollutants in the natural environment. Sediments act both as sinks and potential sources of Hg (Covelli et al.[81]) and once contaminated may pose a risk

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to aquatic life for many years (Kudo[187]). Depending on the prevailing physical, chemical and biological conditions, Hg compounds in aquatic systems can be interconverted and can be released from sediments to the water phase, taken up by aquatic biota, be lost to the atmosphere, or be transported with sediment particulate matter to new, previously uncontaminated locations.

The ecological and toxicological effects of Hg are strongly dependent on the chemical form (species) present (Clarkson[63]). Inorganic Hg forms may be transformed to organic, methylated species that are many times more toxic to aquatic organisms (WHO;[332,333] Boening[46]). The formation of methylmercury (MMHg), a potent neurotoxin, is of particular importance. Owing to its lipophilic and protein-binding properties, MMHg is readily accumulated by aquatic biota and may thus also pose a threat to humans and other fish-eating animals. Notorious incidents of mercury poisoning occurred in the 1950s and 1960s at Minamata Bay and on the Agano River in Japan (Takizawa[310]).

Many of the chemical and biological processes that control Hg methylation and bioaccumulation are still insufficiently understood, but if Hg pollution is to be effectively managed, we need to have a better understanding of the behavior of mercuric contaminants in the natural environment. This review discusses the behavior of Hg in aquatic systems and the factors that are thought to play a role in environmental MMHg formation. It also identifies areas in need of further research.

II. MERCURY IN THE AQUATIC ENVIRONMENT

A. Mercury Species in Aquatic Systems

Mercury occurs in three valence states (0, +1, and +2) and may be present in various physical and chemical forms in the natural aquatic environment. The nature and reactions of these species determine the solubility, mobility, and toxicity of Hg in aquatic ecosystems, as well as the potential for methylation. The main dissolved Hg species are elemental mercury (Hg^0), complexes of Hg(II) with various inorganic and organic ligands, and organic Hg forms, mainly methylmercury (MMHg) and dimethylmercury (DMHg). Between 10 to 30% of the dissolved Hg in the ocean is present as Hg^0 (Kim and Fitzgerald;[176] Mason and Fitzgerald[212]), and similar concentrations have been found for freshwaters (Vandal et al.;[313] Xiao et al.[341]). Hg^0 in surface waters occurs mainly from the reduction of Hg(II) compounds by aquatic microorganisms (Furukawa et al.;[111] Nelson et al.;[250] Mason et al.[216]) as well as from abiotic reduction by humic substances (Alberts et al.;[3] Miller;[237] Allard and Arsenie[4]), decomposition of organic Hg forms (Mason and Fitzgerald;[212] Mason and Sullivan[223]), and from anthropogenic discharges, a typical source being the chloralkali industry. Recent studies have shown that photoreduction of divalent Hg is another important mechanism of Hg^0 production in a wide

range of aquatic systems (Xiao et al.;[341,342] Schroeder et al.;[288] Amyot et al.;[5-9] Krabbenhoft et al.[181]), and that this process is mediated by humic material (Costa and Liss[79,80]). Hg^0 is relatively unreactive and is stable under mildly oxidizing or reducing conditions, but can be oxidized to Hg(II), particularly in the presence of chloride ions (Demagalhaes and Tubino;[89] Yamamoto[347]). Amyot et al.[5,6] have demonstrated the oxidation of Hg^0 in lake water and coastal seawater.

Most surface waters are supersaturated in Hg^0 relative to the atmosphere, especially in summer (Vandal et al.;[313] Fitzgerald et al.[104]). Due to its relatively high volatility, elemental Hg is readily lost from the aquatic environment at normal temperatures. The evasion of Hg^0 from water surfaces plays an important part in the global Hg cycle (Mason et al.;[214] Fitzgerald and Mason[105]). It has also been suggested that Hg^0 production is an important mechanism in aquatic systems for reducing the Hg(II) substrate used in the microbiological synthesis of MMHg (Fitzgerald et al.;[103,104] Mason et al.[215]).

Hg(I) is only stable as a dimer (Hg_2^{2+}) in aqueous solution and readily disproportionates into Hg^0 and Hg^{2+}, the most stable form in water. Until very recently, it was generally considered that the Hg^{2+} ion is the main species that is methylated in a bacterially mediated process (cf. Section III). Recent research, however, has shown that uncharged Hg complexes are much more likely to be taken up by bacteria (cf. Section III.B.1). Therefore, Hg speciation is a primary factor governing the methylation potential of a system.

The chemical form of Hg in aquatic systems is strongly influenced by redox (E_h) and pH conditions as well as by the concentrations of inorganic and organic complexing agents. Both the Hg^{2+} ion and the methylmercuric (CH_3Hg^+) cation have a high tendency to form complexes, in particular with soft ligands such as sulfur. Lindqvist[200] gives a list of potentially important inorganic and methylmercury complexes for fresh and sea water, and predominance diagrams showing the relative regions of stability of various soluble Hg species can be found in the literature (Hem;[90] Gavis and Fergusson;[118] Lockwood and Chen;[201] Beneš and Havlík;[24] Hudson et al.;[148] Stumm and Morgan[304]). In the absence of sulfide, the speciation of inorganic Hg in freshwaters is dominated by three uncharged complexes, $Hg(OH)_2$, HgOHCl, and $HgCl_2$ (cf. Figure 1). In the presence of increasing chloride ion concentrations, Hg^{2+} forms $HgCl^+$, $HgCl_2$, $HgCl_3^-$, and $HgCl_4^{2-}$ complexes, and in full-strength seawater (3.5% salinity), containing an average concentration of 0.56 *M* of Cl^-, it exists primarily as $HgCl_4^{2-}$ and $HgCl_3^-$ (Lockwood and Chen;[201] Hahne and Kroontje;[134] Stotzky and Babich[303]). Methylmercuric hydroxide, CH_3HgOH, is the most stable methylmercury species in the freshwater environment, whereas in seawater MMHg is present mainly as the chloride, CH_3HgCl (Craig;[82] Stumm and Morgan[304]). Equilibrium constants for MMHg and some of its complexes have been published, for example, by Stumm and Morgan.[304]

Predominance diagrams do not usually consider organic complexation due to a paucity of thermodynamic data on Hg and especially MMHg binding with polyfunctional natural ligands such as humic and fulvic acids. Hg speciation in

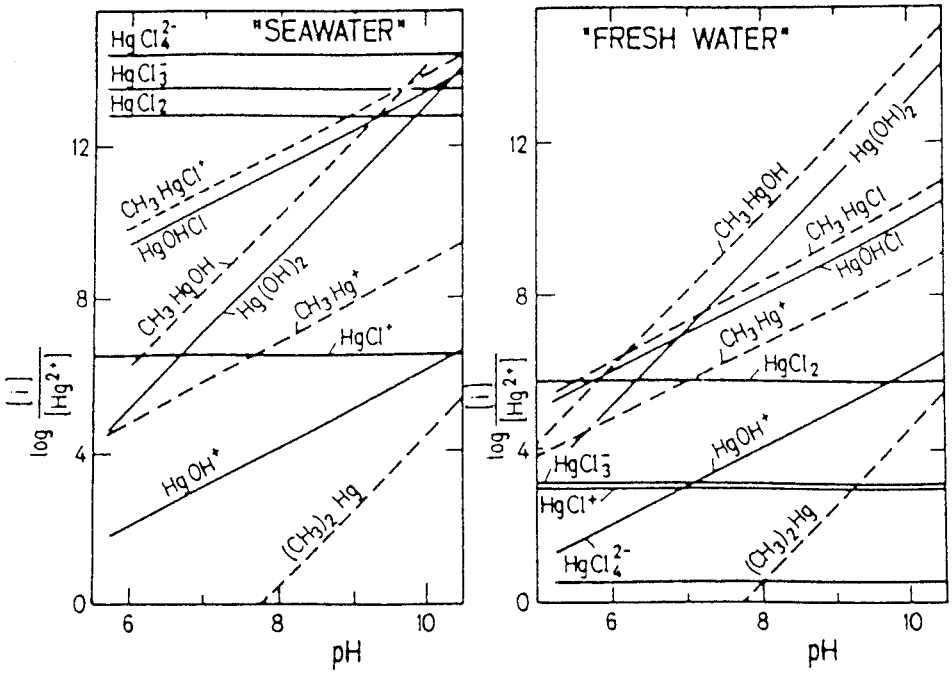

FIGURE 1. Concentration ratio diagrams illustrating the relative thermodynamic stability of mercury species in fresh water and sea water. Conditions: sea water [Cl^-] = 0.6 *M*, [$CH_{4(aq)}$] = 10^{-4} *M*: fresh water [Cl^-] = 2×10^{-4} *M* [$CH_{4(aq)}$] = 10^{-4} *M*. (Source: Stumm and Morgan.[304] Reprinted by permission of John Wiley & Sons, Inc.)

natural waters is largely dominated by organic rather than chloride or hydroxide complexes, however (Lövgren and Sjöberg;[202] Coquery et al.[71]). Particularly strong associations are formed with humic matter, where the Hg atom is most likely bound to thiol (-RSH) groups (Gavis and Fergusson;[118] Reimers et al.;[275] Beneš and Havlík;[24] Lindqvist[200]). Organic colloids comprise a substantial proportion of the traditionally defined dissolved Hg fraction (<0.45 μm) in freshwater, estuarine and marine environments (Mason et al.;[213] Watras et al.;[326] Leermakers et al.;[195] Stordal et al.;[302] Guentzel et al.[129]). In freshwaters more than 90% of Hg is complexed by organic matter (Mantoura et al.;[208] Meili[233]). Most MMHg (>70%) is probably also associated with dissolved organic carbon (DOC) in lake water (Lindqvist;[200] Hudson et al.[148]). Hudson et al.[148] have modeled the cycling of Hg in Wisconsin lakes and have calculated that 94 to 99+% of Hg(II) and 72 to 97% of MMHg in lakewaters is complexed by dissolved humic matter. In seawater, however, the proportion of Hg^{2+} bound to humics is decreased due to chloride ion competition (Lindberg and Harriss;[198] Mantoura et al.;[208] Leermakers et al.[195]). Hg complexation with humic matter also varies greatly depending on redox and pH conditions (cf. Section II.C), and the presence of sulfide ligands. Hudson et al.[148] calculated that in oxic waters sulfide may outcompete humic acid for Hg(II) and MMHg at a concentration of 10 μ*M*.

Although organic complexation is likely to dominate in oxic fresh water, under anoxic conditions the chemistry of Hg is mainly controlled by sulfide. In sediments Hg is mainly bound to sulfur as well as organic matter and inorganic particles (Morel et al.;[242] Lindberg and Harriss;[198] Dyrssen and Wedborg;[95] Fabbri et al.;[97] Mason and Lawrence[225]). Mercuric sulfide (HgS) is the main insoluble (L_{HgS} = 10^{-53} mol^2 l^{-2}) inorganic Hg compound in aquatic systems. Mercuric oxide (HgO), which is sparingly soluble (10^{-4} mol l^{-1}) is also commonly encountered in contaminated environments (Sakamoto et al.[283]). Hg compounds in the mud of Minamata Bay, for example, were mainly sulfides and oxides (Fujiki and Tajima[110]). HgS formation is generally favored at low pH and low sulfide concentrations. Under low E_h and high pH conditions, or if an excess of sulfide ions is present, HgS can be converted to soluble Hg-S complexes such as HgS_2^{2-}. Organic matter also enhances the solubility of HgS and may lead to a significant release of Hg into solution (Ravichandran et al.[270]), but other complexing agents do not appear to enhance HgS dissolution (Frimmel;[109] Ravichandran et al.[270]). Early work suggested that mercury in the HgS form is not available for bacterial methylation under anaerobic conditions, which was believed to be the reason for the generally lower MMHg concentrations encountered in sulfidic sediments, but recent research suggests that dissolved HgS^0 can in fact be methylated (Benoit et al.[26]), and that the mechanism of sulfide inhibition of Hg methylation is more complex (cf. Section III.B.6*)*.

At high sulfide concentrations, for example, in sulfidic marine waters and interstitial waters of bottom sediments, Hg forms soluble bi- and polysulfide complexes such as $HgSH^+$, $Hg(SH)_2$, $Hg(SH)S^-$, HgS_2^{2-}, $Hg(S_x)_2^{2-}$, or $Hg(S_x)OH^-$, depending on pH and E_h conditions and S^0/S^{2-} concentrations (Gardner;[117] Dyrssen and Wedborg;[95] Paquette and Helz;[257] Jay et al.[163]). Methylmercury also forms highly stable complexes with sulfur ligands (Zepp et al.[348]), but in contrast to Hg^{2+}, the chloride complex dominates at low concentrations (0.1 n*M*) of H_2S and thiols (Dyrssen and Wedborg[95]). The most important sulfide complex of methylmercury is CH_3HgS^-.

Organomercurials may be present in surface waters due to natural processes such as biomethylation of inorganic Hg or human activities. Many of these compounds have in the past been widely used, for example, as fungicides, slimicides, or industrial catalysts, but with most of these uses now banned in many parts of the world, transformation of inorganic Hg is the predominant source of methylated Hg compounds in aquatic systems (Craig[82]). Atmospheric deposition is the main source of inorganic Hg to oceanic waters (Mason et al.;[215] Mason and Fitzgerald[220]) and many lakes (Watras et al.[328]), but it is not a significant source of MMHg (Mason and Fitzgerald[210,211]). Precipitation and surface run-off can be important sources of MMHg to freshwaters besides internal methylation (Rudd[280]).

Only methyl- and dimethylmercury are thought to occur naturally in waters, where they can be formed from divalent inorganic Hg by various mechanisms (cf. Section III). MMHg is the most ubiquitous organomercury compound in freshwa-

ter and estuarine systems, while DMHg is not normally detected. MMHg is kinetically inert toward decomposition, which accounts for its remarkable stability in natural waters (Stumm and Morgan[304]). It is efficiently degraded by microbial action, however, and can also be decomposed photochemically (cf. Section III.A.4). Organomercury compounds other than MMHg decompose rapidly in the environment (Jensen and Jernelöv;[166] Craig[82]), with typical breakdown products being organic compounds such as ethane and inorganic Hg (Hg^0 and Hg^{2+}). Compounds such as dimethyl and diphenyl Hg are volatile, nonpolar, and very poorly soluble in water. Unlike MMHg, DMHg is readily lost from aquatic systems by evaporation (Talmi and Mesmer[311]) and is not considered to be available for accumulation by aquatic organisms (Morel et al.[243]).

In contrast to freshwater systems, DMHg is the dominant methylated species in deep ocean waters (Mason and Fitzgerald;[210,211] Cossa et al.;[75] Mason et al.;[218]), where it appears to be produced from labile inorganic Hg complexes predominantly, although not exclusively, in the low-oxygen region (Mason and Fitzgerald;[210,211,220] Cossa et al.;[77] Mason et al.[221]). Little or no methylated Hg species are found in oceanic surface waters (Mason and Fitzgerald[210,211]; Cossa et al.[75]; Mason et al.[218,221]; Mason and Sullivan[223]), with enhanced demethylation, evaporation, and/or photodegradation of DMHg, and particulate scavenging of MMHg from surface waters being suggested as potential loss mechanisms (Mason and Fitzgerald;[212] Mason et al.[218,221]).

B. Mercury Concentrations in the Aquatic Environment

1. Water

Mercury is naturally present in waters at very low levels. It should be noted that accepted background levels have fallen steadily in recent years following significant improvements in both sampling and analytical techniques (Horvat[146]), while previously reported high results are now believed to have resulted from sample contamination. Recently established Hg levels in aquatic systems in Antarctica have been suggested as global baseline values. Total Hg in surface waters of antarctic lakes and glacial streams ranged from 2.2 to 9.5 p*M*, dissolved Hg from 0.5 to 2.2 p*M* and MMHg from <0.4 to 2.1 p*M* (Vandal et al.;[314] Lyons et al.[206]). Uncontaminated freshwaters generally contain <5 ng l^{-1} (≅ 25 p*M*) total Hg (Bloom;[37] Craig[82]), although up to 10 or 20 ng l^{-1} can be found in humic lakes or rivers rich in particulate Hg (Meili[233]). Total Hg concentrations in the marine environment are much lower and were found to range between 0.5 and 4 p*M* in the Mediterranean and North Atlantic (Cossa et al.;[77] Mason et al.[221]). Mercury concentrations in contaminated waters can be in the μg l^{-1} range. Dissolved Hg concentrations in the River Nura in Central Kazakhstan were typically between 0.2 and 0.5 μg l^{-1}, for example, depending on season and suspended solids content

(Heaven et al.[140]). Considerably less data are available on organic Hg compounds in natural waters. Recommended water-quality criteria in the Netherlands give target values of 0.05 μg l^{-1} for total dissolved Hg and 0.005 μg l^{-1} for organic Hg (Stumm and Morgan[304] after Behra et al., 1993).

The proportion of MMHg to total Hg is usually higher in the water column than in sediments, and is higher in freshwater than in estuarine environments. In estuarine and marine waters, MMHg is typically less than 5% of total Hg content (Coquery et al.;[71] Mason and Sullivan[223]), whereas up to about 30% of total Hg can be found as MMHg in freshwater lakes and rivers (Kudo et al.;[186] Meili;[233] Leermakers et al.[196]). Elevated concentrations of both total Hg and MMHg are frequently found in anoxic waters. Bloom[37] reported MMHg concentrations in natural surface waters are typically in the range of 0.02 to 0.1 ng l^{-1} (0.1 to 0.5 p*M*), but found up to 4 ng l^{-1} (37% of total Hg) in the anoxic bottom waters of a stratified pristine lake. DMHg has not been detected in temperate freshwater lakes (e.g., Vandal et al.;[313] Cossa et al.[74]) but is the most common methylated species in the marine environment. Up to 280 f*M* MMHg and 670 f*M* DMHg were found below the thermocline in the equatorial Pacific (Mason and Fitzgerald[210]), and up to 0.29 p*M* DMHg were detected in the Western Mediterranean (Cossa et al.[75]); average DMHg concentrations in the North Atlantic were 0.08 p*M* (Mason et al.[221]).

2. Sediments

Sediments constitute the main reservoir of Hg in freshwater systems. Background levels of Hg in uncontaminated sediments are comparable to levels in unpolluted surface soils, with average concentrations in ocean sediments in the order of 0.02 to 0.1 μg g^{-1} (Lindqvist et al.[199]). Craig[82] reported concentration ranges of 0.2 to 0.4 μg g^{-1} total Hg for uncontaminated sediments, whereas sediments in urban, industrial, or mineralized areas can contain up to 100 μg g^{-1} total Hg and up to 100 ng g^{-1} MMHg. Methylmercury concentrations in sediments are typically only about 1 to 1.5% of total Hg content and tend to be lower (typically <0.5%) in estuarine and marine environments (Olson and Cooper;[251] Bartlett and Craig;[21] Craig and Moreton;[85] Craig;[82] Bubb et al.;[53] Gobeil and Cossa;[126] Gagnon et al.;[114] Benoit et al.[25]). Total Hg concentrations in sediment porewaters are usually much higher than in the overlying watercolumn, however (e.g., Gobeil and Cossa;[126] Cossa and Gobeil[78]), and the proportion of MMHg can reach between 30 and 85% (Gagnon et al.;[114] Covelli et al.;[81] Hines et al.[141]).

Contaminated sediments may exhibit extremely high total Hg concentrations. Mud from Minamata Bay contained up to 908 μg g^{-1} (d.w.) Hg (Fujiki and Tajima[110]). MMHg was mostly less than 0.005 μg g^{-1} (d.w.) with a maximum of 0.03 μg g^{-1} (Hosokawa[147]), however, possibly due to the high sulfide content of the sediment, or the inhibition of microbial activity at high Hg levels (Chen et al.[59]). The River Nura has average sediment concentrations between 150 and 240 μg g^{-1}

(d.w.) total Hg in the most polluted section (Heaven et al.[140]), and River Elbe sediments were found to contain 12 μg g^{-1} (d.w.) total Hg and 35 ng g^{-1} (d.w.) MMHg (Hintelmann and Wilken[142]). DMHg has rarely been detected to date, but Quevauviller et al.[263] reported 211 to 233 ng g^{-1} DMHg (d.w.) in subsurface mangrove sediments.

Sediment quality criteria for Hg have been set in some countries, but due to the uncertainties regarding the bioavailability of Hg, it has been suggested that these should be applied with caution and in concert with other site-specific data (Chapman et al.[58]). It is also important to note that there has been considerable controversy in recent years regarding the 'true' methylmercury content of environmental samples, in particular sediments, after it was found that MMHg may be artificially formed during the sample preparation process. Although methods have been devised since to overcome this problem (e.g., Hintelmann et al.[144]), MMHg values cited in the literature should be interpreted with caution, and it is now generally accepted that values in excess of ca. 1% of total Hg content are probably unrealistic.

3. Biota

Freshwater biota can accumulate detectable quantities of Hg even from natural sources, and most fish nowadays have analyzable levels in their tissues. Maximum background levels for Hg in uncontaminated freshwater fish are about 0.2 μg g^{-1}, although considerably more can be found in large predators and in fish from waters near geological sources. Craig[82] reported concentration ranges of 0.01 to 1.5 μg Hg g^{-1} and 0.14 to 0.75 μg Hg g^{-1} for unpolluted marine fish and shellfish, respectively, and 0.2 to 1 μg g^{-1} for uncontaminated freshwater fish. For comparison, fish and shellfish from the highly polluted Minamata Bay contained up to 15 μg Hg g^{-1} (w.w.) and 178 μg Hg g^{-1} (d.w.), respectively (Fujiki and Tajima[110]). Human exposure to mercury occurs mainly from the ingestion of contaminated fish and seafood (Myers et al.[245]), and quality criteria have been set by various regulatory bodies. EEC quality objectives state a limit value of 0.3 μg Hg g^{-1} (w.w.) in fish (Craig[82]), whereas WHO[332] and the U.S. Food and Drug Administration (FDA[101]) have suggested maximum permissible concentrations of 0.5 and 1 μg Hg g^{-1}, respectively.

C. Mercury Transport and Distribution in Surface Waters

Mercury has a high tendency to be sorbed on surfaces. Therefore, in natural waters it is mostly bound to sediments, and a large proportion of Hg in the water phase is attached to suspended particles (Andren and Harriss;[11] Craig;[82] Mason et al.;[213] Cossa et al.[76]). MMHg is also strongly sorbed (Craig;[82] Baeyens et al.;[14] Rytuba[282]), although usually to a lesser extent than inorganic Hg (e.g., Suchanek

et al.[305]) Thus, suspended matter plays an important role in the transport of Hg and MMHg in aquatic systems (Kudo et al.;[183,185] Baeyens and Leermakers;[13] Coquery et al.;[71] Mason and Sullivan;[222,223] Maurice-Bourgoin et al.;[230] Lawson et al.[191]). Particulate transport is more important in particle-rich fresh and coastal waters than in the open sea (Coquery and Cossa;[69] Coquery et al.;[71] Fitzgerald and Mason[106]). Particulate Hg consists of Hg bound to inorganic particles and particulate organic matter, as well as biogenic particles such as bacteria, algae, and phytoplankton. Inorganic Hg tends to bind more strongly to mineral particles and detrital organic matter, whereas MMHg is more strongly associated with biogenic particles (Hurley et al.;[150] Meili[233]). In freshwater lakes, the distribution of Hg and MMHg is largely controlled by particulate scavenging in surface waters and particulate dissolution at the redox boundary (Hurley et al.[149]). Settling of particulate matter is considered a major Hg delivery mechanism to the sediment/water interface, the main site for methylation, whereas (redox-driven) upward diffusion from sediment porewater is probably less important (Hurley et al.;[149,151] Watras et al.[323]). Similarly, vertical transport of particulate matter in the ocean is the main supplier of Hg to low-oxygen waters and thus is a major factor controlling Hg methylation (Mason and Fitzgerald;[212,220] Mason and Sullivan[223]).

Oxyhydoxides and organic matter are the main vectors controlling the mobility and transport of Hg in aquatic systems. Due to the high stability of Hg-humic complexes, a high percentage of Hg in natural waters is present in organically complexed form (cf. Section II.A), and Hg concentrations in lake water or in the interstitial waters of sediments are often significantly correlated with dissolved organic matter (Lindberg and Harriss;[198] Meili et al.;[232] Watras et al.[325,326]). Hg concentrations in sediments or suspended particles are also often closely related to organic content (Lindberg and Harriss;[198] Coquery et al.;[70] Benoit et al.;[25] Mason and Lawrence;[225] Harland et al.;[139] Lawson et al.[191]). Hg appears to be more strongly sorbed by humic substances than MMHg (Hudson et al.;[148] Sjöblom et al.[291]), which may be the reason why it is less easily mobilized from sediments than MMHg (Bloom et al.;[42] Gill et al.[119]). In watersheds, MMHg is also considered more mobile than inorganic Hg (Bishop and Lee;[33] Mason and Sullivan;[222] Hurley et al.;[152] Lawson et al.[191]). The strong association of Hg with humic matter has important implications for the watershed transport of Hg (Bishop and Lee[33]). Transport of terrestrial organic matter with surface runoff can be a major source of Hg and MMHg to lakes and rivers (Mierle and Ingram;[236] Verta et al.;[317] Hurley et al.;[152] Lee et al.[194]) and may even constitute the main source of MMHg in drainage lakes receiving high amounts of runoff (Lee and Hultberg[193]). In seepage lakes, on the other hand, the relative importance of atmospheric MMHg deposition and in-lake MMHg production is increased (Verta et al.[317]). Watershed characteristics such as catchment type, land use, and soil organic content play an important role in Hg and MMHg fate and transport (Bringmark[52]). Wetlands and peatlands are sites of active MMHg production and have been recognized as important sources of MMHg for freshwaters (St. Louis et al.;[301] Hurley et al.;[152] Branfireun

et al.;[49-51] Waldron et al.[330]). Soil erosion and increased mobilization of Hg by runoff is an important source of Hg to tropical aquatic ecosystems, especially during the rainy season (Roulet et al.;[278] Maurice-Bourgoin et al.[230]), and in arid regions storm-driven runoff following forest fires may lead to elevated sediment Hg levels while simultaneously providing a carbon source for microbial methylation processes (Caldwell et al.[54]).

Iron and manganese oxides play a particularly important role in the cycling and transport of Hg in aquatic systems. This is due to their large surface areas and high capacity to adsorb and co-precipitate Hg, and to rerelease it after their dissolution (Fagerström and Jernelöv[99]). Many workers have found the distribution and concentration of dissolved and particulate Hg species to be influenced, among other factors, by the redox cycling of Fe, and less frequently Mn (e.g., Mason et al.;[213] Hurley et al.;[151] Bonzongo et al.;[47] Gagnon et al.;[115] Regnell et al.;[274] Quemerais et al.;[262] Gobeil et al.;[127] Bloom et al.[41]). Bloom et al.[41] reported, for example, that the mobility of MMHg in estuarine surface sediments was linked to the Fe redox cycle, while the mobility of Hg(II) was controlled by the formation of soluble polysulfide or organic complexes. The formation and dissolution of Fe and Mn oxides is strongly controlled by the redox state and oxygen content of waters and sediments. In anoxic conditions, oxyhydroxides dissolve and release any associated Hg (Gobeil and Cossa;[126] Gagnon et al.;[115] Cossa and Gobeil[78]), which is thought to be one reason for the frequently observed Hg and MMHg enrichment in (seasonally) anoxic waters (Hurley et al.;[149] Cossa et al.;[74] Watras et al.[327]). Seasonal and diurnal trends in MMHg concentrations in sediment porewaters (Covelli et al.;[81] Gill et al.[119]) may also be linked with redox effects. Meili[233] noted that oxyhydroxides form labile complexes with organic matter and clay minerals, which may further increase their metal scavenging capacity. The formation and dissolution of oxyhydroxides and organic complexes may influence methylation by controlling the availability of inorganic Hg.

Sediments can act both as sinks and as secondary sources of Hg. Covelli et al.[81] estimated that in the Gulf of Trieste up to 25% of Hg may be released annually from sediments and recycled at the sediment/water interface, and Stein et al.[300] have reviewed the chemical and physical processes governing the distribution of Hg between environmental media. Partition coefficients describe the equilibrium partitioning of Hg between the solid and dissolved phases. Sediment-water partition coefficients (K_d = mg sorbed Hg per kg sediment/mg dissolved Hg per liter) vary widely both within and between systems but are broadly in the order of 10^4 to 10^6 for Hg and 10^3 to 10^5 for MMHg (Hurley et al.;[150] Watras et al.;[326] Stordal et al.;[302] Coquery et al.;[71] Lyon et al.;[205] Mason and Sullivan;[222] Bloom et al.;[41] Lawson et al.[191]). Sorption/desorption phenomena and precipitation reactions are also likely to affect Hg bioavailability (King et al.[177]) and need to be taken into account when estimating rates of MMHg production in the natural environment (Bisogni[35]).

D. Influence of Environmental Factors on Hg Partitioning

The cycling and distribution of Hg between the sediment and water phases may be physically, chemically, or biologically mediated, and hence may be affected by parameters such as pH, temperature, redox changes, availability of nutrients and complexing agents. This should be considered when evaluating the effect of environmental factors on Hg methylation. The degree of binding of MMHg by sediments, for instance, depends on sediment properties as well as pH and dissolved oxygen concentrations (Reimers et al.;[275] Kudo et al.;[182] Gambrell et al.[116]). Although the proportion of Hg in dissolved form may sometimes decrease under anoxic conditions due to the formation of reduced species such as HgS (Baeyens and Leermakers[13]), oxic conditions generally favor sediment uptake of Hg and MMHg, whereas anoxic conditions favor Hg release (Wang et al.;[320] Regnell and Tunlid;[272] Regnell et al.[273]). The observed effects are most likely linked to the precipitation and dissolution of Fe and Mn oxides and oxyhydroxides. The solubility of Hg and MMHg under anoxic conditions may also be increased due to the formation of soluble sulfide complexes (Regnell et al.;[273] Benoit et al.[25]). Apart from redox effects, seasonal variations in the partitioning of Hg and MMHg may also be related to changes in biotic particulate matter (Hurley et al.;[149] Watras et al.;[323] Coquery et al.[70]).

Methylmercury release from sediments also increases with increasing temperature and nutrient addition (Wright and Hamilton[339]) and decreasing pH. Miller and Akagi[238] reported that a change in pH from 7.0 to 5.0 doubles the release of MMHg from sediments, and Hintelmann et al.[143] found that the binding of MMHg to humic and fulvic acids decreases with decreasing pH. The observed pH-dependent changes in the partitioning of MMHg between the sediment and water phases may be partly responsible for the often noted increased Hg concentrations in fish from low-pH lakes (e.g., Lindqvist et al.[199]).

The presence of organic or inorganic complexing agents also affects the partitioning of Hg. The formation of soluble humic complexes may significantly increase the solubility and mobility of Hg in aquatic systems (Miller;[237] Reimers et al.;[275] Miskimmin;[239] Melamed et al.;[234,235] Ravichandran et al.[270,271]), especially above pH 5, while $HgCl_2$ is effectively sorbed at lower pH values (Stein et al.[300] after Bodek et al. 1988). The situation in sediments may be comparable to that in soils, where adsorption of Hg to humus predominates in acidic conditions, and Hg is preferentially sorbed to mineral particles (Fe oxides and clay minerals) in the neutral to alkaline pH range, due to formation of the more particle reactive $HgOH^+$ species (Bringmark[52]). High chloride concentrations appear to reduce the amount of Hg associated with suspended particulate matter and organic colloids, most likely due to competition of Cl^- for binding sites. Increased mobilization of Hg with increasing salinity was observed both in model experiments (Reimers et al.[275]) and in estuarine and marine environments (Cossa and Noel;[72] Cossa and Martin;[73] Leermakers et al.;[195] Guentzel et al.[129]).

E. Accumulation in Aquatic Biota

Mercury, and in particular methylmercury, is effectively taken up by aquatic biota, and bioconcentration factors in the order of 10^4 to 10^7 have been reported (WHO;[332] Stein et al.[300]). Accumulation in the aquatic food chain therefore can be high even at the generally very low environmental MMHg concentrations. While MMHg typically constitutes between 10 and 30% of total Hg in the water phase, more than 85 to 90% of Hg in fish is present in the MMHg form (Grieb et al.;[128] Bloom;[39] Southworth et al.[292]). Other organomercurials are also sometimes detected. Fish caught downstream of a source of phenylmercury effluent contained both methyl and ethylmercury (Ashby and Craig[12] after Frieberg 1971), and methylmercury methanethiol (CH_3HgSCH_3) has been found in shellfish (Ashby and Craig[12] after Kitamura 1963 and Lofroth 1969). The Hg content of aquatic organisms and the percentage present as MMHg usually increases with increasing size and increasing level in the food chain (Boudou and Ribeyre;[48] Meili;[233] Watras et al.;[329] Mason et al.[226]). Hg concentrations in fish often remain high for many years after Hg inputs have ceased or contaminated sediments have been dredged (Rada and Findley;[264] Kudo;[187] Francesconi et al.;[108] Southworth et al.[293]).

The precise factors controlling the accumulation of Hg in aquatic biota are poorly understood. The high tendency of MMHg for bioaccumulation is usually explained by its high stability and lipid solubility, and by its high tendency to bind to -SH groups associated with proteins. However, this alone cannot account for the predominance of MMHg in fish muscle tissue (Mason et al.;[217] Boudou and Ribeyre[48]). MMHg is taken up by fish mainly through their diet, while direct uptake from the water is of minor importance (Bodaly et al.;[45] Boudou and Ribeyre;[48] Meili[233]). Hg concentrations in fish thus are primarily determined by the accumulation of MMHg at the base of the food chain, that is, in phyto- and bacterioplankton (Mason et al.[217,219]; Watras et al.[329]). The predominance of MMHg in fish appears to be the result of its greater trophic transfer efficiency compared with inorganic Hg (Watras and Bloom;[322] Mason et al.[219]). Uptake into biota is influenced by the physicochemical form in which Hg exists in the water. Uncharged lipophilic chloride complexes ($HgCl_2$ and CH_3HgCl) appear to be most bioavailable (Mason et al.[217,219]; Laporte et al.[190]), whereas DMHg and Hg^0 are not bioaccumulated (Morel et al.[243]). A number of other factors such as temperature, DOC, alkalinity, and in particular pH may also influence Hg bioaccumulation as well as methylation (Watras and Bloom;[322] Boudou and Ribeyre;[48] Meili;[233] Watras et al.[329]). The accumulation of Hg in the aquatic food chain has been reviewed recently (Bodaly et al.;[45] Boudou and Ribeyre[48]).

III. METHYLATION OF MERCURY IN THE AQUATIC ENVIRONMENT

A. General Aspects

The methylation of inorganic Hg in waters and sediments constitutes a key step in the cycling of Hg in aquatic systems (Fitzgerald and Mason[106]) and takes place

in both remote and impacted environments (Cossa et al.[74]). It is important to note that since both methylation and demethylation processes occur, environmental MMHg concentrations reflect *net* methylation rather than actual rates of MMHg synthesis. It appears that the combined effect of MMHg production and degradation leads to a state of equilibrium with a near constant level of MMHg in sediments (Beijer and Jernelöv;[23] Pak and Bartha[256]) that rarely exceeds 1 to 1.5% of total Hg concentration (cf. Section II.B.2), whereas the proportion of MMHg in fish and other aquatic biota may be much higher (cf. Section II.E). On the basis of mass balance studies, estimated rates for MMHg production in temperate freshwater lakes currently range from 0.5 to 5 g MMHg per km^2 per year (Watras et al.[328]).

Methylation occurs predominantly in sediments and to a lesser extent in the water column (Olson and Cooper;[251] Robinson and Tuovinen;[277] Callister and Winfrey;[55] Korthals and Winfrey;[180] Xun et al.[343]), but it should be borne in mind that water column methylation is potentially more important, because the volume of water is typically much larger than the volume of surficial sediments. Maximum methylation rates usually occur at the redox boundary, which may vary seasonally and frequently coincides with the sediment-water interface, and decrease with increasing sediment depth (Rudd et al.;[279] Korthals and Winfrey;[180] Matilainen[227]). In tropical systems, the root zones of floating aquatic macrophytes are further important sites of methylation (Mauro et al.;[231] Guimarães et al.[130]).

The effects of environmental factors on MMHg formation and decomposition were studied in the past mainly by relating MMHg concentrations in sediments, water, and aquatic biota to changes in environmental conditions. In recent years the use of radiotracers and stable isotopes has made it possible to distinguish between the two opposing processes of MMHg formation and decomposition, but it must be borne in mind that rates measured after Hg additions may differ considerably from *in situ* rates. Gilmour and Henry[122] give an overview of the techniques that are typically employed for measuring MMHg concentrations and methylation/demethylation rates in aquatic systems, and their limitations.

The methylation of Hg requires the presence of a suitable methyl donor molecule. In the natural aquatic environment, a large variety of potential donor molecules are present, most of which are biologically synthesized. Whereas it had first been assumed that Hg methylation requires the presence of bacteria, both microbially mediated and abiotic methylation mechanisms are now known, although the latter is thought to be of only minor importance.

1. Biomethylation

Biological methylation of inorganic Hg was first observed in sediments from aquaria and lakes and in coastal waters in Sweden (Jernelöv;[167] Jensen and Jernelöv[165]) and has been studied since by many other workers. Hg methylation by organisms may be enzymatic or nonenzymatic. Enzymatic methylation requires the presence of actively metabolizing organisms, while nonenzymatic methylation

requires only the methylated products of active metabolism. Detailed mechanisms for Hg methylation were first proposed by Wood et al.[336] and Landner.[188] Wood et al.[336] suspected that methylcobalamin, a vitamin B_{12} derivative (methylcorrinoid) produced by many organisms, is involved in microbial Hg methylation and suggested that the process involves nonenzymatic transfer of the methyl group of methylcobalamin to the mercuric ion. DeSimone et al.[91] have shown that methyl transfer to Hg^{2+} is a carbanion (CH_3^-) process. Although there are many potential methyl donor molecules in the aquatic environment, methylcobalamin is thought to be the only natural methylating agent capable of transferring methyl groups as carbanions (Ridley et al.[276]). This together with its prevalence in anaerobic ecosystems and living organisms makes it the most likely methyl source for environmental Hg methylation.

Metabolically produced methylcobalamin can spontaneously methylate Hg^{2+} in aqueous solution (Bertilsson and Neujahr;[31] Imura et al.[154]), but little is known about the biochemistry of MMHg formation in the natural environment. Organisms capable of Hg methylation have been found among anaerobes, facultative anaerobes, and aerobes, but the potential for microbial methylation is generally thought to be higher under anaerobic conditions, and sulfate-reducing bacteria have been identified as the principal methylators of inorganic Hg in anaerobic sediments (Compeau and Bartha[66]). Methylation of Hg is generally thought to occur inside bacteria by transfer of a methyl group from a methylcorrinoid donor molecule, although Parkman et al.[258] suggested that methylation is an extracellular process that is enhanced by the activity of bacterial exoenzymes that also catalyze the microbial decompositon of organic matter. Choi and Bartha[60] demonstrated that methylcobalamin is the methyl group donor when divalent Hg is methylated by the LS strain of *Desulfovibrio desulfuricans*. Within the cell, Hg methylation appears to be an enzyme-catalyzed process rather than a spontaneous chemical reaction, with the rate of methylation at pH 7 being 600-fold higher than transmethylation by free methylcobalamin (Choi et al.[62]). The process is oxygen sensitive, with optimal methylation conditions at 35°C and pH 6.5. The enzyme responsible for transferring methyl groups from methylcorrinoid protein to Hg^{2+} has yet to be identified. As biological Hg methylation takes place within microorganisms, cellular uptake of Hg plays a key role in the methylation process. This is discussed in detail in Section III.B.1.

2. Abiotic Methylation

Purely chemical methylation of Hg is also possible if suitable methyl donors are present. DeSimone[90] showed that water-soluble methylsilicon compounds react with Hg^{2+} to form MMHg. Organosiloxanes and other silicone-related substances have also been considered as possible methylating agents (Nagase et al.[248,249]; Watanabe et al.[321]). Akagi et al.[1] demonstrated the photochemically induced alky-

lation of mercuric chloride with methanol, ethanol, acetic acid, and propionic acid. Sewage effluent and industrial wastewater have also been reported as methyl sources in the photochemical methylation of Hg. Hamasaki et al.[136] have summarized some of the available data on photochemical methylation.

Wood[337] suggested Hg methylation can also occur as a result of transmethylation reactions between Hg and lead and tin alkyls used as gasoline additives. Jewett et al.[171] demonstrated that both trimethyl lead chloride and trimethyltin chloride are able to transfer methyl groups to Hg^{2+}. Trimethyl lead was found to be a particularly effective methylator for Hg, and high MMHg concentrations in sediments of the St. Clair River were attributed to transmethylation reactions caused by alkyllead emissions (Beijer and Jernelöv[23] after Jernelöv et al., 1972). More recent investigations of Hg methylation by organolead, organotin, and organoarsenic compounds have been carried out, for example, by Ebinghaus et al.[96]

Humic matter may be another significant environmental methylating agent (Weber[331]). Abiological formation of MMHg by humic compounds has been demonstrated, for example, by Nagase et al.[246,247] The capacity for MMHg formation generally increased with increasing temperature and Hg concentration, but was low at naturally occurring temperatures and pH values. Falter and Wilken[100] have shown that small amounts of MMHg can be formed abiotically at environmentally relevant temperatures and pH values, however. More than 400 pg MMHg, corresponding to ca. 0.05% of the added $^{200}Hg^{2+}$ spike, were produced in the acetone extract of a river sediment within 2 h at 40ºC between pH 3 and 7. At 35ºC, up to 160 pg could still be formed. In the river sediment itself, however, methylation was only detected at 40ºC, with between 50 and 100 pg MMHg (0.005 to 0.01% of added $^{200}Hg^{2+}$) being formed.

Thus, mercury methylation may be biotic or abiotic, or may involve a mixture of biotic and abiotic processes, such as the bacterial methylation of tin (IV) species followed by abiotic methyl transfer to Hg. The relative importance of abiotic vs. biotic methylation mechanisms in the natural aquatic environment has not yet been established, but it is generally believed that Hg methylation is predominantly a microbially mediated process, and Berman and Bartha[30] demonstrated that in anoxic sediments MMHg levels resulting from chemical methylation were approximately one order of magnitude lower than those formed by biochemical Hg methylation. Ebinghaus et al.[96] reported that organo Pb, Sn, and As compounds are more effective methylators than biogenic methyl donors such as methylcobalamin, but this is probably not material in the natural environment, because *in vivo* Hg methylation is enzymatically catalyzed and is much faster than transmethylation by free methylcobalamin (Choi et al.[62]).

3. Methylation Products

MMHg may be formed from ionic Hg and many divalent Hg compounds (Yamada and Tonomura[344]), as well as from organic Hg compounds and metallic

Hg (Jernelöv;[168] Jacobs and Keeney[162]), possibly via formation of Hg^{2+}. DMHg can be synthesized from both methyl- and ionic Hg (Craig and Moreton;[85,86] Baldi et al.;[18] Filipelli and Baldi[102]). There is still considerable uncertainty, however, regarding the pathways of MMHg and DMHg formation. Filipelli and Baldi[102] have demonstrated that the initial product of the reaction between methylcobalamin and Hg^{2+} is MMHg, which is then further transformed into DMHg. The reaction is pH and temperature dependent and MMHg and DMHg formation rates are of similar magnitude at 20°C. Low pH values appear to favor the production of MMHg, while DMHg formation is favored under neutral and basic (pH>7) conditions (Jensen and Jernelöv;[165] Beijer and Jernelöv;[23] Fagerström and Jernelöv[99]). Below pH 5, DMHg is thermodynamically unstable and decomposes to form MMHg (Fagerström and Jernelöv;[99] Fitzgerald and Mason[106]), which may be one reason why DMHg has not been detected in freshwaters, where the pH is typically lower compared with estuarine and marine systems. Mason et al.[218] suggested that DMHg forms directly from Hg(II), but is rapidly decomposed to MMHg in freshwaters and hence does not accumulate to detectable levels. In deep ocean waters, on the other hand, the stability of DMHg might be enhanced by low-light, low-temperature, and high pH conditions (Fitzgerald and Mason;[106] Mason et al.[221]). Pongratz and Heumann[259,260] have also suggested that DMHg may be the primary biogenic methylation product in the ocean, and it appears that MMHg in the deep ocean is formed by decomposition of DMHg (Mason and Fitzgerald;[210,212] Fitzgerald and Mason;[105,106] Mason et al.;[221] Mason and Sullivan[223]). DMHg decomposition is thought to be primarily abiotic (Fitzgerald and Mason[106]), whereas MMHg decomposition is predominantly biologically mediated (see below). Because DMHg formation in the ocean also occurs in oxygenated environments (Mason et al.;[218,221] Cossa et al.[75]), it has been suggested that it may be formed by a different mechanism than in freshwaters (Mason et al.;[220,221] Fitzgerald and Mason[106]).

4. Demethylation

The biological and abiological decomposition of methylated Hg species is an important process regulating the organic Hg content of sediments and waters. MMHg degradation is thought to be predominantly microbially mediated (Robinson and Tuovinen[277]). Numerous bacterial strains capable of demethylating MMHg are known (Spangler et al.;[294,295] Billen et al.;[32] Robinson and Tuovinen;[277] Oremland et al.;[254] Matilainen and Verta[228]), including both aerobic and anaerobic species, but demethylation appears to be predominantly accomplished by aerobic organisms (cf. Section III.B.5). Bacterial demethylation has been demonstrated both in sediments (e.g., Billen et al.;[32] Oremland et al.[254]) and in the water column of freshwater lakes (Xun et al.;[343] Winfrey and Rudd;[335] Matilainen[227]). Degradation of methyl and phenyl mercury by fresh water algae has also been described (Beneš and Havlík[24] after Havlík *et al.,* 1979a,b).

Mercury demethylation by bacteria appears to be a predominantly reductive process (Furukawa et al.;[111] Spangler et al.;[294,295] Nelson et al.[250]). The commonly accepted mechanism of microbial MMHg decomposition involves cleavage of the carbon-mercury bond by the organomercurial lyase enzyme, yielding methane and Hg^{2+}, followed by the reduction of Hg^{2+} to Hg^0 by the mercuric reductase enzyme (Robinson and Tuovinen;[277] Summers;[309] Walsh et al.[319]). Synthesis of these enzymes is encoded by the *merB* and *merA* genes in bacteria possessing broad-spectrum Hg resistance. More recent work indicates that *mer* detoxification is not the only microbial degradation pathway, however. Oremland et al.[254] found that while methane was the sole product of MMHg degradation in aerobic estuarine sediments, aerobic demethylation in freshwater sediments and anaerobic demethylation in both freshwater and estuarine sediments produced primarily carbon dioxide, indicating the presence of an oxidative pathway. Oremland et al.[255] and Hines et al.[141] have since shown that oxidative demethylation is significant in both contaminated and uncontaminated river sediments and is most pronounced at sediment surfaces. Inhibitor studies suggest that both sulfate reducers and methanogens, and possibly other anaerobes, are involved in oxidative demethylation (Oremland et al.;[254,255] Marvin-Dipasquale and Oremland[209]). Marvin-Dipasquale and Oremland[209] recently have proposed specific mechanisms for the oxidative demethylation of Hg by sulfate-reducing bacteria and methanogens and have suggested that methanogens dominate MMHg degradation at *in situ* concentrations. Either process produces Hg^{2+}, but it is unclear whether the Hg^{2+} produced in oxidative demethylation is subsequently reduced to Hg^0 as has been demonstrated for the *mer*-mediated pathway (Robinson and Tuovinen[277]). Alternatively, it may be remethylated, bound by sulfur species, or volatilized as DMHg (Baldi et al.[16]). At present, it is also not known which of the abovementioned degradation pathways (i.e., organomercurial-lyase, or oxidative demethylation by sulfate reducers and/or methanogens) dominate under specific environmental conditions. The relative importance of these pathways has major implications for the fate of Hg in natural systems, however, and thus may ultimately determine its residence time in sediments.

Photolytic decomposition appears to be the only significant *abiotic* decomposition mechanism. DMHg in the atmosphere is photolytically decomposed to Hg^0 and hydrocarbons (Craig[82]). Phenylmercury and sulfur-bonded MMHg species (e.g., CH_3HgS^-) can undergo quite rapid photolytic decay, but photodegradation was thought to be insignificant for methylmercuric ion and methylmercuric hydroxide due to their low sunlight absorption rates (Baughman et al.[22]). Suda et al.[307] have shown that methyl- and ethylmercury are photodegraded by singlet oxgen in seawater, however, and recent work by Sellers et al.[289] demonstrates that MMHg is photolytically decomposed in surface waters, and that this process is potentially an important step in the aquatic Hg cycle. Mass-balance calculations show that microbial demethylation may not be the dominant removal mechanism for MMHg in epilimnetic freshwaters. Model simulations by Branfireun et al.[50] have since

confirmed the findings of Sellers et al.[289] The overall impact of photodegradation on the aquatic Hg cycle is still unclear, however, because the end products of MMHg photodegradation in natural waters have not yet been identified. Furthermore, although photolytic decay contributes to Hg demethylation in the water phase, it is unlikely to be significant in deeper sediments, where bacterial demethylation is more important (Xun et al.;[343] Ramlal et al.[268]).

The ability of microorganisms to degrade Hg can be employed in the treatment of sewage (Hansen et al.[138]) and Hg-contaminated liquid wastes (Baldi et al.[16,17]). Hansen et al.[138] reported that >98% of Hg present at a concentration of 70 mg l^{-1} can be removed from municipal sewage water by bacterial treatment. However, it should be noted that sewage treatment plants themselves can be sources of MMHg (Gilmour and Bloom;[124] Carpi et al.[57]). In the bioremediation field, efforts have been made to devise methods for reducing the amount of MMHg in contaminated aquatic ecosystems by stimulating the bacterial conversion of MMHg and Hg^{2+} to less harmful elemental Hg (Saouter et al.[284]). Very recently, transgenic plants have been specifically engineered to express bacterial *mer* genes (Rugh et al.;[281] Bizily et al.[36]). Such plants show a high resistance to inorganic Hg and organomercurials and may in the future be used to degrade MMHg at polluted sites and to accumulate Hg for later safe disposal.

B. Factors Affecting Methylation

The synthesis of MMHg in aquatic systems is influenced by a wide variety of environmental factors. The efficiency of microbial Hg methylation generally depends on factors such as microbial activity and the concentration of bioavailable Hg (rather than the total Hg pool), which in turn are influenced by parameters such as temperature, pH, redox potential, and the presence of inorganic and organic complexing agents. Total Hg concentrations generally are not useful in predicting MMHg concentrations (Kelly et al.[174]). While there is no simple relationship, it appears that enhanced rates of MMHg production are linked in particular with low pH, low salinity, and the presence of decomposable organic matter in reducing environments. The main factors known to affect methylation are discussed below; it should be borne in mind, however, that they cannot be viewed independently from each other, as they often interact, forming a complex system of synergistic and antagonistic effects.

1. Microbiology

Microorganisms play a pivotal role in aquatic Hg cycling and catalyze many of the inter-conversions between different forms of Hg, such as the conversion of Hg^{2+} to methyl and dimethyl Hg and the reduction of Hg^{2+} to Hg^{0} (Summers and

Silver;[308] Robinson and Tuovinen;[277] Silver[290]). Mercury compounds are acutely toxic to freshwater microorganisms, but many bacteria are known to have developed resistance mechanims (Baldi;[19] Hobman and Brown[145]), and positive correlations are often found in sediments between the distribution of Hg compounds and Hg-resistant microorganisms (Timoney et al.;[312] Bubb et al.[53]). Bacterial Hg resistance is inducible and is regulated by the *mer* operon (Baldi[19]). Hg volatilization is regarded as a detoxification mechanism, whereas Hg methylation appears to be an accidental process and not a detoxification mechanism as previously suggested.

A large number of organisms, including strict and facultative anaerobes as well as aerobes, have been shown to methylate Hg *in vitro* (Wood et al.;[336] Kitamura et al.;[179] Yamada and Tonamura;[344-346] Vonk and Sijpesteijn;[318] Robinson and Tuovinen[277]), but it is not certain whether these bacteria are responsible for Hg methylation in the natural aquatic environment. Several more recent studies have indicated that anaerobic sulfate-reducing bacteria (SRB) are the principal methylators of inorganic Hg in both freshwater and estuarine sediments (Compeau and Bartha;[66,67] Berman and Bartha;[29] Gilmour and Henry;[122] Gilmour et al.[123]). Contrary to earlier assumptions (e.g., Wood et al.[336]), methanogenic bacteria seem to play only a minor role in MMHg production. Interestingly, the same bacteria that are primarily responsible for MMHg production also appear to mediate MMHg degradation (Robinson and Tuovinen[277]). Both sulfate reducers and methanogens are important demethylators in estuarine and freshwater sediments (e.g., Oremland et al.;[254,255] cf. Section III.A.4). In pure culture, the formation of DMHg from MMHg is also mediated by SRB (Baldi et al.[16,18]). DMHg formation in the ocean is thought to be microbial (Pongratz and Heumann;[259,260] Mason and Sullivan[223]), but is is not known whether SRB or other organisms are the primary methylators (Mason et al.;[220,221] Fitzgerald and Mason[106]).

Hg methylation activity in sediments is often significantly correlated with sulfate-reduction rates (Choi and Bartha;[61] King et al.[177,178]) or with the distribution of SRB populations (Devereux et al.;[92] Macalady et al.[207]), but not all SRB are capable of Hg methylation. Many studies have focussed on *Desulfovibrio* populations (e.g., Baldi et al.;[16] Choi and Bartha;[60] Choi et al.[62]) but recently King et al.[178] have noted that SRB capable of acetate utilization (i.e., members of the family *Desulfobacteriaceae*) appear to methylate Hg more effectively than members of the *Desulfovibrio* group. Macalady et al.[207] also found that *Desulfobacter* populations are important methylators in lake sediments and that they were more abundant than *Desulfovibrio*.

The efficiency of microbial MMHg production appears to depend chiefly on the activity and structure of the bacterial community (Macalady et al.[207]), Hg availability, the availability of nutrients, and the abundance of electron acceptors such as sulfate (Choi and Bartha[61]). At low concentrations, sulfate stimulates both sulfate reduction and methylation (Compeau and Bartha;[66] Gilmour et al.[123]). The *in situ* addition of small amounts of sulfate thus may lead to increased MMHg production in freshwater environments when sulfate is limiting (Gilmour et al.;[123]

Branfireun et al.[51]). Although a sulfate concentration of <10 mg l^{-1} (0.1 m*M*) generally starts to become limiting for the activities of SRB (Ingvorsen et al.;[155] Lovley and Klug[203]), they can remain active even at the very low sulfate concentrations (ca. 3 mg l^{-1}, 0.03 m*M*) typically encountered in freshwater systems by successfully competing with methanogens for common substrates, that is, hydrogen and acetate (Lovley and Klug;[203] Matilainen[227]). Compeau and Bartha[66] reported that the methylating potential of SRB is highest when sulfate is limiting and other organic substrates are available that can be utilized in place of sulfate, which may be due to the inhibitory effect of sulfide on Hg methylation. At high sulfate concentrations, the accumulation of sulfide generated by sulfate respiration interferes with Hg methylation, thereby limiting MMHg production (e.g., Baker et al.;[15] Compeau and Bartha;[66,67] Winfrey and Rudd[335]). Sulfide inhibition was previously ascribed to HgS precipitation, but is now thought to be linked with charged Hg-S complexes (cf. Section III.B.6). Gilmour and Henry[122] proposed an optimal sulfate concentration range of 0.2 to 0.5 m*M* SO_4^{2-} for Hg methylation by SRB in sediments, above which methylation is inhibited, and below which sulfate becomes limiting for methylation and sulfate-reduction processes. For comparison, seawater has ca. 28 m*M* or 2.7 g l^{-1} SO_4^{2-} (Ingvorsen et al.[155]), which may explain the typically low MMHg levels encountered in estuarine and marine environments (cf. Section III.B.7). Methylation is only partly inhibited by sulfur chemistry, however. For example, King et al.[177] have observed active MMHg formation in the presence of 30 m*M* sulfate and millimolar concentrations of dissolved sulfide. The addition of amorphous Fe(III) oxyhydroxide to sediments may inhibit both sulfate reduction and methanogenesis (Lovley and Phillips[204]), probably due to iron-reducing bacteria suppressing hydrogen and acetate concentrations. Whether this might lead to lower Hg methylation rates in Fe(III)-rich sediments still needs to be determined, however.

Many researchers have noted that net MMHg production in methylation experiments is highest in the first few days or weeks of equilibration (depending on study), after which accumulation apparently stops, and in some cases MMHg concentrations decline, and some studies have noted a cyclical production pattern for MMHg (Jacobs and Keeney;[162] Spangler et al.;[295] Hamdy and Noyes;[137] Olson;[253] Furutani and Rudd;[112] Ikingura and Akagi[153]). It has been suggested that cyclical variations in the supply of bacterial substrates may be the cause (Stary et al.[297]), but changes in the bacterial population may be a more likely explanation. Bacterial life stages can also affect the speciation and fate of Hg, but the available data appear contradictory. Ramamoorthy et al.[266] found growing bacterial cells promote Hg^0 formation, whereas living but nongrowing cells cause demethylation, and dead cells lead to the formation of MMHg. This would appear to agree with Parkman et al.,[258] who suggested Hg methylation is an accidental process that does not require the presence of living bacterial cells. In contrast, Ebinghaus et al.[96] observed active methylation during the phase of exponential growth of sediment bacteria, whereas demethylation became dominant when the bacterial population

began to die off, and Pongratz and Heumann[260] reported methylated Hg species were preferably formed in the stationary period of bacterial growth.

Compeau and Bartha[65] reported MMHg concentrations approached a steady state after 8 to 12 days of incubation, but renewed addition of Hg^{2+} resulted in MMHg synthesis at the previous rate. The percentage of total Hg converted to MMHg declined significantly with increasing spiking levels, however, a phenomenon that has also been noted by other authors (Berdichevsky et al.;[28] Jeffries;[164] Lexmond et al.;[197] Robinson and Tuovinen[277]). Chen et al.[59] observed an increase in methylation rates when the $HgCl_2$ spike was less than or equal to 15.3 $\mu g\ g^{-1}$ d.w., whereas microbial methylation activity appeared to be inhibited at concentrations exceeding this value. Sediments containing high levels of Hg have also shown higher rates of demethylation compared with less-contaminated sediments (Gilmour and Henry;[122] Oremland et al.[255]). The results suggest that high concentrations of inorganic Hg may depress MMHg production or may favor demethylation. In water samples, on the other hand, an increase in specific methylation rates that was proportionally greater than the increase in added Hg^{2+} was observed, possibly due to increased availability of Hg following the saturation of binding sites (Xun et al.[343]). The above results may explain why the ratio of methyl : total Hg in sediments or waters is frequently found to increase with increasing distance from the pollution source (e.g., Suchanek et al.;[305], Hines et al.[141]). The apparent cyclical nature of the methylation process together with a possible inverse relationship of net MMHg production with total Hg concentrations may be one reason why MMHg levels in sediments rarely exceed a threshold value of 1%.

The availability of nutrients is an important factor controlling microbial Hg methylation in aquatic systems (Jernelöv;[169] Langley;[189] Wright and Hamilton[339]). Methylation and sulfate reduction rates therefore are generally highest in the upper layers of sediments, where microbial activity and nutrient supply are greatest, and on suspended organic material (Jernelöv;[169] Callister and Winfrey;[55] Korthals and Winfrey;[180] Jorgensen and Bak;[172] Bubb et al.;[53] Choi and Bartha;[61] Gilmour et al.;[125] Bloom et al.;[41] Hines et al.[141]). Microbial DMHg formation in the ocean is also driven by the supply of labile organic matter (Mason and Sullivan[223]). Many studies have found a positive correlation between sediment organic matter content and MMHg production (Callister and Winfrey;[55] Jackson;[158] Choi and Bartha;[61] Hadjispyrou et al.;[133] Pak and Bartha[256]). Macalady et al.[207] observed a correlation between microbial community structure and organic carbon content and suggested that organic-rich sediments support microbial communities with higher Hg methylation activity per unit of microbial biomass. Because of the generally stimulating effect of organic matter on microbial activity, bacterial demethylation rates may also be increased (Ramlal et al.;[268] Pak and Bartha[256]). Ramlal et al.[268] found net MMHg production in organic-rich soils from a recently flooded reservoir was always higher compared with clay sites, but the organic sites also had rapid demethylation rates.

The creation of new hydroelectric reservoirs and enlargement of lakes significantly increases MMHg production, leading to elevated Hg concentrations in fish that can remain high for several decades (Morrison and Therien;[244] Jackson;[161] Bodaly et al.;[45] Schetagne et al.[286]). Kelly et al.[175] found that MMHg production increased by almost 40 times following the experimental flooding of a boreal forest wetland. Recent data by Montgomery et al.[241] indicate that dissolved MMHg concentrations in flooded environments are on average about four times greater than in natural lakes. It is thought that the flooding of vegetation and soils releases associated inorganic Hg as well as large amounts of organic matter and nutrients, thereby stimulating microbial methylation activity (Porvari and Verta;[261] Bodaly et al.[45]). The effect is enhanced further by the prevailing anaerobic conditions, but it may be mitigated by the provision of additional Hg-binding sites when an excess of organic substrates is supplied (Jackson[161]). Surprisingly, reservoir creation does not appear to increase microbial demethylation rates (Bodaly et al.[45]).

The availability of Hg to methylating bacteria is frequently believed to be determined by the concentration of free Hg^{2+} ions. However, microbial uptake of Hg involves diffusive transport of Hg across bacterial membranes, which are known to have higher permeability for uncharged molecules than for ionic species (e.g., Gutknecht[131,132]). Whereas uncharged $HgCl_2$ may diffuse rapidly through lipid bilayers, charged chloride complexes HgOHCl and $Hg(OH)_2$ do not cross membranes at a significant rate under physiological conditions, for example (Gutknecht[131]). Recent studies (Mason et al.;[219] Barkay et al.;[20] Benoit et al.;[26] Wright and Mason[340]) therefore have suggested that Hg bioavailability is controlled by the concentration of neutral dissolved Hg complexes. $HgCl_2$ may be the key chemical species determining cellular uptake of inorganic Hg in oxic waters (Morel et al.[243]), while uncharged HgS^0, bisulfide $Hg(SH)_2^0$, or polysulfide HgS_n^0 complexes may be important for bacterial uptake in anoxic waters (Hudson et al.;[148] Benoit et al.;[26] Jay et al.[163]). Wright and Mason[340] speculated that there may be other mechanisms of uptake besides passive diffusion, because bioavailability is reduced but not inhibited by organic complexation (Barkay et al.[20]).

Other factors that may affect microbial Hg methylation and/or demethylation are discussed in the following. In many cases these parameters appear to affect methylation by controlling the bioavailability of inorganic Hg. Net MMHg production rates in natural aquatic systems appear to depend to a large extent on the environmental conditions that determine whether bacterial methylation or demethylation will dominate.

2. Temperature

It has been observed frequently that Hg methylation rates in aquatic systems peak during the summer months (Jackson et al.;[157] Callister and Winfrey;[55] Korthals and Winfrey;[180] Bubb et al.;[53] Hintelmann and Wilken;[142] Watras et al.[326]). Most

studies have shown maximum methylation activity occurs during mid or late summer, although Bloom et al.[41] found a sharp peak in sediment MMHg production in early spring, followed by a slow decrease throughout the remainder of the year. Seasonal variations in MMHg production and decomposition generally have been attributed to temperature effects, but are probably also linked with seasonal changes in productivity/nutrient supply and redox conditions (cf. Section III.B.5).

Temperature most likely affects methylation as a result of its effect on the overall microbial activity (Bisogni and Lawrence[34]). Wright and Hamilton[339] noted that MMHg release from sediments at 4°C was only 50 to 70% of that observed at 20°C, suggesting that net MMHg production may be significantly decreased in winter due to lower rates of growth and metabolic activity, and Callister and Winfrey[55] reported microbial Hg methylation in surficial river sediments had a temperature optimum of 35°C. Korthals and Winfrey[180] found that while both temperature and anoxic conditions were important factors influencing net methylation, temperature alone accounted for about 30% of the variation. The data suggested that increased net MMHg production was partly due to decreased demethylation rather than an increase in the actual methylation rate, however. Several other workers have also found that demethylation is favored by low temperatures, whereas higher temperatures favor methylation, leading to a large increase in net MMHg production in the summer (Bodaly et al.;[44] Ramlal et al.[269]). Abiotic methylation by humic substances has also been shown to gain in importance with increasing temperature (cf. Section III.A.2), but it is probably of little/minor significance compared with biotic methylation. In contrast to the findings of Ramlal et al.[269] and Bodaly et al.[44], Matilainen et al.[229] found that the highest rates of *both* methylation and demethylation in surficial lake sediments coincided with maximum temperatures. Similarly, Matilainen and Verta[228] found microbial demethylation rates in aerobic surface waters of small forest lakes (up to 13.2% d^{-1}) were decreased by low temperatures.

Temperature is clearly an important factor controlling both methylation and demethylation. It appears that moderately high temperatures have a stimulating effect on Hg methylation, which is most likely due to increased microbial activity. Together with seasonal changes in oxygen levels and organic content/primary production, this seems to account for the increased MMHg production rates usually observed in the summer. The results for Hg demethylation are somewhat contradictory, but most workers found demethylation is favored by lower temperatures. It may be that the rate of methylation increases faster than the rate of demethylation with increasing temperature.

3. pH

The effect of pH on the methylation of Hg has received considerable attention over the last 2 decades, in particular with regard to lakewater acidification caused

by atmospheric deposition. Many workers have noted elevated Hg levels in fish from acidified lakes (e.g., Scheider et al.;[285] Akielaszek and Haines;[2] Wren and McCrimmon;[338] Lindqvist et al.;[199] Håkanson et al.;[135] Spry and Wiener[296]), and there has been concern that low pH values may lead to an increase in the production and/or bioaccumulation of MMHg. Modeling results suggest that observed inverse correlations between lakewater pH and fish Hg content are due to a combination of generally higher MMHg concentrations at low pH and lower bioconcentration factors at high pH (Hudson et al.[148]). There are, however, many ways in which pH changes may influence MMHg concentrations in aquatic systems, and the effect of pH is not necessarily a direct effect on methylation rates. The solubility and mobility of Hg and MMHg is pH dependent, for example, and acid rain/snow may increase Hg inputs from watersheds (Lee and Hultberg[193]). Furthermore, the added sulfate may stimulate MMHg production (Gilmour et al.;[123] Branfireun et al.[51]). Acid mine drainage, which typically is high in sulfate, has also been linked to elevated MMHg concentrations in lake water (Suchanek et al.[306]).

Low pH conditions generally facilitate the release of heavy metals from sediments and particulate matter, but data on the partitioning and mobility of Hg are somewhat contradictory. Some workers have noted that the mobility of Hg is higher in the acidic pH range (Beijer and Jernelöv;[23] Duarte et al.[94]), but Jackson et al.[156] found that Hg was not leached from sediments by HCl, and Schindler et al.[287] reported that lakewater acidification caused a higher proportion of Hg to bind to particulates, thereby decreasing the solubility of Hg in the water column. The amount of dissolved Hg in sediment porewater was also found to decrease with decreasing pH (Ramlal et al.[267]). The available data on the pH-dependent partitioning of MMHg between the sediment and water phases and the transport of MMHg in watersheds (cf. Sections II.C and II.D) strongly suggest that the solubility of MMHg is increased at low pH values. Thus, lakewater acidification probably does not result in the release of Hg^{2+} from organic sediments, but affects the partitioning of MMHg.

Several studies have indicated that the volatilization of Hg^0 may be positively correlated with lakewater pH (Winfrey and Rudd[335] after Rada et al., 1987, Hudson et al.;[148] Watras et al.[326]), which may decrease Hg(II) substrate concentrations for methylation in high pH waters (Fitzgerald et al.[103]). Modeling calculations by Hudson et al.[148] predict an increase in the ratio of Hg^0/Hg(II) and Hg^0 evasion rates with increasing pH, whereas low pH values favor methylation over Hg(II) reduction. In agreement with this, Watras et al.[326] observed an increase in Hg^0 and a corresponding decrease in MMHg with increasing pH values. High pH values also favor the formation of volatile DMHg (cf. Section III.A.3). Neutral and slightly alkaline conditions thus may reduce MMHg concentrations, whereas low pH waters may contain a relatively higher share of MMHg. This would appear to agree with Swedish field studies that have shown that the treatment of lakes with lime to raise lakewater pH can help reduce the Hg content of fish (e.g., Andersson and Håkanson[10]).

The effect of pH on Hg methylation has been studied both in waters and sediments. MMHg concentrations in lake water generally have been found to increase with decreasing pH (e.g., Xun et al.;[343] Bloom et al.;[40] Miskimmin et al.[240]). Xun et al.[343] reported that net MMHg production in lake water was about seven times faster at low pH (ca. 4.5) than at high pH (ca. 8.5), although in samples that were artificially acidified the observed effect may have been partly due to sulfate stimulation. A pH decrease at the aerobic sediment-water interface resulted in a two- to threefold increase in MMHg production. Miskimmin et al.[240] also reported that a reduction in lakewater pH from 7.0 to 5.0 led to significant increases in net methylation rates. In anaerobic sediments, on the other hand, net MMHg production was generally found to be decreased at low pH values (Steffan and Winfrey;[298] Furutani et al.;[113] Ramlal et al.;[267] Steffan et al.[299]). The acidification of surficial lake sediments always resulted in a significant decrease in ^{203}Hg methylation rates. Ramlal et al.[267] reported that the decrease in ^{203}Hg methylation with decreasing pH appeared to be linked to a reduction of available inorganic Hg in the sediment porewater, which may have been due to increased sorption to particles at low pH. Aerobic methylation in surface sediments was also found to decrease with decreasing water pH (Matilainen et al.[229]).

Demethylation rates are also pH sensitive. Matilainen et al.[229] observed a decrease in anaerobic demethylation in surface sediments with decreasing water pH and speculated that high MMHg concentrations found in the anoxic bottom waters of stratified, low pH lakes may be partly the result of a decrease in demethylation rather than an increase in methylation. Other workers have also found a decrease in demethylation activity at low pH values, but in general demethylation rates in both sediments and lake water were found to be much less affected by pH than methylation rates (Ramlal et al.;[267] Xun et al.;[343] Steffan et al.[299]), indicating that the changes observed in net MMHg production are largely due to an effect of pH on methylation rather than demethylation. However, the results of Ramlal et al.[267] and Steffan et al.[299] show that in sediments demethylation may gain in importance at low pH values. Steffan et al.[299] found little change in demethylation over the pH range 8.0 to 4.5, but methylation decreased sharply with decreasing pH, leading to a substantial increase in the relative importance of demethylation vs methylation under acidic conditions. This may also explain why Ramlal et al.[267] did not observe methylation below pH 5.0.

One of the ways in which pH might affect methylation may be by decreasing microbial activity under acidic conditions, causing a corresponding decrease in bacterial methylation rates. The published literature indicates that microbial activity in lakes is not reduced after acidification, however. Furutani et al.[113] and Kelly and Rudd[173] reported that acidification did not affect general microbial activity (CO_2 + CH_4 production) in sediments, and Miskimmin et al.[240] found that microbial respiration rates had only a very small effect on net MMHg production in lake water and were insensitive to pH changes between pH 5 and 7. However, there are indications that the activity of sulfate-reducing bacteria may be significantly

decreased in the acidic pH range (Connell and Patrick[68]), and Furutani et al.[113] observed a decrease in sulfate reduction at low pH that was independent of general microbial activity. It may also be that pH affects the population distribution of methylating vs. demethylating bacteria in sediments such that demethylation processes dominate at low pH values. This would agree with the results obtained by Ramlal et al.[267] and Steffan et al.[299] and might merit further investigation. It is also possible that pH affects cellular uptake of Hg, but Gutknecht[132] found that the diffusion of Hg^{2+} through lipid bilayer membranes was only dependent on Cl^- concentrations and not on pH.

In summary, it appears that acidic conditions generally favor Hg methylation in lake water and at the sediment/water interface, whereas methylation in anoxic sediments is decreased, possibly due to increased demethylation activity at low pH values. Lakewater acidification thus may lead to increased methylation in the water phase, but it is unlikely to substantially affect methylation in deeper sediments. The observed differences in the effect of pH on Hg methylation in waters and sediments may be related to differences in redox conditions: whereas sediments were generally studied under anoxic conditions, the water samples appear to have been oxygenated to some degree.

It is not clear whether the stimulation of methylation in lake water is a direct effect of low pH on the methylation process, or whether it is related to other factors that are influenced by pH, such as the loss of volatile Hg species from water surfaces, or changes in Hg solubility and partitioning. Winfrey and Rudd[335] hypothesized that the likely decrease in DOC binding sites at low pH values resulting from the protonation of functional groups may stimulate methylation by promoting Hg binding directly onto microbial cells. Increased MMHg concentrations in the water phase at low pH are also likely to be partly attributable to increased desorption of MMHg from surficial sediments (Miller and Akagi;[238] Hintelmann et al.[143]), and thus do not necessarily reflect increased methylation.

It should be mentioned briefly that the abiotic methylation of Hg by organic substances is also pH dependent, but the data are somewhat contradictory (Nagase et al.;[246,247] Varshal et al.;[315] Falter and Wilken[100]). Nagase et al.[246] reported that MMHg formation in fulvic acid solution was strongly enhanced at pH 4 and declined at higher pH values, whereas Varshal et al.[315] found MMHg production increased with increasing pH, for example. While the relative importance of abiotic mechanisms in the methylation of Hg under natural environmental conditions is still unclear, it is generally thought to be low.

4. Organic Material

The role of organic matter in the methylation of Hg is not well understood. Conversion rates of inorganic Hg to MMHg are generally much higher when sediments contain organic substances and can be very high in or near sewage

treatment plants (Jernelöv;[168] Jackson[158]). Observed increases in MMHg concentrations in water, sediments, or fish tissue with increasing levels of organic carbon (Olson and Cooper;[252] Furutani and Rudd;[112] Wright and Hamilton;[339] Lee and Hultberg;[193] Fjeld and Rognerud[107]) generally have been attributed to a stimulating effect of organic nutrients on microbial methylation activity (cf. Section III.B.1), but in some cases transport of (methyl)mercury-DOC complexes to surface waters with runoff (Section II.C) is likely to be an additional factor. Direct abiotic methylation by humic and fulvic acids generally is considered to be of minor importance (cf. Section III.A.2), although it is possible that its influence is increased in organic-rich lakes. However, the data of Porvari and Verta[261] indicate that although humic substances are chiefly responsible for the transport of MMHg, they are not themselves active methylating agents. To date it is not clear to what extent abiotic methylation contributes to MMHg production in organic-rich sediments and lake waters.

Many workers have reported decreased methylation at high concentrations of organic matter, and several studies have suggested that dissolved organic carbon (DOC) may have a mitigating effect on the production and/or bioaccumulation of MMHg in natural waters (Grieb et al.;[128] Jackson;[161] Miskimmin et al.;[240] Driscoll et al.;[93] Watras et al.;[326] Barkay et al.[20]). Miskimmin[239] reported that natural levels of DOC had no effect on the production of MMHg in sediments, although they enhanced the water solubility of MMHg. However, Miskimmin et al.[240] demonstrated that MMHg production in lake water is reduced at high DOC concentrations, presumably as a result of complexation of inorganic Hg with organic matter. A reduction in pH from 7.0 to 5.0 significantly increased methylation rates at both low and high DOC concentrations (500 to 2600 μM), possibly due to competition of H^+ with Hg^{2+} for negatively charged binding sites and increased bioavailability of Hg. Using a bioindicator that responds exclusively to bioavailable Hg^{2+}, Barkay et al.[20] demonstrated that DOC affects the rate of MMHg synthesis by reducing the availability of the Hg^{2+} substrate to methylating bacteria. The exact nature of the Hg-DOC interaction remains unknown, however. The reduction in bioavailable Hg was more pronounced under neutral (pH 7) than under acidic (pH 5) conditions, which is in good agreement with the study by Miskimmin et al.[240]

The availability of Hg for methylation reactions may also be decreased by complexation with sulfur ligands (cf. Section III.B.6). The degradation of organic matter in aquatic environments leads to the production of low-molecular-weight S compounds (Cutter and Krahforst[88]) that can potentially form complexes with Hg^{2+}. On the other hand, increased oxygen consumption during the degradation of organic matter causes progressively more anoxic conditions at the sediment/water interface, which may lead to the mobilization and potential methylation of inorganic Hg (Gagnon et al.;[115] Cossa and Gobeil[78]). DOC also significantly enhances the solubility of HgS (Ravichandran et al.[270]) and may inhibit the precipitation and aggregation of HgS even at low concentrations (Ravichandran et al.[271]).

Humic substances are capable of reducing Hg^{2+} to Hg^0 in aqueous systems (e.g., Miller[237]), which may lead not only to reduced availability of Hg^{2+} for methylation, but potentially also to a reduction in the overall Hg content. Allard and Arsenie[4] suggested Hg^0 production is highest in anaerobic systems in the absence of chloride at a pH of about 4.5, but it is considerably reduced by the presence of competing ions. In contrast to the findings of Miskimmin et al.,[240] Watras et al.[326] observed an increase in the MMHg fraction in Wisconsin lakewaters with increasing levels of DOC, in particular at DOC concentrations >5 mg l^{-1}, whereas the Hg^0 fraction decreased. This is in agreement with modeling calculations by Hudson et al.,[148] which predict that as DOC increases, the fraction of Hg(II) that is reduced declines, while the fraction that is methylated increases. The relative importance of Hg^0 evasion is increased in humic-rich lakes, however, despite the observed decrease in the Hg^0 fraction. Watras et al.[328] hypothesized that high DOC conditions in lakes favor either methylation (at low pH) or evasion (at high pH), whereas low pH low DOC conditions favor sedimentation processes.

The role of humic matter in the methylation of Hg remains unclear. It seems that, on the one hand, organic carbon can enhance methylation by stimulating the activity of heterotrophic microorganisms, or through direct abiotic methylation of Hg by humic or fulvic substances. On the other hand, Hg methylation may be inhibited at high DOC concentrations due to increased complexation of Hg with organic ligands, reducing Hg bioavailability to bacteria, particularly in the neutral pH range. The observed differences may partly reflect different methylation mechanisms. Anaerobic methylation was found to be enhanced by high concentrations of organic matter, presumably due to stimulated microbial growth, whereas aerobic methylation frequently has been observed to be suppressed by high organic matter or particulate concentrations and does not appear to be microbially mediated (cf. Section III.B.5).

5. Redox Conditions

Mercury methylation occurs in both aerobic and anaerobic environments. Early work based on pure culture studies showed that methylation was faster under aerobic conditions (Bisogni and Lawrence;[34] Hamdy and Noyes;[137] Ramamoorthy et al.[266]), but in the natural environment, methylation rates are highest in anoxic sediments and waters, and it is now generally accepted that Hg methylation takes place mainly in anaerobic conditions (Olson and Cooper;[252] Compeau and Bartha;[65] Callister and Winfrey;[55] Craig and Moreton;[87] Jackson;[159] Rudd et al.;[279] Matilainen et al.[229]). Both methylation rates and the stability of MMHg in sediments appear to be enhanced under anaerobic conditions (e.g., Olson and Cooper;[252] Compeau and Bartha[65]), whereas methylation rates are low under aerobic conditions, probably because of the reduced activity of anaerobic sulfate-reducing bacteria. Compeau and Bartha[65] found that Hg methylation in estuarine sediments was strongly

favored at low (-220 mV) E_h, for example, and Callister and Winfrey[55] reported that the oxygenation of sediments inhibited microbial methylation activity. Regnell and Tunlid[272] used radiolabeled $HgCl_2$ in model aquatic systems to demonstrate that Hg methylation in freshwater sediments and water is significantly higher under anaerobic than under aerobic conditions. MMHg concentrations in anaerobically incubated water and sediment samples from a Hg-contaminated lake were also at least an order of magnitude higher than in aerobic incubation (Regnell et al.[273]); both the production and water solubility of MMHg appeared to be increased under anaerobic conditions.

On the other hand, the degradation of MMHg appears to be generally favored by aerobic conditions. Although some workers have found demethylation rates in freshwater sediments were similar under aerobic and anaerobic conditions (Billen et al.;[32] Matilainen et al.[229]), most studies have shown that MMHg degradation is faster under aerobic/high E_h conditions (Olson and Cooper;[252] Compeau and Bartha;[65] Ramlal et al.;[268] Oremland et al.;[254] Ebinghaus et al.[96]). Oremland et al.[254] found that demethylation in estuarine sediments was more rapid and extensive under aerobic conditions, but anaerobic sulfate reducers were also important demethylators, suggesting that there are multiple degradation pathways (cf. Section III.A.4).

It may be that different mechanisms are responsible for Hg methylation under aerobic and anaerobic conditions. Anaerobic methylation was found to be enhanced by high concentrations of organic matter, presumably due to stimulated microbial growth (Olson and Cooper;[252] Compeau and Bartha[65]). Aerobic methylation on the other hand is frequently observed to be suppressed by high organic matter or particulate concentrations, and does not appear to be microbially mediated (Matilainen et al.;[229] Matilainen;[227] Matilainen and Verta[228]). Matilainen[227] found, for example, that aerobic methylation was abiotic and was suppressed by humic compounds and particulate matter, whereas methylation in the anaerobic hypolimnion was microbial. Matilainen et al.[229] reported that aerobic methylation in organic-rich surficial lake sediments was abiotic and was slow compared with anaerobic methylation, but increased in importance with increasing sediment mineral content. Aerobic methylation and the methylation/demethylation ratio correlated positively with the Fe and Mn content of the sediment. The authors suggested that sediments with high metal content may have more bioavailable Hg, owing to the interaction of these metals with sulfur, which would appear to agree with more recent results by Gagnon et al.,[114] who found that high dissolved Fe concentrations in sediment porewaters seem to limit the amount of dissolved H_2S that may potentially interfere with the methylation process. A possible catalytic effect of Fe on Hg methylation can also not be ruled out. Lee et al.[192] reported that Hg methylation in lake waters in the presence of fulvic acid was increased by the addition of metal ions, and in particular Fe.

In most aquatic sediments, only the upper few millimetres are aerobic, while the rest of the sediment is in an anaerobic state. MMHg concentrations are usually highest in the moderately anaerobic surface sediments and rapidly decline with

increasing sediment depth (Korthals and Winfrey;[180] Bubb et al.;[53] Hintelmann and Wilken;[142] Bloom et al.;[41] Hines et al.[141]). In sediment porewaters, MMHg concentrations were very low in the oxic zone, but were high in anoxic layers (Gagnon et al.[114]). Bubb et al.[53] suggested that subsurface maxima of methylation activity just below the sediment/water interface are caused by increased MMHg production under moderately anaerobic conditions, whereas bacterial degradation of MMHg dominates in the oxygenated surface zone, and in deeper sediment layers where conditions are strongly reducing sulfide limits the availability of Hg for methylation (cf. Section III.B.6). MMHg concentrations in sediments are also influenced by the redox cycling of Fe and Mn oxides that partly control dissolved Hg concentrations in sediment porewaters (Gobeil and Cossa;[126] Gagnon et al.[115]), thereby influencing Hg bioavailability. In the oxidized surface layers of marine sediments, Hg was found to be primarily associated with fresh particulate organic matter and Fe and/or Mn oxyhydroxides, which was limiting dissolved Hg concentrations (Gagnon et al.[115]). High dissolved Hg concentrations were observed at the redox boundary, however, due to the accumulation and subsequent dissolution of oxyhydroxides (Gagnon et al.[115]). Similarly, Gobeil and Cossa[126] found that dissolved Hg and Fe concentrations increased below 2 cm from the sediment/water interface.

In the water column, MMHg (and DMHg) production is also related to zones of low oxygen concentration (e.g., Bloom et al.;[40] Hurley et al.;[149] Verta and Matilainen;[316] Mason and Fitzgerald;[211,212] Mason et al.[214]), whereas levels are typically low in the oxic zone, both in freshwater lakes (Bloom et al.;[40] Cossa et al.;[74] Watras and Bloom[323]) and ocean waters (e.g., Mason and Fitzgerald[210,211]). In stratified lakes and estuaries, MMHg concentrations are usually highest in the oxic/anoxic boundary layer and in anoxic water layers (Bloom et al.;[40] Mason et al.;[213] Cossa et al.;[74] Parkman et al.;[258] Verta et al.;[317] Watras and Bloom;[323] Watras et al.;[324] Matilainen[227]). High MMHg concentrations at the oxic/anoxic boundary do not necessarily reflect *in situ* MMHg production, but could result from the accumulation of settling particulate matter. For instance, Matilainen[227] found MMHg concentrations were elevated in the particle-rich oxic/anoxic boundary layer despite low methylation rates (<0.1% d^{-1}), apparently as a result of the settling of particle bound MMHg from the epilimnion. The low net methylation rates were attributed to the binding of Hg to particles and demethylation by heterotrophic bacteria. Cossa et al.[74] also observed a peak in particulate MMHg in the upper region of the redoxcline. The results suggest that methylation occurs mainly in the low oxygen region, but the concentration and distribution of MMHg are strongly influenced by the redox cycling of Fe and Mn at the oxic/anoxic boundary.

Seasonal variations in MMHg concentrations are also strongly linked to changes in redox state. MMHg levels in hypolimnetic waters of seasonally stratified lakes and reservoirs generally increase during summer stratification, and decrease again following fall turnover (Bloom and Effler;[38] Bloom et al.;[40] Watras and Bloom;[323] Watras et al.;[324] Driscoll et al.;[93] Regnell et al.;[274] Canavan et al.[56]). Similar trends

are observed in surface sediments (Korthals and Winfrey[180]). The increased decomposition of organic matter and primary production during the summer months renders sediments and hypolimnetic waters progressively more anoxic, which together with the generally higher temperatures is thought to have a stimulating effect on bacterial methylation activity. Hypolimnetic enrichment of MMHg and Hg in (seasonally) anoxic lake waters may also be due to redox-controlled release of Hg from bottom sediments or sedimenting particles (Hurley et al.;[149,151] Mason et al.[224]). Meili[233] suggested that the build-up of MMHg in anoxic waters may be due to suppressed demethylation rather than enhanced methylation, however. Passive uptake of neutral $Hg(SH)_2^0$ and HgS^0 complexes by methylating bacteria may be another reason for increased Hg methylation in anoxic waters (Hudson et al.;[148] Benoit et al.[26]). Demethylation processes are expected to dominate when hypolimnetic waters are reaerated during lake turnover.

In summary, it is clear that microbially mediated methylation is generally favored by anaerobic conditions, while demethylation is favored by aerobic conditions. On the other hand, abiotic methylation appears to be largely aerobic. Sediment redox state also affects the partitioning of Hg species between the sediment and water phases. Other environmental factors can interact significantly with redox effects, in particular organic matter and pH.

6. Sulfide

Hydrogen sulfide plays an important role in the chemistry of anaerobic sediments where it is produced as a result of bacterial sulfate reduction. Conditions of high sulfide typically develop in anoxic, organic-rich sediments that are high in sulfate, but can also occur in surface waters as a result of industrial or domestic wastewater discharges. Early studies noted that high sulfide concentrations appear to inhibit MMHg formation in soils, sediments, and bacterial cultures (Fagerström and Jernelöv;[98] Bisogni and Lawrence;[34] Yamada and Tonomura;[346] Jacobs and Keeney;[162] Talmi and Mesmer[311]), and significant reductions of MMHg in fish were achieved in aquarium experiments by adding sulfides as S^{2-}, FeS, or FeS_2 (Jernelöv and Åséll[170]). An inverse relationship between (dissolved) sulfide concentration and MMHg production or concentration in sediments or sediment porewaters has also been noted in many more recent studies (e.g., Craig and Moreton;[85] Compeau and Bartha;[64,67] Winfrey and Rudd;[335] Gilmour et al.;[125] Benoit et al.[25,26]). Craig and Moreton[85] found MMHg levels in sediments were initially in direct proportion to sulfide concentrations, but declined sharply beyond a sulfide concentration of about 1.8 mg g^{-1}, and Berman and Bartha[29] observed that Hg added to sediments containing 7.06 mg g^{-1} (d.w.) acid labile and 1.98 mg g^{-1} (d.w.) free sulfide became rapidly unavailable for methylation, whereas increasing amounts of MMHg were formed when the sediment was diluted with a low-sulfide control sediment, or when it was partially depleted of sulfide.

The presence of sulfide clearly decreases the availability of Hg^{2+} for methylation. However, although MMHg production is generally greatly reduced at high sulfide concentrations, it is not usually completely inhibited. Furutani and Rudd[112] found that $^{203}Hg^{2+}$ was actively methylated in anaerobic sediments even in the presence of about 30 μg g^{-1} of bound sulfide (d.w., as amorphous FeS), for example. Furthermore, MMHg levels in sediments are sometimes found to increase with increasing sulfide concentrations (Hintelmann and Wilken[142]), and in stratified lakes and estuaries high MMHg concentrations are frequently found in the sulfidic boundary layer (Bloom et al.;[40] Mason et al.;[213] Parkman et al.;[258] Verta et al.;[317] Watras et al.;[324] Matilainen[227]).

In the presence of sulfide, Hg forms insoluble HgS (cf. Section II.A). Several early reports indicated that mercury in the HgS form is not readily available for methylation under anaerobic conditions (Fagerström and Jernelöv;[98] Gillespie;[121] Yamada and Tonomura[344-346]). In aerobic conditions, the sulfide may be oxidized to sulfate, leading to increased solubility and greater availability of Hg^{2+} (Fagerström and Jernelöv;[98] Jensen and Jernelöv[166]), but aerobic methylation rates are several orders of magnitude lower compared to anaerobic conditions (Fagerström and Jernelöv;[98] Gillespie and Scott;[120] Jacobs and Keeney[162]). Nevertheless, exposure of contaminated sediments to aerobic conditions may lead to the remobilization and subsequent methylation of Hg (Berman and Bartha[29]).

It is commonly speculated that the inhibitory effect of sulfide on Hg methylation is the result of decreased solubility and bioavailability of Hg^{2+} due to HgS precipitation (e.g., Craig and Bartlett;[84] Gavis and Fergusson;[118] Blum and Bartha;[43]Compeau and Bartha;[64,67] Winfrey and Rudd;[335] Gilmour and Henry[122]). However, high dissolved Hg(II) concentrations in the porewater of sulfidic sediments (Gagnon et al.;[115] Benoit et al.;[25] Bloom et al.[41]) indicate that the solubility of Hg is actually increased in the presence of excess sulfide, most likely due to the formation of soluble sulfide complexes. Furthermore, the lack of a relationship between dissolved Hg(II) concentrations in porewater and MMHg production suggests that Hg^{2+} may not be the main species that is methylated (Benoit et al.[25]). The work of Benoit et al.[25-27] shows that sulfide affects the bioavailability of Hg by controlling Hg speciation. Benoit et al.[26] suggest that the bioavailability of Hg in sediments is determined by the concentration of neutral dissolved Hg complexes such as HgS^0, which may readily diffuse across bacterial cell membranes. Under sulfidic conditions, on the other hand, Hg methylation is inhibited due to the formation of charged disulfide complexes which are likely to be less bioavailable (Benoit et al.[27]). The formation of polysulfides (Paquette and Helz;[257] Jay et al.[163]) and complexes with dissolved organic matter (Ravichandran et al.[270,271]) may contribute to the solubility of Hg in sulfidic environments. Barkay et al.[20] have shown that DOC complexation reduces the availability of Hg to bacteria, but the effect of polysulfide formation on Hg methylation is not clear. Jay et al.[163] speculate that although the formation of charged polysulfide species may decrease the concentration of bioavailable HgS^0, bioavailability could potentially be increased

due to the formation of small concentrations of other lipid-soluble uncharged species such as HgS_5.

A number of studies have suggested that in the presence of high sulfide concentrations, MMHg may be converted to volatile DMHg (Craig and Bartlett;[84] Craig and Moreton;[86] Baldi et al.[16,18]). Craig and Bartlett[84] proposed that the reaction proceeds via the formation of an instable organomercury sulfide intermediate, $(CH_3Hg)_2S$, which decomposes into DMHg and HgS. The volatile hydrophobic DMHg produced may diffuse through the water column and be lost to the atmosphere, potentially leading to a significant reduction in the organic Hg content of sediments (Craig;[83] Craig and Moreton[85]). Craig and Moreton[86] demonstrated the evolution of DMHg from a sediment containing a natural unamended level of MMHg on exposure to sulfide. Baldi et al.[18] have shown that MMHg added to polluted sediments can also be converted to DMHg, but the study was performed under high sulfide and high MMHg conditions that would thermodynamically favor DMHg production. The formation of DMHg is considered a potentially important loss mechanism of MMHg from anaerobic sediments high in sulfide (Craig;[83] Baldi et al.[18]), but it is not clear to what extent it occurs in the natural environment.

7. Salinity

The methylating activity of marine and estuarine sediments is usually lower than that of freshwater sediments (e.g., Olson and Cooper;[251] Blum and Bartha;[43] Compeau and Bartha[67]), which generally has been attributed to salinity effects. Blum and Bartha[43] and Compeau and Bartha[67] observed a strong inverse relationship between the salinity of anaerobic sediments and their ability for Hg^{2+} methylation. High-salinity sediments methylated Hg at only 40% of the level observed in low-salinity sediments (Compeau and Bartha[67]). The inhibitory effect of salinity on Hg methylation is particularly pronounced under reducing conditions, and high-salinity conditions appear to promote demethylation processes (Compeau and Bartha[65]). Low-salinity coastal waters have also been found to contain a relatively higher proportion of MMHg (Coquery et al.[71]).

The negative effect of salinity on Hg methylation appears to be mainly linked with the microbial production of sulfide from sea salt sulfate. However, while MMHg production in sediments is often strongly reduced in the presence of sulfate (Baker et al.;[15] Compeau and Bartha;[67] Winfrey and Rudd[335]), methylation does not necessarily stop at high sulfate concentrations. Compeau and Bartha[67] reported that methylation still occurred at 2.4% salinity, corresponding to 19.5 m*M* sulfate per liter and 7.1 mg sulfide per gram of dry sediment, whereas the same level of sulfide had been found to almost completely inhibit methylation in a freshwater sediment (Berman and Bartha[29]). While it was previously believed that sulfide originating from sulfate-reduction processes limits the bioavailability of Hg in anaerobic

sediments due to HgS formation (Blum and Bartha;[43] Compeau and Bartha;[64,67] Winfrey and Rudd[335]), recent evidence suggests that methylation is inhibited at high sulfide concentrations due to changes in Hg speciation (cf. Section III.B.6).

Not only sulfate, but other sea salt anions may also affect Hg speciation and/or methylation in estuarine and marine environments. Compeau and Bartha[64] demonstrated that bicarbonate has a negative influence on Hg methylation under both aerobic and anaerobic conditions, possibly due to the formation of $HgCO_3$. The authors speculated that the availability of Hg for methylation may hence be higher in 'soft' than in 'hard' (i.e., bicarbonate rich) freshwater systems. Compeau and Bartha[64,67] found no noticeable effect of chloride on Hg methylation, but it has been suggested that the negative charge of mercuric chloride species may reduce their availability to methylating bacteria. Using a mercury-specific bioindicator, Barkay et al.[20] demonstrated that uncharged $HgCl_2$ is indeed more bioavailable than anionic forms. On the basis of the data available to date, it would appear that the formation of charged sulfide and chloride complexes offers the best explanation for the apparently reduced methylation activity in estuarine and marine environments.

IV. SUMMARY AND CONCLUSIONS

Mercury methylation is mainly a microbially mediated process with methylcobalamin being the most likely environmental methyl donor. Abiotic methylation appears to be of minor importance, although its influence may be increased in organic-rich lakes. The precise mechanism of MMHg and DMHg formation is still unclear. Although it is generally believed that DMHg is the final product of Hg methylation, MMHg in the ocean appears to be produced mainly by decomposition of DMHg, indicating that there may be more than one methylation mechanism. More research is also needed into the factors controlling bacterially mediated and abiotic demethylation processes.

Mercury methylation and demethylation rates in aquatic systems are clearly influenced by both the speciation and biochemical availability of Hg and by a large number of environmental variables, many of which are interrelated. Biological activity, nutrient availability, pH, temperature, redox potential, and the presence of inorganic and organic complexing agents all have significant effects, with the net rate of MMHg production being determined by their complex interaction. Which factors dominate is likely to differ from ecosystem to ecosystem. Furthermore, the distribution of Hg between the sediment and water phases as well as the gaseous evasion of volatile Hg species is also influenced by environmental factors. The interrelatedness of these processes has often hampered research into the factors controlling Hg methylation. Nevertheless, certain general trends are apparent. MMHg formation is generally favored under anaerobic conditions, whereas aerobic conditions promote demethylation processes. In stratified lakes and estuaries,

MMHg formation occurs primarily at the oxic/anoxic interface, whether this occurs in bottom waters or surface sediments. Methylation in the ocean is not confined to low-oxygen zones, however, which is another indicator that there may be more than one mechanism for MMHg/DMHg formation. Seasonal variations in MMHg production appear to be mainly related to temperature and redox effects, as well as seasonal changes in productivity and hence nutrient availability. Moderately high temperatures have a stimulating effect on methylation, whereas demethylation processes are favored by lower temperatures. Lakewater acidification may lead to increased methylation in the water column, but in sediments methylation is generally found to be decreased, which may be due to a reduction in the activity of sulfate-reducing bacteria, or increased demethylation. It may also be that different mechanisms are responsible for Hg methylation in waters and in sediments, and there are indications that methylation in the water column may be abiotic and linked to particles. Studies investigating the effect of pH on Hg methylation should consider that increased MMHg concentrations in the water phase are likely to be partly attributable to increased desorption of MMHg from sediments at low pH.

Sulfur chemistry is a particularly important factor controlling methylation. Sulfate-reducing bacteria are important methylators of Hg in anaerobic sediments, and sulfate stimulates microbial Hg methylation at the typically low sulfate concentrations prevailing in freshwater systems. However, at high levels in reducing conditions methylation is inhibited due to sulfide formation, which may be one reason why MMHg levels in sediments rarely exceed 1% of the total Hg concentration. Recent studies have shown that the inhibitory effect of sulfide on Hg methylation is not due to HgS precipitation, but that sulfide lowers the availability of Hg for bacterial methylation by formation of less bioavailable charged Hg-S complexes.

The role of organic matter in the methylation of Hg is not well understood. Humic matter is an important factor controlling the solubility and mobility of Hg in natural waters. Organic nutrients generally stimulate microbial activity and hence Hg methylation, although they may also have an effect on bacterial demethylation activity. Direct abiotic methylation of Hg by humic and fulvic acids has also been reported. On the other hand, high levels of dissolved organic carbon appear to have a mitigating effect on both the production and bioaccumulation of MMHg due to Hg complexation, particularly in the neutral pH range. The formation and dissolution of Hg-OM complexes is pH sensitive, with complexation being reduced at low pH.

Unfortunately, despite a vast body of literature on the subject, we are still unable to predict Hg methylation rates and the likely effects of environmental perturbations on methylation and demethylation processes in aquatic systems. Owing to the complexity of processes in the natural environment, it is difficult to directly compare the results of the studies that have been published to date. Future laboratory-based studies of methylation/demethylation rates that address not only

the direct effects of environmental variables but that place particular emphasis on understanding how these factors interact would be desirable. These studies should aim to quantify Hg transformation rates at environmentally relevant concentrations, thereby providing a more realistic assessment of *in situ* rates than the traditionally large Hg additions. The effect of pH under oxic compared with anoxic conditions should receive particular attention. Further research is also needed on the binding and partitioning of both inorganic and MMHg, which is also influenced by the above-mentioned factors and that may to a certain extent confound the primary effects of these variables on methylation/demethylation rates. This work is particularly important if we are to find more effective ways of minimizing the ecological risk of mercury in the aquatic environment.

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CATCHMENT AREA COMPOSITION AND WATER CHEMISTRY HEAVILY AFFECTS MERCURY LEVELS IN PERCH (*PERCA FLUVIATILIS* L.) IN CIRCUMNEUTRAL LAKES

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Abstract. The environmental impact on the mercury level in perch (*Perca fluviatilis* L.) is examined using Partial Least Square regression (PLS) on 48 environmental descriptors assessing land use, various catchment area and lake characteristics, lake water chemistry, and fish stock. The lake specific intercepts of Hg content vs. fish length regressions are used to describe the Hg level in the fish. The Hg levels in perch from 78 circumneutral lakes were largely influenced by land use in the surroundings. Boreal forest lakes had the highest Hg burden in the fish, while fish from lakes heavily influenced by arable land possessed lower contents. The Hg levels also showed a negative relationship to the concentrations of dissolved ions and total nutrients in lake water, and to the perch growth rate, whereas the relationship was positive to the concentration of TOC/humic matter. Lake pH did not have any significant influence on the Hg content in perch in these circumneutral lakes. The Hg levels in perch from lakes surrounded by large amounts of wetland were less satisfactorily explained by the presently examined environmental descriptors, which suggests that the Hg burden in fish from these lakes are influenced by other factors.

Keywords: catchment area, fish, land use, mercury (Hg), partial least square regression (PLS), perch (*Perca fluviatilis*), pH, water chemistry

1. Introduction

High mercury levels in fish is a prolonged major concern for many areas in the boreal forest region of Sweden (Björklund *et al*., 1984; Lindqvist *et al*., 1984, 1991), Finland (Verta *et al*., 1986), Russia (Haines *et al*., 1995), Canada (Wren *et al*., 1991) and northern U.S.A. (Lathrop *et al*., 1989). The large reductions in Swedish Hg emissions during the 1970's and 1980's have still not resulted in any obvious decline in fish Hg levels. On the contrary, there might even have been a small increase in fish from lakes without any known direct Hg inputs (Håkanson *et al*., 1988; Lindqvist *et al*., 1991). This is probably caused by continued import of airborne Hg emissions from central Europe and Great Britain, and/or Hg leaching out from the catchment areas (Håkanson *et al*., 1990). Although the domestic Hg emissions are drastically reduced, Lindqvist *et al*. (1991) found that about 10 times more Hg was deposited on a typical Swedish forested catchment area than

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what was reaching the lake. This net accumulation in catchment areas implies that high mercury levels in lakes and aquatic organisms might be an even more serious problem in the future (Bishop *et al*., 1995).

Enhanced analytical capabilities of different Hg compounds during the last decade have enabled more accurate Hg budgets (Rudd, 1995). Hence it was clarified that the major Hg sources to lakes without any point discharge of Hg, are dry and wet atmospheric deposition. Though, only a minor fraction of this atmospheric Hg is in methylated form (Downs *et al*., 1998). This implies that the (mono)methylmercury (MeHg), which is the most readily biomagnified Hg form in aquatic ecosystems and the most common form in fish (Westöö, 1967; Bloom, 1992), generally is produced within the lake ecosystems (including the catchment areas). Two major sites of methylation are recognised: (1) wetlands (St. Louis *et al*., 1994, 1996; Verta *et al*., 1994; Bishop *et al*., 1995; Branfireun *et al*., 1996; Kelly *et al*., 1997); and (2) lake sediments (Jensen and Järnelöv, 1969; Ramlal *et al*., 1993). Occasionally, significant methylation also is found in the water column, mainly in connection to suspended particles (Henry *et al*., 1995; Matilainen, 1995).

The catchment area affects the Hg bioavailability in aquatic ecosystems mainly by governing the Hg transport from terrestrial soils to lakes, and via altering the chemical properties of Hg and thereby changing its mobility. The Hg transport to lakes is largely governed by co-transport with humic matter (Meili *et al*., 1991; Mierle and Ingram, 1991; Johansson and Iverfeldt, 1994). Chemical alteration to more mobile forms, like MeHg, will increase the flux of Hg to lake ecosystems and thereby enhance the load of this highly bioavailable Hg form (Lee *et al*., 1994).

Mercury cycling studies in aquatic ecosystems has primarily been focused on areas affected by acidification, as such lakes have been found to exhibit high Hg levels in fish (Björklund *et al*., 1984; Lindqvist *et al*., 1984; Håkanson *et al*., 1990; Turunen and Alm, 1990). Only a few studies have been accomplished in circumneutral or alkaline lakes, notably in Canada and northern U.S.A. (MacCrimmon *et al*., 1983; Lathrop *et al*., 1989; McMurtry *et al*., 1989; Wren *et al*., 1991). In Sweden there seems to be a sampling bias towards acidic lakes (Sonesten, 2000, 2001), chiefly because the problem with high Hg levels in biota from circumneutral lakes are considered to be low (Andersson *et al*., 1987; Håkanson *et al*., 1988). In this study I test whether the assumed low Hg level in such lakes is true, and I make an assessment of the environmental impact on the Hg level in fish from circumneutral or slightly alkaline lakes. This study is focused on the basal Hg level in perch (*Perca fluviatilis* L.), but comparisons are also made to the level in roach (*Rutilus rutilus* L.) caught within the same survey (Sonesten, 2001). The perch is well known to change its food items during its lifetime. Principally, from being zooplanktivorous, it turns successively to feed on zoobenthos and finally becomes a piscivorous species when it is sufficiently large (Collette *et al*., 1977). Although, there are some recent studies that indicate piscivory, and especially cannibalism, to be important during the first months after the perch is hatched, at least in high fish abundancies in laboratory experiments and ponds (Brabrand 1995, 2001). The

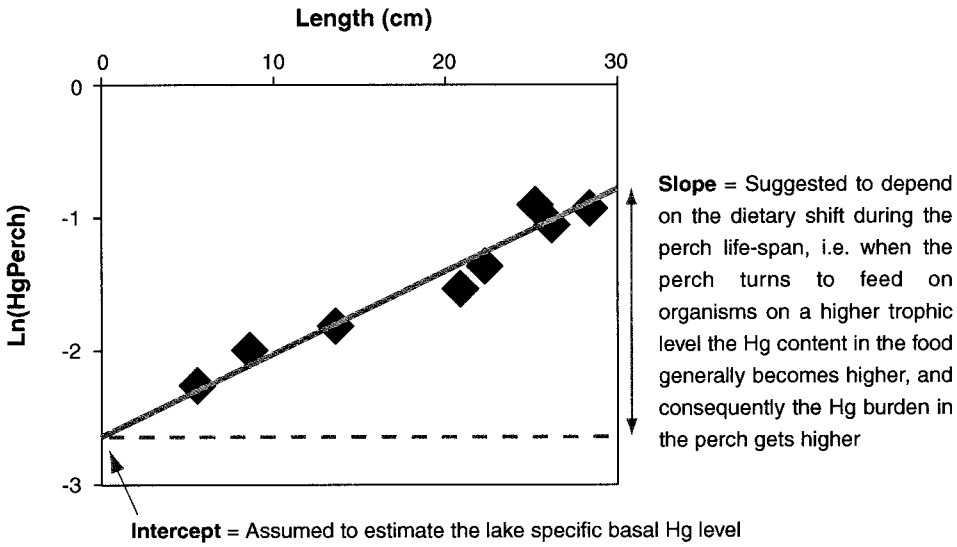

Figure 1. The linear regression on Hg content and fish length in perch from lake Vikasjön showing the separation into the intercept, which estimates the lakespecific basal Hg level in perch, and the regression slope that depends on the Hg bioaccumulation during the perch lifetime.

degree of this behaviour in lakes is not clear, as it has only been indicated by size-dependent mortality studies (op. cit.). Also, if this presumed early piscivory do have any effect on the Hg content in the perch larvae is still not shown, and no comparisons on the Hg content in perch larvae and other food items are known to have been published. However, by changing food items during its lifetime the perch successively feeds at different trophic levels and hence it is an exceedingly interesting link in the transfer of mercury within the food web. The lake specific basal Hg levels in perch used in this study are obtained by splitting lake specific linear regressions of Hg content in perch vs. fish length into intercepts and slopes, where the intercepts are estimates of the Hg level and the slopes are assessing the Hg bioaccumulation (Figure 1). The ontogenethic diet chift in perch has been suggested to be the main contributor to the Hg bioaccumulation, as there is no significant environmental impact on the regression slope of the Hg content vs. fish size (L. Sonesten, manuscript).

2. Material and Methods

Total mercury level in perch (*Perca fluviatilis* L.), from a regional survey of 78 lakes in the county of Uppsala, Sweden, is related to 48 environmental variables describing land use in the catchment area, lake morphometry, lake water chemistry, and fish landings from the fish survey (Table I).

TABLE I

Definitions[a] and statistics of environmental variables used to analyse the environment impact on the Hg levels in perch from 78 lakes in the County of Uppsala, Sweden, 1991–1993

Variable	Unit	Mean	Min	Max	Definition
HgPerch, ln(mg Hg kg^{-1} ww)			–4.98	–1.21	The intercept of the lineary regressed Hg content in perch vs. fish length
HgRoach, ln(mg Hg kg^{-1} ww)			–3.24	–1.17	The geometric lake mean Hg content in roach
X					X co-ordinate according to the Swedish National Grid
Y					Y co-ordinate according to the Swedish National Grid
Z					Distance from the NW–SE separator (cf. Figure 2)
m.a.s.l.	m	26	0.3	88	Meters above sea level
TotAltDiff	m	32	5	110	Altitude difference within the whole catchment area
AltDiff	m	27	5	75	Altitude difference within the catchment area (excl. subcatchments)
TotCatchArea	km^2	60	0.16	704	The surface of the whole catchment area
CatchArea	km^2	15	0.16	103	The surface of catchment area
TotCatch/lake		99	2.93	1842	The ratio between the whole catchment and lake areas
Catch/lake		26	2.93	205	The ratio between the catchment area and lake area
Forest%	%	76	34	95	Forest coverage of the catchment area
Arable land%	%	10	0	65	Arable land coverage of the catchment area
Wetland%	%	14	0	57	Wetland coverage of the catchment area
Urban%	%	1	0	11	Coverage of other kinds of land use of the area (mainly urban areas)
TotForest%	%	75	40	96	Forest coverage of the whole catchment area
TotArable%	%	105	0	48	Arable land coverage of the whole catchment area
TotWetland%	%	13	0	57	Wetland coverage of the whole catchment area
TotLakes%	%	2	0	12	Lake coverage of the whole catchment area

TABLE I
(continued)

Variable	Unit	Mean	Min	Max	Definition
TotUrban%	%	1	0	8	Coverage of other kinds of land use of the whole catchment area
Lake area	km^2	0.97	0.05	9.42	Lake area
Lake volume	Mm^3	2.08	0.03	26.5	Lake volume
Lake length	km	2.0	0.25	15	Maximum lake length
Lake width	km	0.69	0.12	2.6	Maximum lake width (perpendicular to max. length)
Max depth	m	3.7	1	12.5	Maximum lake depth
Mean depth	m	1.9	0.5	6.4	Average lake depth
VD		1.63	0.51	2.43	Volume development = 3 $*$ mean depth/max depth (describes lake shape)
Tr	days	189	1.6	1570	Theoretical lake water retention time
Ca	$\mu eq\ L^{-1}$	1110	170	2560	Total amount of Ca[b]
Mg	$\mu eq\ L^{-1}$	178	40	660	Total amount of Mg[b]
K	$\mu eq\ L^{-1}$	28	1	84	Total amount of K[b]
Na	$\mu eq\ L^{-1}$	243	77	765	Total amount of Na[b]
Fe	$\mu eq\ L^{-1}$	4.1	0.6	21	Total amount of Fe[b]
pH		7.7	6.5	8.8	pH[c]
Colour	mg Pt L^{-1}	92	13	260	Water colour measured on filtered water (Whatman GF/C) with comparator 1991–1992 and calculated from absorbances 1993 (420 nm)[c]
Conductivity	mS m^{-1}	19.3	4.4	49.3	Water conductivity[c]
TotP	$\mu g\ P\ L^{-1}$	34	3	275	Total amount of P in unfiltered deep frozen water. Molybdate reactive phosphate after $K_2S_2O_8$ oxidation
TotN	$\mu g\ N\ L^{-1}$	1020	405	2980	Total amount of N in unfiltered deep frozen water. Measured by second derivate spectroscopy
TOC	mg L^{-1}	18.5	5	39.8	Total amount of organic carbon after H^+ and aeration of unfiltered deep frozen water
Dec O_2	mg L^{-1}	8.1	0.2	12.6	O_2 content at 0.5 m depth in December 1988 (after 1 month of ice coverage as a measure on the capacity to withstand oxygen depletion)
TotCPUE	kg	3.7	0.33	17.0	Total fish catch per unit effort
TotNCPUE		86	8.8	384	Average total number of fish per unit effort

TABLE I
(continued)

Variable	Unit	Mean	Min	Max	Definition
CPUE roach	kg	0.8	0.0	2.7	Catch of roach (*Rutilus rutilus*) per unit effort
NCPUE roach		39	0.0	302	Average number of roach per unit effort
CPUE perch	kg	0.9	0.07	3.1	Catch of perch (*Perca fluviatilis*) per unit effort
NCPUE perch		31	1.0	215	Average number of perch per unit effort
Growth rate	mm yr^{-1}	39	24	53	Perch growth rate from linear regression of fish length vs. fish age
No. species		6.3	2	13	Number of fish species caught

[a] Distinction is made between 'whole catchment area', which includes subcatchment areas belonging to eventual upstream lakes, whereas 'catchment area' refers to the area exluding eventual subcatchments.
[b] Measured on unfiltered deep frozen water by atomic absorption spectrophotometry.
[c] Measured at 25 °C on cold stored water (<8 °C) within 48 hr.

2.1. AREA DESCRIPTION

The county of Uppsala is situated just north of Stockholm, Sweden (Figure 2). The area belongs to the boreal forest region, but in contrast to most other parts of the country, calcareous moraines heavily affects the soils (Ingmar and Moreborg, 1976). Consequently, even humic lakes are predominantly non-acidic, with high concentrations of dissolved ions. A comprehensive description of the area can be found elsewhere (Sonesten, 2001).

The county can be divided into three different physical geographic regions (CABU, 1986; SNA, 1992). The southern part is a fissure-valley terrain with clayey valleys, lakes and streams. Coniferous forests and arable land dominate the mosaic-like landscape. The eastern part of the county is an extension of the Stockholm and Roslagen archipelagos with a hilly fissure-valley landscape dominated by coniferous forests. The north and north-western part of the county is a plain, belonging to the transitional zone to the Taiga terrain, dominated by coniferous forests, large mires and eskers.

Two historically important point discharges of Hg emissions to the air are identified, the waste incineration and peat combustion plant in Uppsala and a chlor-alkali plant just north of the county (Figure 2). The waste incineration and peat combustion plant was responsible for large emissions to the air during the 1960's–1980's, resulting in raised Hg levels in terrestrial mosses in the main trajectory to Northeast (Skye and Lindman, 1997), which is an area virtually without lakes. The emissions were effectively reduced in the mid 1980's due to enhanced treatment of com-

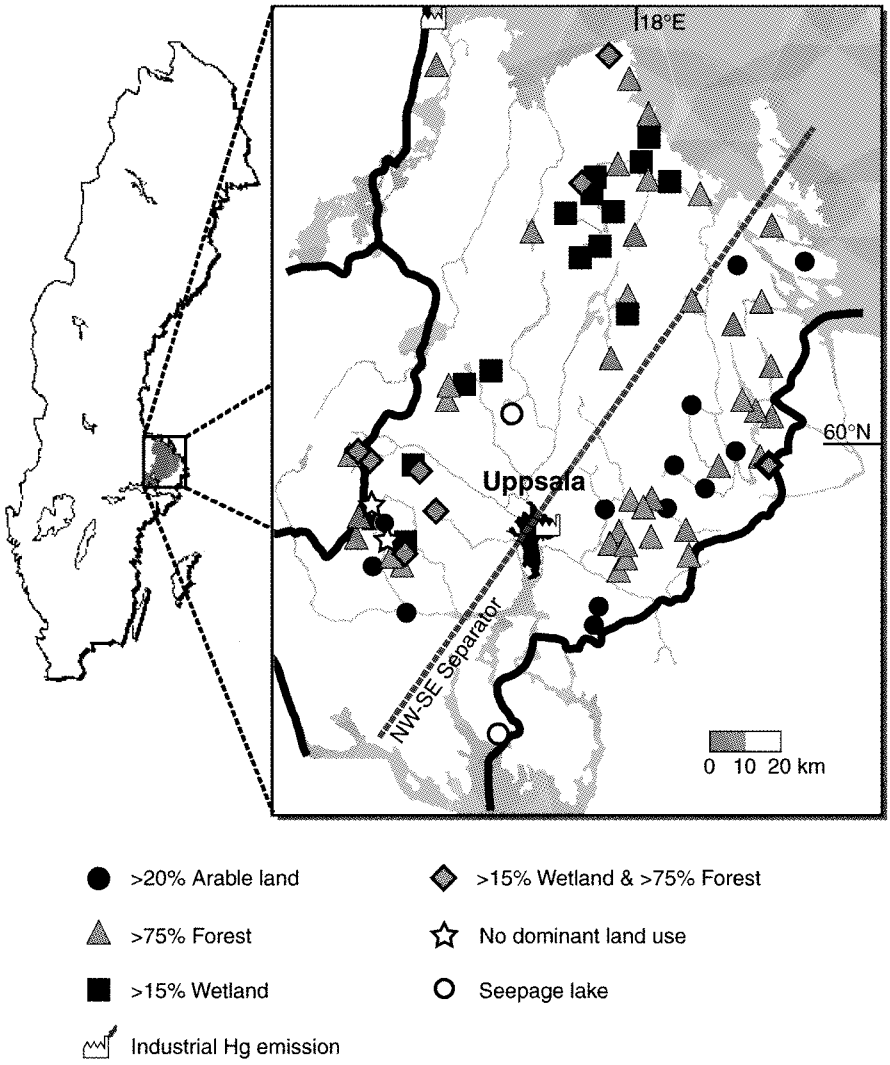

Figure 2. The geographic location of investigated lakes in the County of Uppsala, Sweden, 1991–1993. Lakes are marked according to main land use in their catchment areas. The NW–SE separator, used to separate between two geologically distinct areas, is also shown.

bustion gases (op. cit.). The chlor-alkali plant has been responsible for large Hg emissions to the air as well as to the Baltic sea (Lindqvist *et al.*, 1984). As the dominant winds in the area are from the Southwest (Skye and Lindman, 1997), most of these emissions ought to have blown out over the Baltic Sea. Additionally, the effect of these two local Hg sources on the investigated lake ecosystems are believed to be fairly small, since the impact from comparable sources generally have been detectable only in the close vicinity of the outlets (<5–10 km), even

though the major part of the emitted Hg precipitated far away from the outlets (Lindqvist *et al*., 1984; Lodenius, 1994).

2.2. Fish samples

Perch were caught by means of a standardised fishing during 1991–1993, starting in the end of July and continuing to the beginning of September each year (Nyberg, 1999). The fishing effort was standardised in relation to lake morphometry to give comparable landings, and benthic multi-mesh gillnets were used to get representative specimens of varying size (Nyberg and Degerman, 1988). The fish were handled, and skin-free dorsal muscle samples were taken and analysed for Hg content by CV-AAS, according to Sonesten (2000, 2001). The Hg analyses were made on lyophilised samples, but the Hg contents were back-calculated to wet weights (w.w.) before use. Additionally, the opercula of all specimens were used for age determination, which was later used to calculate perch growth rate.

2.3. Environmental data

Data on land use and lake morphometry is taken from the literature (Brunberg and Blomqvist, 1998 and ref. therein), with some minor additions and corrections. Distinction is made between the whole catchment area and the part closest to the lakes, which is defined as the catchment area excluding eventual sub-catchments of upstream lakes. This distinction is done because the immediate surroundings potentially have the largest influence on lakes, especially in headwater lakes, and lakes with long water retention time. The lake water chemical composition was measured on subsurface samples (0.5 m) collected concomitantly to the fishing. The capacity to withstand oxygen depletion during winter time is assessed by using the dissolved oxygen content in the lakes, after one month of ice cover, from a survey in 1988 (Sonesten, 1989). The chemical analyses were done according to Swedish Standard Methods or similar methods described in Goedkoop and Sonesten (1995).

The amount of fish caught per unit effort (CPUE) in the standardised fishing is used as an estimate on fish biomass. The landings are given as the total number and weight of all species, as well as separate measures for perch and roach (*Rutilus rutilus* L.). The roach biomass is included because small specimens are important as food for large perch and the roach biomass is also an estimate of lake eutrophication (Persson *et al*., 1991).

The lake X and Y co-ordinates within the Swedish National Grid, as well as its distance (Z) to the NW–SE separator (Figure 2), describes its geographical location. The separator divides the county into two geologically distinct areas (Sonesten, 2001). One area is the hilly fissure-valley landscapes of the southern and eastern parts of Uppsala County, and the other area is the plain with coniferous forest, mires and eskers in the north and north-western part of the county. The separator also describes the lake ontogenesis in the area, as the northwestern part

emerged from the Litorina Sea, a predecessor to the Baltic Sea, substantially earlier than the southeastern area (cf. Segerberg, 1999).

2.4. LAKE SPECIFIC MERCURY ESTIMATE

In this study, the lake specific intercept of the (linear) regression line of mercury content in perch vs. fish length, is used as a typical lake specific estimate of the basal Hg level in the perch. Some fish species, particularly carnivorous species like perch, possess a prominent Hg and fish-size covariation, which has to be taken into account during the evaluation process. Most frequently the Hg content in fish is normalised to some arbitrary fish size or the size is treated as a covariate in an analysis of covariance (ANCOVA), to circumvent the fish-size effects. In some occasions, fish within a narrow size range (usually age 0^+ or 1^+) is used to avoid the size covariation effects (e. g. Nilsson and Håkanson, 1992; Post *et al.*, 1996). The practice of normalising the Hg content or using ANCOVA's have been criticised, since the fish size covariation may not be completely removed (Somers and Jackson, 1993; Tremblay *et al.*, 1998; Sonesten, 2000; L. Sonesten, manuscript). The remaining size dependency after normalisation is an effect of non-parallel regression slopes of Hg content vs. fish size when different lakes are compared. This has the serious implication that the outcome of the study might merely be an artifact depending on the fish size used (op. cit.). It is assumed that the intercepts used in this study are good estimates of the basal Hg levels in the fish and they are believed to estimate the Hg content in age 0^+ perch (Sonesten, 2000; L. Sonesten, manuscript).

2.5. STATISTICAL EVALUATION

The impact of the different environmental variables on the mercury level in perch are statistically investigated by applying Partial Least Square regression models (also called Projections on Latent Structures or simply PLS) to the data set. PLS is a biased multivariate regression method similar to Principal Component Regression (PCR) (Höskuldsson, 1988; Garthwaite, 1994). The PLS components are similar to the principal components used in the PCR-analysis. However, there is one principal difference between the two different kinds of latent components. The PLS is a biased method as it uses the information in the response variable(s) to extract only the useful variance among the explanatory variables to form its components, i.e. the PLS maximize the covariance between the explanatory and response variable(s). This has the implication that latent components of the PLS analysis are usually smaller that comparable PCA components, but on the other hand they gives a better relationship between the X-and Y-spaces. In contrast, the PCA components of the PCR method are formed, irrespective of the response variable, in a previous principal component analysis. This procedure might even obstruct the analysis if the first PCA components are irrelevant to the response variable. Furthermore, the PLS and the PCA methods also produce two similar plots, the X-score and the

loading plots, which are vital for model evaluation. These plots are complementary and superimposable on each other. The X-scores project the relationship between observations (lakes), i.e. observations close to each other in the plot are comparatively more similar than distant observations. The loadings show the relationship between the variables. In contrast to PCA, there are two kinds of loadings in PLS, the analogue to the PCA loadings and the PLS weights. Most frequently, the weights are used, as they summarize the correlation structure between the explanatory and response variables (environmental predictors and ^{137}Hg levels, respectively). In addition to the PLS weights there are two other possibilities for model interpretation, especially suited for complex models (op. cit.). The PLS regression coefficients are summarising the information over all PLS dimensions (components), which gives one vector of model information per response variable. The VIP (Variable Influence on Projection) gives a summary of the information in the PLS weights and regression coefficients, i.e. it is pooling the information over all Y-variables and PLS dimension, resulting in one VIP-value for every explanatory variable. In comparison, the PLS weights gives both the correlation structure (multi-dimensional) and the strength. The regression coefficients give the direction (one-dimensional) and strength of the influence, whereas the VIP only gives the strength of the relationship. The VIP might be used to find the most significant explanatory variables to the model. Unfortunately, no defined limit exists for the statistical significance, but limits of 0.7–0.8 or 1.0 are often used (Eriksson *et al.*, 1999). In this study significant explanatory variables is defined as having a VIP > 1.0, a moderately significant variable having VIP = 0.8–1.0, whereas VIP < 0.8 signifies low importance.

In the model presented here, the environmental predictors are kept untransformed, as transformations did not significantly improve the model. All statistical analyses are made on predictors that are mean centred and scaled to unit variance (autoscaled). This gives all the predictors the same weight in the analyses and thereby they have the same influence on the analyses, even though they are not measured on the same scale (Geladi and Kowalski, 1986). Predictive ability of the different PLS models are estimated by cross-validation (Eriksson *et al.*, 1995; Lindgren *et al.*, 1996). Permutation tests are used to avoid spurious results caused by serious inherent background correlation. In the permutation test, the data set is analysed for latent structures by randomised reordering the response variable 25 times and retesting the model with cross-validation on every new data set. The background correlation is given by the intercepts of the permuted R^2 and Q^2 (cross-validated R^2) regressed against the R^2 of the original Hg levels and the scrambled levels (Lindgren *et al.*, 1996). The PLS models are made using Simca-P® 7.0 (Umetrics AB) and SAS® (V612 for the Macintosh, SAS Institute Inc.).

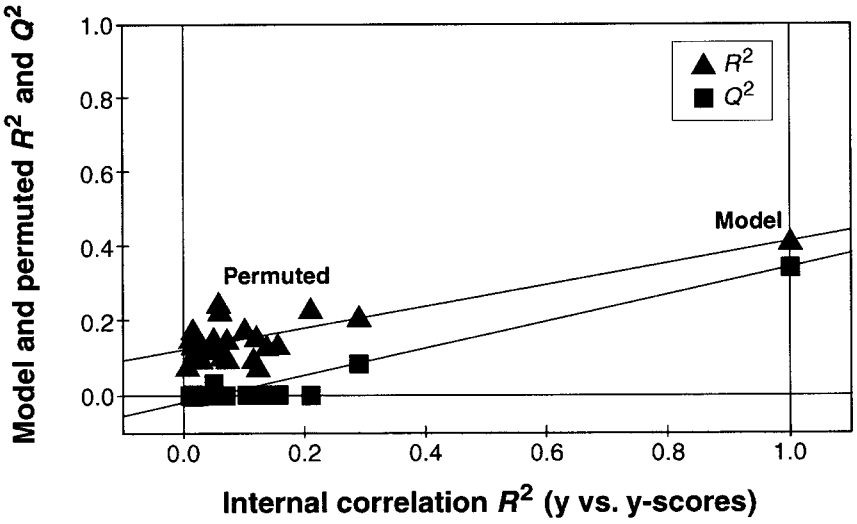

Figure 3. The PLS model on Hg levels in perch vs. 48 environmental variables is well separated from any eventual inherent background correlation, as measured by the intercepts of the permuted R^2's and Q^2's regressed against the observed Hg levels and the permuted levels (0.12 and –0.02, respectively).

3. Results and Discussion

In general, the Hg content in perch was found to be high. Out of the 78 lakes investigated, 51 lakes had at least one perch sample with a Hg content exceeding 0.5 mg Hg kg^{-1} (w.w.). Hence, in a majority of lakes the Hg concentration exceeded the internationally most common food consumption advisory level, which is also the Swedish national limit for selling the perch (NFA, 1996). Samples exceeding the Swedish food consumption advisory level 1.0 mg Hg kg^{-1} (w.w.) were found in 19 of these lakes. The range of the 573 fish samples analysed was 0.02–2.42 mg Hg kg^{-1} (w.w.), with an average content of 0.31 mg Hg kg^{-1} (Table II). Generally the Hg levels were low, in this study 90% of the samples had a content within 0.05–0.69 mg Hg kg^{-1} (w.w.). Though, high Hg levels were often found in a few (large) specimens. The observed Hg levels in perch are well within the range of other studies on Hg content in perch in Northern Europe (Table II). Great care should though be taken when comparing different data sets because of the strong covariation of the Hg content with fish size, implying that comparisons have to be made between fish of similar size.

3.1. PLS MODELS EVALUATING THE ENVIRONMETAL IMPACT ON Hg LEVELS IN PERCH

The environmental impact on the mercury level in the perch (as measured as the intercept of the lake specific linear regression of Hg content in perch vs. fish

TABLE II

Mercury content in perch (*Perca fluviatilis* L.) in European lakes and reservoirs, including the present study

Hg content (mg kg^{-1} ww)		Fish size	No. of lakes	Country	Reference	Comments
Lake average	Sample range					
0.35–1.4	0.12–2.6	?	20	Finland	Verta *et al.*, 1986	Acid and brownwater reservoirs
	0.04–0.4	'Small'	8	Sweden	Lindqvist *et al.*, 1991	Slightly acid brown water lakes
	0.12–1.2	'Large'	8	Sweden	Lindqvist *et al.*, 1991	As above
	0.04–0.29	age = 1^{+}	11	Sweden	Paulsson and Lundbergh, 1991	Acid brown water lakes
0.05–0.45		10 g	76	Sweden	Nilsson and Håkanson, 1992	Mainly oligotrophic softwater forest lakes
	0.03–1.09	70–780 g Mainly >200 g	44	Sweden (County of Stockholm)	Sonesten, 1993	Mainly circumneutral lakes
≈0.2–1.1		10–100 g	6	Sweden	Andersson *et al.*, 1995	Acid lakes before liming
0.08–0.8		50 g	26	Russia	Haines *et al.*, 1995 (pH 4.5–10.0)	Mainly acid softwater forest lakes
0.29–0.35		?	2	Czech Republic	Svobodová *et al.*, 1999	Reservoirs (pH 6–7.3)
	0.02–2.42	1–1160 g	78	Sweden (County of Uppsala)	**Present study**	Circumneutral forest and plain country lakes
	0.02–0.66	<50 g	78			
	0.08–2.42	>200 g	78			

length) was analysed by several PLS models describing different features as spatial grouping and potential outliers. As all models were consistent regarding the major environmental influence in explaining the observed mercury levels in perch, only the simplest model will be presented here. All models were also consistent in explaining about 41–44% of the variation in Hg level in perch, using about 24% of the variation of the environmental variables (Table III). This illustrates how PLS uses only a limited but significant amount of information from the X-matrix, which is a great advantage in comparison to ordinary multiple linear regression techniques (MLR). The MLR would incorporate the remaining 76% of the variation in the x-matrix, which was found to be excessive in the PLS analysis. The result would be addition of 'noise' into the model and, consequently, it becomes 'overfitted'. This is indicated by the large difference of the MLR model R^2 and R^2_{adj} (0.77 and 0.42, respectively). On the contrary, the cross-validation of the PLS model, which gives the predictive ability and the stability of the model, agrees well with the explained variance ($R^2 = 0.41$, $R^2_{adj} = 0.40$ and Q^2 (i.e. cross-validated R^2) = 0.34). If more components are added to the model, the predictive ability and the model stability are drastically reduced (Table III), which indicates overfitting by noise addition. Actually, a full ranked PLS model, i.e. the same number of latent components as X-variables, would be the same as the MLR model. The model R^2 and Q^2 are also well separated from any spurious background correlation, caused by an inherent structure in the environmental data, as the intercepts of the permuted R^2's and Q^2's (0.12 and –0.02, respectively; Figure 3) are well separated from the model. Even though the model contains only one significant PLS component, two-dimensional plots of the X-scores and the PLS weights are used to increase the interpretability of the model. The significant first component is of course emphasized in the interpretation.

3.2. Land use effects on Hg in perch

Among the X-scores, a pattern showing the strong impact of land use in the lake catchment areas is eminent (Figure 4). All lakes but four have at least 50% of their catchment area covered by forests, but lakes that are comparatively more affected by arable land are generally found in the left part of the X-scores plot, whereas lakes highly influenced by wetlands in their surroundings are on the right side. Three lakes are detected as potential outliers by their X-scores (Figure 4), but as they do not have any exceptionally strong influence on the analysis, they are considered as lakes in the margin of the investigated lake types and therefore kept within the model. Lakes with high amounts of wetlands in their catchment areas deviates from the model, especially the lakes in the lower right corner of the X-scores plot (Figure 4). These lakes probably exert some particular properties that are not fully described by the presently investigated environmental variables. This phenomenon is also seen when the environmental impact on the Hg content in roach (*Rutilus rutilus* L.) is analysed (Sonesten, 2001). It also illustrates the

TABLE III

Percent variation explained (R^2) and predictive ability (Q^2) of the PLS model on Hg levels in perch vs. 48 environmental predictors (cf. Table I). The variation in the X-matrix (X) used by the model is also given

PLS	Percent variation			
component	X	R^2	R^2_{adj}	Q^2
1	24	41	40	34
2	29	59	58	22
3	36	65	63	<0
4	42	67	66	<0
5	48	69	67	<0
6	54	70	68	<0

importance of the surrounding soils on the Hg turnover in lake ecosystems, which warrants further studies, especially on the influence of different kinds of wetlands on Hg bioavailability.

3.3. Environmental influence on Hg level in perch

Five distinct functional groups of the most important environmental variables are apparent in the PLS weights plot (Figure 5) and the PLS regression coefficients (Figure 6). These groups describes:

(i) the spatial location (X and Y co-ordinates and Z [cf. Figure 2]);
(ii) the amount of dissolved ions in lake water (Conductivity, Ca, Mg, Na and K);
(iii) the lake nutrient status (Total P and N, and fish stock characteristics);
(iv) main land use (arable land, forests, wetlands and urban areas);
(v) the influence of humic matter (water colour, TOC and Fe).

The importance of the separate environmental variables are illustrated by the PLS regression coefficients for the first significant component (Figure 6). The major groups of explaining factors are the same groups as are found for the Hg content in roach (Sonesten, 2001). Also, the directions of their influence in the weights plot are virtually the same as in the Hg in roach model (cf. Sonesten, 2001), which strengthens the accuracy of the two different models, as well as the interpretation of the underlying causes to the observed Hg levels in the fish. Additionally, the most important single factor in explaining the Hg level in perch is the Hg content in roach

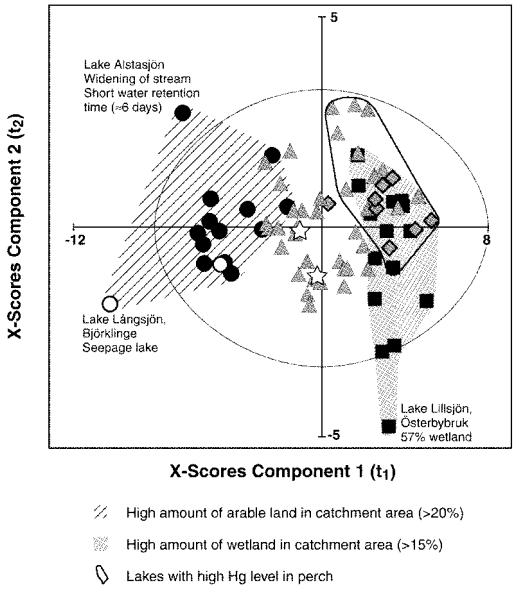

Figure 4. Similarities between the lakes, as given by the X-scores (t_1, t_2) for the 1st and 2nd latent PLS components of the model on Hg levels in perch vs. 48 environmental variables. The ellipse shows Hotelling's T^2 with significance level $p = 0.05$. Symbol explanations as given in Figure 21. Note! The figure is complementary to Figure 4.

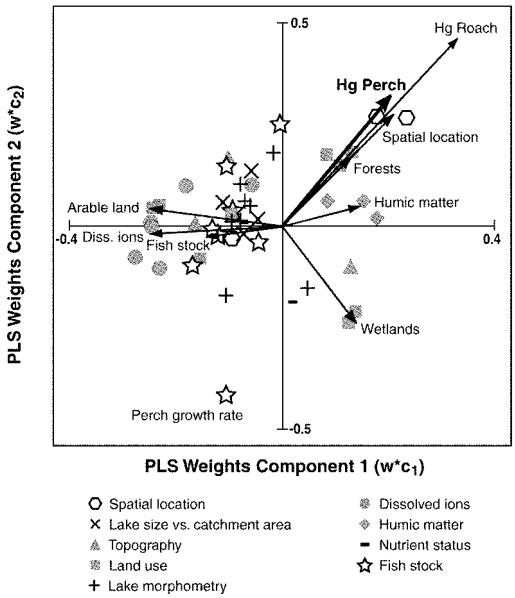

Figure 5. The correlation structure between environmental predictors and the observed Hg levels in perch, as given by the PLS weights (w^*c_1 vs. w^*c_2) for the 1st and 2nd latent PLS components. The most important environmental variables are subjectively grouped into functional groups (arrows) giving the direction and an approximation of the strength of the correlative relationship. Note! The figure is complementary and superimposable to Figure 4.

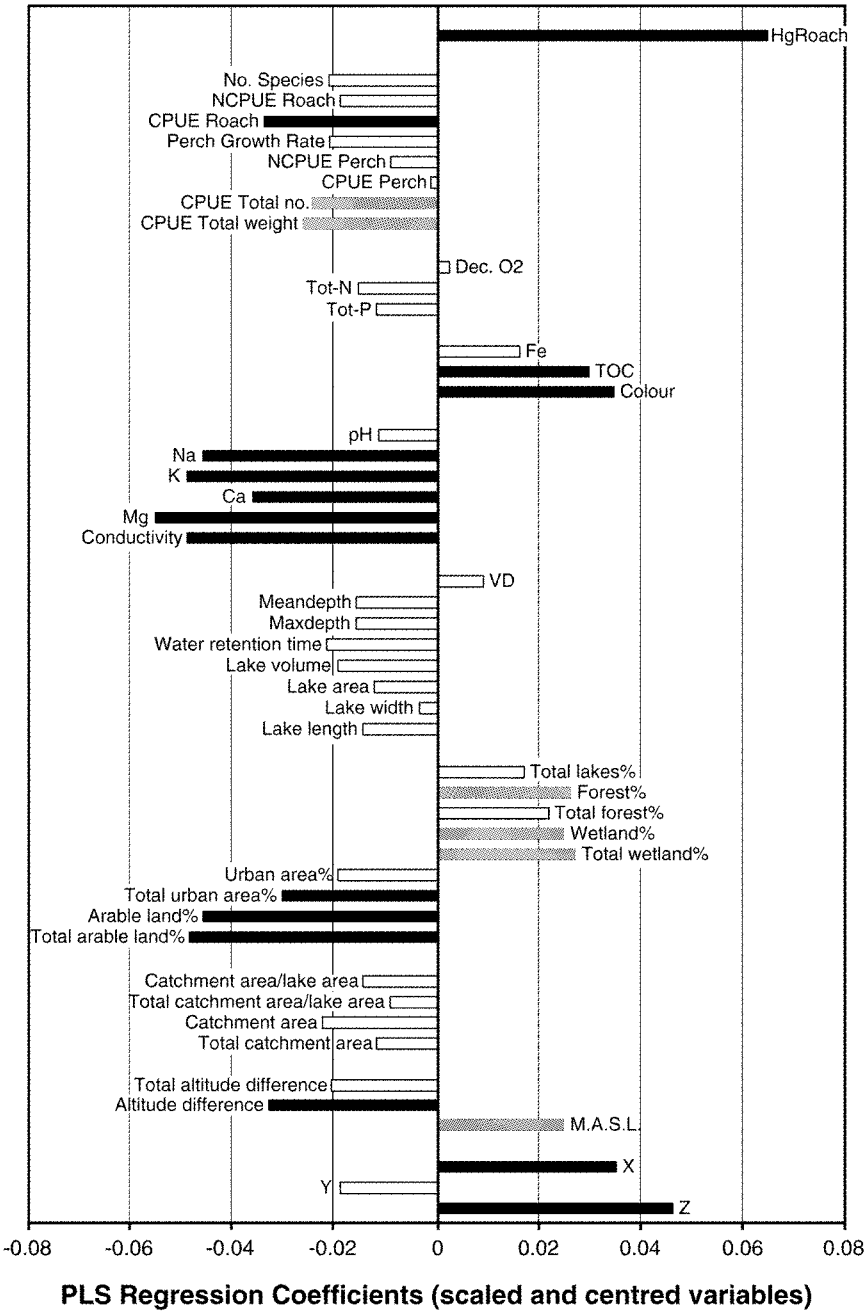

Figure 6. The PLS regression coefficients for the significant first PLS component of the Hg levels in perch vs. 48 environmental variables. The coefficients are on autoscaled variables for immediate comparison of influence. Black bars illustrates highly significant influence on the model (Variance Influence on Projection, VIP > 1.0); Gray bars shows moderate significant influence (VIP = 0.8–1.0); White bars indicates low influence (VIP < 0.8).

(Figures 5 and 6). Due to the similarities of the two models, this highly significant influence is interpreted to be a measure of the 'Hg burden within the lake biomass' and not necessarily, a measure of the Hg content in the perch food items. This is assumed as the investigated Hg levels (the intercepts of the Hg vs. length regressions) in perch are believed to estimate the Hg content in young-of-the-year specimens, which generally are believed to still have not turned to piscivory (Persson *et al.*, 2000).

High Hg level in fish is a common problem, especially in low productive (acidic) dystrophic softwater lakes, all over the boreal forest zone (Björklund *et al.*, 1984; Verta *et al.*, 1986; Meili, 1994; Wren *et al.*, 1991; Haines *et al.*, 1995; Sonesten, 1993, 1997, 2001). Due to the severe multicollinearity between the components in the humus, dissolved ions, pH, available nutrient complexes, it is difficult to reveal the causal effect(s) on the fate of Hg in lake ecosystems (Meili, 1994). A serious problem is the chelating properties of humic substances binding phosphorous and cations, e.g. Ca^{2+} and Mg^{2+} (cf. Hessen and Tranvik, 1998). An additional complication is the coagulative properties of Ca^{2+} and Mg^{2+} on humic substances, resulting in precipitation of the complexes (Stumm and Morgan, 1981). Altogether, these negative relationships between humic matter and P, Ca and Mg, makes dystrophic lakes generally have low amounts of dissolved ions (low salinity) and low amounts of easily bioavailable nutrients. Accordingly, it also makes high salinity lakes to be predominantly low in humic DOC (Stumm and Morgan, 1981). The deviant behaviour of wetland lakes in the present study, suggest that there are at least two, possibly three, co-occurring processes governing the observed Hg levels in fish. The two most plausible processes are the co-transport of Hg with humic substances from surrounding soils and biodilution. The Hg co-transport with humic substances is suggested to cause the high Hg level in fish from brownwater lakes (Mierle and Ingram, 1991) and biodilution of methylmercury is suggested to be the reason for the low levels in eutrophic lakes, due to the higher total biomass that the Hg is distributed within (Lindqvist *et al.*, 1984; Meili, 1994). A third possible process may be acting upon the wetland lakes. These lakes can be classified, by their PLS weights and regression coefficients (Figures 5 and 6), as being predominantly small, shallow lakes at comparatively high altitude with small altitude differences within the catchment areas. As mentioned before, these lakes are not completely modelled by the present study, and needs to be investigated further.

In dystrophic ecosystems, an overall high Hg transfer from the surroundings results in a high total amount of Hg in the lakes. A major part of this Hg is inorganic, but potentially available for methylation and bioaccumulation. In many recent studies wetlands *per se* have been found to be a major source of methylmercury, especially in headwater lakes with comparatively short turnover time (St. Louis *et al.*, 1994; Verta *et al.*, 1994; Bishop *et al.*, 1995; Branfireun *et al.*, 1996; Kelly *et al.*, 1997), but there are large differences in methylmercury output from different kinds of wetlands (St. Louis *et al.*, 1996). These studies also have revealed the importance of the methylating and demethylating capabilities of wetlands in changing the

Hg bioavailability within the systems. Consequently, the final amount of Hg that reaches the biota will depend on the Hg bioavailability, which in turn is dependent on the net methylation capacity within the whole system. Additionally, both the bioavailability and the methylating/demethylating capacity are also intricately affected by the amount of dissolved organic matter (DOC) in the lake water, but this subject is not completely revealed and beyond the scope of this study.

The organic-rich topsoils of arable land in this region contains on average more Hg (10–15 kg Hg km^{-2}; SCB, 1990; Klang and Eriksson, 1997), than do the corresponding mor layer of forested soils (2–2.5 kg Hg km^{-2}; Nilsson *et al.*, 1989). This suggests that Hg to a larger extent is retained in cultivated soils, whereas the Hg is more readily leached out from forested soils. This finding, together with the strong impact of land use on the basal Hg level in fish, suggests that the transport of Hg from the catchment area is crucial to the observed high Hg levels in fish in boreal forest lakes. At the moment, no data is available on Hg concentrations in water or various parts of the catchment areas. Instead, this study reflects the net effects of the different processes that affect the Hg levels in perch. Altogether, this strengthens the earlier postulation that more research is needed to elucidate the influence of surrounding catchment areas, and especially the wetlands, on Hg levels in fish. Such an investigation should preferably be made in a few typical catchment areas, and should include bioavailable Hg concentrations in water and Hg fractions in surrounding land.

3.4. Lack of lake pH effect on Hg in perch

Interestingly, lake pH is shown to have only a limited impact on the Hg level in perch (Figure 6). The possible effects of lake acidity on Hg in living organisms are exhaustively investigated in other studies, but with very divergent results (cf. Richman *et al.*, 1988; Winfrey and Rudd, 1990; Downs *et al.*, 1998). The causal impact of lake pH on Hg turnover in lakes is therefore questioned and a plausible explanation to the occasionally observed relationship might be the covariation of pH with lake water colour and productivity (Meili, 1994). Possibly, the very divergent results could be due to the fact that, in most studies correlations or (stepwise) multiple linear regressions (MLR) are used to analyse the environmental impact on the Hg content in biota. These methods are very sensitive to intercorrelations between the variables and causal effects are hard to reveal. MLR is even improper to use, as the method does not permit serious interdependencies among the x-variables (Draper and Smith, 1981). This is likely to result in spurious conclusions about causal relationships, especially if stepwise selection of the variables is used (Eriksson *et al.*, 1995).

4. Conclusions

This study on Hg in perch from circumneutral hardwater lakes demonstrates that:

(i) The Hg level is comparable to levels found in other studies on perch, mainly in more acidic softwater lakes, in Northern Europe.
(ii) The Hg level in the perch is greatly affected by the catchment area composition and land use.

The lowest Hg levels in perch are observed in lakes strongly influenced by arable land and having high concentrations of dissolved ions in the lake water. Lakes dominated by forests in the catchment area have, on the other hand, generally high Hg levels in fish. Lakes predominantly affected by wetlands are found to possess deviating properties, which could not be explained in this study and warrants for further studies.

Additionally, some lake water characteristics are found to have a high influence on the Hg level in perch. Especially important are:

(iii) The negative influence of dissolved ions (Conductivity, Ca, Mg, Na and K).
(iv) The negative influence of lake trophic status (Total P and N, fish stock characteristics).
(v) The positive influence of the TOC/humic matter complex. On the contrary, lake pH does not seem to have any large influence on the Hg level in perch from circumneutral lakes.

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Abstract—The sediment, water, and three species of fish from 24 of Massachusetts' (relatively) least-impacted water bodies were sampled to determine the patterns of variation in edible tissue mercury concentrations and the relationships of these patterns to characteristics of the water, sediment, and water bodies (lake, wetland, and watershed areas). Sampling was apportioned among three different ecological subregions and among lakes of differing trophic status. We sought to partition the variance to discover if these broadly defined concepts are suitable predictors of mercury levels in fish. Average muscle mercury concentrations were 0.15 mg/kg wet weight in the bottom-feeding brown bullheads (*Ameiurus nebulosus*) (range = 0.01–0.79 mg/kg); 0.31 mg/kg in the omnivorous yellow perch (*Perca flavescens*) (range = 0.01–0.75 mg/kg); and 0.39 mg/kg in the predaceous largemouth bass (*Micropterus salmoides*) (range = 0.05–1.1 mg/kg). Statistically significant differences in fish mercury concentrations between ecological subregions in Massachusetts, USA, existed only in yellow perch. The productivity level of the lakes (as deduced from Carlson's Trophic Status Index) was not a strong predictor of tissue mercury concentrations in any species. pH was a highly (inversely) correlated environmental variable with yellow perch and brown bullhead tissue mercury. Largemouth bass tissue mercury concentrations were most highly correlated with the weight of the fish (+), lake size (+), and source area sizes (+). Properties of individual lakes appear more important for determining fish tissue mercury concentrations than do small-scale ecoregional differences. Species that show major mercury variation with size or trophic level may not be good choices for use in evaluating the importance of environmental variables.

Keywords—Mercury Fish Perch Bullhead Bass

INTRODUCTION

During the past 10 years, a growing awareness of the problem of high mercury concentrations in freshwater fish has generated a proliferation of studies at the international [1–3], national [4,5], and state [6,7] levels.

Massachusetts has surveyed contaminants in freshwater fish since 1983 [8], focusing primarily on areas of known or suspected contamination or on areas where biological effects were observed. These studies have shown that the variation in fish mercury contamination is relatively high in surface waters. Concentrations have been sufficiently high in some species to warrant the issuance of Fish Consumption Advisories for specific water bodies as well as a statewide health advisory cautioning pregnant women of the possible health risk associated with eating fish from Massachusetts freshwater bodies (excluding stocked and farm-raised fish).

Many factors contribute to the dynamics of contaminant accumulation in fish populations. An ecoregional approach partially explained geographic variation in fish mercury concentrations [9]. Lake productivity and lake trophic status affect the accumulation of persistent pollutants in fish [10]. The complexity of the definitions of ecoregion and lake trophic status makes these concepts potentially apt descriptors for ecosystems, which are inherently complex systems.

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Two ecoregions and 13 ecological subregions have been delineated in Massachusetts [11]. Shared components of ecoregions included soils, vegetation, climate, geology, and physiography. Patterns of animal migration and land use were also used to delineate ecoregions. Lakes in Massachusetts are either glacial (~10,000 years old) or they date back to the last mountain-building episode, roughly 200 million years ago. Most lakes were altered in colonial times to increase their utility to industrious New Englanders. The ecoregion concept may prove to be an effective tool for statistical analysis, research, and assessment of environmental resources, because it characterizes relatively homogeneous geographic regions, incorporating more information than do individual physical or chemical measurements.

In this study, yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), and brown bullheads (*Ameiurus nebulosus*) were sampled for muscle mercury concentration determinations in 24 lakes not likely to have been affected by nonpoint sources (e.g., landfills, industrial facilities, hazardous waste sites, wastewater treatment facilities). We also attempted to determine the relative degrees of influence on these concentrations of geographic location as well as lake biological, physical, and chemical characteristics.

MATERIALS AND METHODS

Lake selection

The lakes chosen for sampling were identified on the basis of the region of the state in which they were located and the

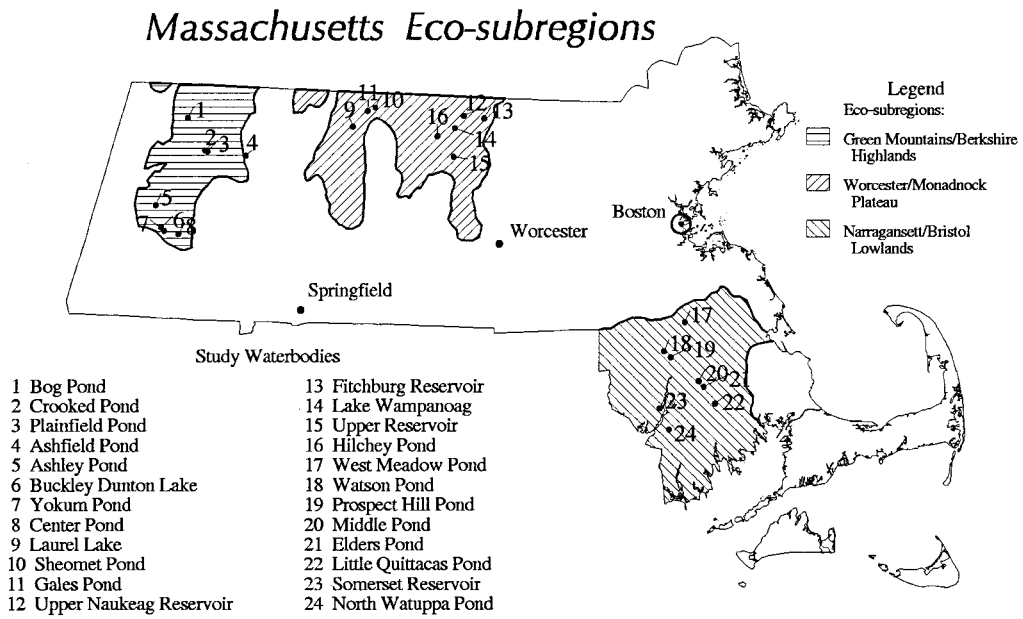

Fig. 1. Subecoregions of Massachusetts and study lake locations.

degree of development on or near the lakes. Eight lakes within each of three ecological subregions [11], representing contrasting environmental settings in Massachusetts, were selected (Fig. 1).

The Green Mountain/Berkshire Highlands subregion, located in northwestern Massachusetts, is characterized by relatively high elevations, which reach approximately 305 to 762 m above mean sea level. Metamorphic geology composed of schists, gneiss, and marbles creates a steep terrain that is overlaid by thin deposits of glacial till. Forest types include northern hardwoods (maple, beech, birch), spruce, and fir. Surface waters are generally low in phosphorus, with alkalinity under 200 μg/L [11].

The Worcester/Monadnock Plateau is located in the north-central part of the state at 152 to 457 m above sea level. The monadnocks are formed of granite plutons that dominate the surrounding geology of metamorphic schists and gneiss. Forest types include transition hardwoods (maple, beech, birch; oak, hickory) and some northern hardwoods. Surface waters are poorly buffered and acidic, with alkalinities generally between 50 and 100 μg/L [11]. Some surface waters exhibit moderate to high concentrations of dissolved organic compounds.

The Narragansett/Bristol Lowland is located in the southeastern part of the state. The landscape of this region consists of flat to rolling plains that seldom exceed 61 m above mean sea level, with numerous wetlands and bogs. Extensive deposits of glacial till and outwash material make up the soils and sediments. Central hardwoods (oak, hickory) are common, as are elm, ash, red maple, cottonwood, white pine, and red pine. Phosphorus in surface waters ranges widely, and alkalinities are in the 50 to 400 μg/L range [11].

The suitability of each lake identified in each ecosubregion on U.S. Geological Survey (USGS), 7.5′ series topographical maps was assessed using the following exclusion criteria in order to identify 24 lakes for study: surface area less than four hectares; proximity to concentrated urban, agricultural, or industrial areas; evidence of impact from human activities based on prior studies [12,13]; potential point or nonpoint sources of pollution.

Lake watershed areas were delineated based on USGS topographic quadrangles. Wetlands within the watersheds were delineated from U.S. Fish and Wildlife Service National Wetlands Inventory maps (1:24,000) and from stereoscopic analysis of high-altitude aerial photographs. Lake areas were calculated from digitized 1:25,000 coverages or from USGS topographic quadrangles.

Fish, water, and sediment sampling

The test species were selected principally because they encompass a range of fish trophic levels. Largemouth bass are fish-eating predators, although their diet also includes invertebrates and amphibians. The species did not occur in all of the study lakes. Yellow perch are omnivorous, consuming insects, invertebrates, and other fish, and brown bullhead are bottom-feeding omnivores [14].

Nine individuals of each species were targeted for collection from each lake. Fish sampling was conducted in the early fall after summer spawning. Total length criteria of 20 to 25 cm for yellow perch and brown bullhead and 30 to 36 cm for largemouth bass were established. The larger size was selected for largemouth bass because 30.5 cm is the legal minimum size limit for this species and may be representative of fish retained for consumption. Fish obtained by electrofishing, gill netting, and trot lines were rinsed in ambient water, chilled on ice, wrapped individually in aluminum foil, placed inside polyethylene zip-lock bags, and delivered to the laboratory on ice within 24 h of collection.

Water-quality sampling was conducted during midsummer, not coincident with fish sampling but during the period when lakes would be thermally stratified and when measures of degree of eutrophy might be strongest. In stratified lakes, a composite sample of water taken from the deepest part of the lake at 1.5 m below the surface, taken at mid-thermocline, and taken at 1.5 m above the bottom was prepared. The composite was then divided into three precleaned glass containers for chemical analyses. Single samples were taken from mixed lakes (non–thermally stratified) at 1.5 m below the surface. All water-quality sampling and handling was performed in accor-

dance with U.S. Environmental Protection Agency (U.S. EPA) protocols [15]. The following parameters were measured in the field using a Datasonde® Hydrolab (Hydrolab, Austin, TX, USA): pH, dissolved oxygen (DO), temperature, depth, and conductivity. Water clarity was measured using a Secchi disk. Chlorophyll *a* samples were taken at the deepest part of the lake, 1.5 m below the surface. The samples were filtered in the field following U.S. Environmental Monitoring and Assessment Program (EMAP) protocols [15].

Sediments were sampled using an Ekman dredge (GENEQ, Montreal, QC, Canada) at two locations in each body of water—at the deep hole and halfway to a shore. These samples were combined. In addition, a replicate sample was taken at the deep hole. Precleaned, wide-mouthed glass jars were inverted and pushed into the portion of sediment sample away from the sides of the dredge and were then capped with Teflon®-lined caps (VWR, Canlab, Mississauga, ON, Canada) and placed on ice for shipment to the lab. All sediment sampling and handling was performed in accordance with U.S. EPA protocols [15].

Laboratory methods

Fish specimens were processed for analysis in accordance with U.S. EPA procedures [16]. Dissection and tissue homogenization were conducted in a small, clean laboratory (not class 100) dedicated for fish processing.

Individual fish homogenates were analyzed for total mercury by cold-vapor atomic absorption spectrometry, using U.S. EPA method 245.6 [17], within their recommended holding-time limit for mercury (28 d) [16]. All handling of fish homogenates prior to analysis was conducted in a laminar airflow polypropylene fume hood for trace metal analysis that exceeds federal standard 209B for class-100 clean benches. Trace metal–grade sulfuric and nitric acids were used for fish sample digestions. The method detection limit (MDL) for mercury analysis in fish tissue of 0.020 mg/kg was experimentally determined using the conventional U.S. EPA procedure [18]. Accuracy for spiked fish samples and precision of the analyses were 104 ± 12.4 and 12.1 ± 9.7% (means ± 1 SD). The reference standard for mercury in fish tissue was freeze-dried oyster tissue (NBS 1566A). The accuracy of analyses of that standard was 101 ± 14.1%. Mercury in all laboratory reagent blanks was less than the MDL of 0.0002 mg/L.

Water-column samples were analyzed for chloride, using the argentometric method [19]; for calcium, using inductively coupled plasma–atomic emission spectrometry (ICP-AES) using U.S. EPA method 200.7 [20]; for sulfate, using turbidimetric nephelometry using U.S. EPA method 375.4 [21]; for ammonia-N (MDL = 0.02 mg/L), nitrate-N (MDL = 0.02 mg/L), and total phosphorus (MDL = 0.01 mg/L), using automated colorimetry on an autoanalyzer using U.S. EPA methods 350.1 [22], 353.1 [17], and 365.4 [17], respectively; and for dissolved organic carbon on glass-fiber–filtered samples, using ultraviolet (254-nm) absorbence, with potassium biphthalate as the standard [19].

Sediment samples were analyzed for total mercury and selenium. Sample aliquots for mercury analysis were digested in concentrated nitric and sulfuric acids and analyzed by cold-vapor atomic absorption spectrometry using U.S. EPA method 7471A [23]. For total selenium, the sediment samples were digested according to U.S. EPA method 3050A [23] and were analyzed by graphite furnace atomic absorption spectrometry using U.S. EPA methods 7060A and 7740 [23]. Accuracy for field sediments and precision for mercury determinations were 104 and 0.8%, respectively, and for selenium, they were 80.5 and 5.8%, respectively,. All reagent blanks were less than mercury and selenium MDLs of 0.0002 and 0.002 mg/L. The reference standard for sediments was dry river sediment (NBS 1645). Accuracies of analyses of that standard were 98 and 82% for mercury and selenium, respectively. Trace metal–grade acids were used for these analyses. Analyte concentrations were expressed as μg/g (dry weight).

Statistical methods

The number of each species of fish to be sampled in each lake in order to provide adequate statistical validity to the results was determined using fish mercury-concentration sampling variance from 10 years of monitoring in Massachusetts [8] and following consideration of available resources for fish collection and analysis.

Bivariate plots of all pairs of variables were also visually examined for outliers. Prior to statistical analyses of the raw tissue concentration data, the data were examined with linear regression analysis for correlations between mercury content and fish size (length or weight).

Lake trophic states were characterized with Carlson's Trophic State Index (TSI)[24], which gives a scaled measurement of water quality. Chlorophyll *a* measurements were used to calculate TSIs using the formula TSI = 30.6 ± 9.81 ln Chlorophyll *a* (mg/m^3) [25]. The TSIs of water bodies are scaled from 0 to 110, with oligotrophic lakes between 0 and 39, mesotrophic lakes between 40 and 50, and eutrophic lakes between 51 and 110. Lakes were grouped into these three categories. Because of their small number, mesotrophic lakes were grouped with eutrophic lakes for analyses of variance (ANOVA). The oligotrophic and eutrophic or mesotrophic categories were coded as 5 and 4 for statistical analyses. Subecoregions were numerically coded for analyses as follows: 1, Green Mountain/Berkshire Highlands; 2, Narragansett/Bristol Lowland; 3, Worcester/Monadnock Plateau.

The relative importances of the geographical locations of lakes (three subecoregion levels) and of their trophic states (two levels) were assessed with fixed-constants Model I ANOVA of mean lake tissue mercury concentrations, with replication for both yellow perch and brown bullhead. A separate analysis of covariance (ANCOVA) of mean lake tissue mercury concentrations across ecoregions and trophic states, using fish weight as a covariate, was performed for largemouth bass because of an observed relationship between weight (or total length) and mercury concentrations in this species [26]. Lake mean mercury values for each species were normally distributed (Kolmogorov–Smirnov test statistic with an α of 0.05 [26]); therefore, no data transformation was necessary to satisfy normality assumptions. We found unequal regression slopes [26] of tissue mercury on weight between lakes for largemouth bass and brown bullhead and equal slopes for yellow perch. These results were interpreted to mean that fish weight may have a differential effect on fish mercury concentrations between lakes for brown bullhead and largemouth bass. The effect of size may not have been removed from the data set for these two species even if ANCOVA was used to standardize mercury concentrations to a standard-sized fish [27]. Consequently, we chose to treat fish weight as an independent variable in all of our subsequent statistical procedures.

The multivariate data set was analyzed by factor analysis

[28] to assess which environmental parameters might influence regional differences associated with the bioaccumulation of mercury. Pearson's product moment correlation matrices for each species's mercury concentrations and environmental data were calculated. A varimax normalized rotation strategy was needed only with the bullhead data set to improve the separation of variables on factors. In factor analysis, the number of variables analyzed is limited to the number of cases. All species of fish were not available in every lake. We collected brown bullhead in 22 lakes, largemouth bass in 19 lakes, and yellow perch in 22 lakes. Stepwise multiple regressions were used to eliminate poorly correlated variables. Initially, the factor analysis was computed for two factors. The number of factors was increased iteratively until mercury in the species being analyzed scored high on only one factor. All statistical evaluations were performed with the Statistica/W, Version 5.0 software package (StatSoft, Tulsa, OK, USA).

RESULTS

Summary statistics for mercury concentrations in each species in the 24 lakes are presented in Table 1. Nine individuals of each species were not obtained in all water bodies. The results of physical and chemical sampling and measurement are contained in Tables 2 and 3. The pH value of 10.5 for Prospect Hill Pond (Table 2) was eliminated from further analysis as an outlier, since other chemical values for this pond suggested inconsistencies. Results for water ammonia-N, nitrate-N, and total phosphorus are not shown, as the majority of results were below method-detection limits.

Brown bullhead generally had the lowest muscle mercury concentrations, with mean tissue concentrations of 0.15 mg/kg wet weight (range = 0.01–0.79 mg/kg, 95th percentile concentration 0.32 mg/kg); yellow perch were intermediate, with 0.31 mg/kg (range = 0.01–0.75 mg/kg, 95th percentile concentration 0.57 mg/kg); and largemouth bass were highest, with 0.39 mg/kg (range = 0.05–1.1 mg/kg, 95th percentile concentration 0.91 mg/kg) (Table 1). The distribution of individual values of largemouth bass tissue mercury concentrations was somewhat similar to the log-normally distributed mercury concentration values in yellow perch and brown bullhead, in the concentration range of 0.2 to 0.6 mg/kg, but the bass distribution had a tail to the right beyond 0.6 mg/kg, with upper concentrations up to 1.1 mg/kg (plots not shown).

Largemouth bass are the only one of the three species in this study that exhibited a significant correlation ($r = 0.72$; p for H_0; $\rho = 0$ was 0.01) between fish length and mercury content for the combined data set. Similar relationships existed for weight (not shown). Correlation coefficients for regression equations of mercury on length for each species for individual lakes also generally exhibited the same pattern. The slopes of these regression lines were not equal among lakes for largemouth bass ($F_{16,116} = 4.74$; $p \leq 0.01$) and brown bullhead ($F_{17,125} \leq 3.59$; $p \leq 0.01$). They were equal for yellow perch ($F_{20,147} = 1.44$; $p = 0.11$).

The lake trophic-state indicator values ranged from 19 to 75, with 13 lakes falling in the oligotrophic range, 7 lakes in the mesotrophic range, and 4 lakes in the eutrophic range (Table 3). Analyses of variance showed no significant differences in tissue mercury concentrations ($p > 0.05$) between lakes of different trophic states for any of the three species. The ANOVA also determined that significant differences in fish mercury concentrations between subecoregions existed only in yellow perch ($p = 0.05$; $F_{2,16} = 3.62$) (Fig. 2). Regionally, the Narragansett/Bristol Lowlands subecoregion and the Green Mountain/Berkshire Highlands subecoregion have somewhat lower mercury in all species than does the Worcester/Monadnock Plateau.

Mercury concentrations in bass (Fig. 3a) were most strongly positively associated with the weight of the fish, lake size, and variables representing potential source area–contribution sizes (wetlands and watersheds). Mercury concentrations in this species did not correlate with either subecoregion or lake trophic state. Sediment mercury and selenium score high on an independent factor that also correlates with low DO. These two factors explained 46% of the variance in the data set. Mercury concentrations in yellow perch have a high negative correlation with factor 1 (Fig. 3b), while at the opposite end of the factor are high positive correlations for pH, conductance, and calcium, indicating inverse correlations between the tissue mercury and these lake chemistry variables. Variables loading orthogonal to this factor on factor 2 are primarily indicators of lake trophic status and are independent of the species' mercury concentrations. These two factors explained 43% of the total variance in the yellow perch data set. Mercury concentrations in brown bullhead tissue and pH had high opposite sign-factor scores on factor 6 (Fig. 3c). Trophic state indicator variables (DO, chlorophyll *a*) were independent of tissue mercury patterns, having high absolute value scores on factor 1. These two factors explained approximately 29% of the variance in the data set.

DISCUSSION

This study of the variation and possible determinants of fish tissue mercury in relatively non–source affected fresh water lakes in Massachusetts revealed that the order of species mercury concentrations, within the size ranges of fish sampled, was largemouth bass > yellow perch > brown bullhead. The largemouth bass sampled were primarily in the 4+ and 5+ year classes. Comparable mean concentrations to the 0.39 mg/kg for this data set for similarly aged fish in Michigan and Wisconsin data sets were 0.43 and 0.33 mg/kg [6], and they were 0.59 and 0.65 mg/kg in Lake Tohopekaliga, Florida [29]. The mean yellow perch mercury concentration of 0.31 mg/kg primarily represented fish in the 4+ and 5+ year classes. Comparable means for these year classes of yellow perch from other studies were 0.36 and 0.43 mg/kg in the Adirondacks of New York State [30] and 0.25 and 0.27 mg/kg in the Upper Peninsula of Michigan and in Wisconsin [6]. The majority of brown bullhead represented the 2+ through 4+ year classes. The interspecific differences in tissue mercury concentrations recorded in this study were consistent with observations from other studies using the same species or species representing the same trophic level [6,31,32]. They are also consistent with a priori considerations of the trophic level at which each species functions.

Variation in fish muscle mercury concentrations may be the result, in varying degrees, of biological variability associated with the species themselves (age, size, physiology, diet), of geological influences (bedrock and sediments), of chemical variability (water quality and mercury biogeochemistry), of physical variability (e.g., water temperature, lake and watershed size), and of other influences, such as climate and atmospheric deposition [33].

In our study design, we sought to control several sources of potential variation in tissue mercury concentrations. Seasonal influences on fish physiology and subsequently on fish

Table 1. Summary statistics for mercury concentrations in brown bullhead, largemouth bass, and yellow perch in Massachusetts lakes

Species	Region	Lake	*n*	Mercury mean ± 1 SD (mg/kg)	Mean weight (g)
Brown Bullhead					
	Green Mountain/Berkshire	Plainfield Pond	9	0.182 ± 0.069	97.11
		Ashfield Pond	9	0.083 ± 0.029	144.89
		Yokum Pond	6	0.050 ± 0.014	225.89
		Buckley Dunton Reservoir	9	0.168 ± 0.138	185.56
		Center Pond	9	0.123 ± 0.051	195.67
		Ashley Lake	10	0.099 ± 0.029	175.70
		Bog Pond	9	0.149 ± 0.056	72.67
		Crooked Pond	9	0.115 ± 0.046	136.94
	Narragansett/Bristol	Elders Pond	6	0.279 ± 0.265	466.00
		West Meadow Pond	8	0.074 ± 0.019	515.00
		Little Quitticas Pond	4	0.225 ± 0.152	470.75
		Prospect Hill Pond	0	—	—
		North Watuppa	2	0.100 ± 0.002	563.50
		Somerset Reservoir	2	0.187 ± 0.028	733.50
		Middle Pond	3	0.026 ± 0.014	416.00
		Watson Pond	9	0.069 ± 0.025	460.33
	Worcester/Monadnock	Wampanoag Lake	9	0.214 ± 0.123	105.67
		Upper Naukeag	0	—	—
		Hilchey Pond	9	0.186 ± 0.062	205.62
		Sheomet Pond	9	0.097 ± 0.037	66.67
		Upper Reservoir	2	0.260 ± 0.018	224.50
		Laurel Lake	9	0.116 ± 0.054	329.00
		Gales Pond	9	0.322 ± 0.127	142.44
		Fitchburg Reservoir	8	0.107 ± 0.058	172.00
				Species mean = 0.147 ± 0.078	
Largemouth bass					
	Green Mountain/Berkshire	Plainfield Pond	9	0.626 ± 0.281	767.75
		Ashfield Pond	9	0.468 ± 0.315	419.11
		Yokum Pond	9	0.188 ± 0.081	374.50
		Buckley Dunton Reservoir	11	0.426 ± 0.233	572.00
		Center Pond	9	0.323 ± 0.139	729.10
		Ashley Lake	0	—	—
		Bog Pond	9	0.413 ± 0.192	794.44
		Crooked Pond	0	—	—
	Narragansett/Bristol	Elders Pond	9	0.250 ± 0.075	555.78
		West Meadow Pond	9	0.144 ± 0.050	298.33
		Little Quitticas Pond	5	0.280 ± 0.110	272.60
		Prospect Hill Pond	9	0.199 ± 0.049	541.44
		North Watuppa	9	0.724 ± 0.198	1150.56
		Somerset Reservoir	9	0.668 ± 0.298	713.50
		Middle Pond	10	0.330 ± 0.188	556.80
		Watson Pond	9	0.309 ± 0.057	581.22
	Worcester/Monadnock	Wampanoag Lake	9	0.439 ± 0.148	475.11
		Upper Naukeag	1	0.366	328.00
		Hilchey Pond	0	—	—
		Sheomet Pond	0	—	—
		Upper Reservoir	9	0.551 ± 0.107	488.89
		Laurel Lake	9	0.392 ± 0.100	619.11
		Gales Pond	0	—	—
		Fitchburg Reservoir	0	—	—
				Species mean = 0.394 ± 0.165	
Yellow perch					
	Green Mountain/Berkshire	Plainfield Pond	9	0.342 ± 0.126	80.78
		Ashfield Pond	9	0.330 ± 0.085	75.67
		Yokum Pond	9	0.105 ± 0.046	118.11
		Buckley Dunton Reservoir	9	0.272 ± 0.145	96.33
		Center Pond	9	0.181 ± 0.079	121.44
		Ashley Lake	10	0.380 ± 0.176	104.80
		Bog Pond	10	0.284 ± 0.071	133.11
		Crooked Pond	9	0.46 ± 0.076	139.70

mercury concentrations were reduced by the choice of sampling time. Control of the influence of fish size and age on tissue mercury was accomplished by confining our sampling to restricted size ranges of fish. In practice, a wider size range of fish than intended was obtained. However, the lack of correlation, over all samples, between mercury concentration and size in yellow perch or brown bullhead suggests that our attempt to control for fish size by limiting the size range during

Table 1. Continued

Species	Region	Lake	*n*	Mercury mean ± 1 SD (mg/kg)	Mean weight (g)
	Narragansett/Bristol	Elders Pond	9	0.273 ± 0.062	124.56
		West Meadow Pond	0	—	—
		Little Quitticas Pond	9	0.272 ± 0.139	113.89
		Prospect Hill Pond	9	0.106 ± 0.063	122.78
		North Watuppa	9	0.338 ± 0.163	170.88
		Somerset Reservoir	9	0.203 ± 0.054	32.44
		Middle Pond	9	0.155 ± 0.052	258.00
		Watson Pond	9	0.195 ± 0.065	87.89
	Worcester/Monadnock	Wampanoag Lake	9	0.439 ± 0.067	74.88
		Upper Naukeag	9	0.547 ± 0.091	94.67
		Hilchey Pond	9	0.314 ± 0.090	142.67
		Sheomet Pond	0	—	—
		Upper Reservoir	9	0.465 ± 0.148	103.56
		Laurel Lake	9	0.219 ± 0.056	97.56
		Gales Pond	9	0.514 ± 0.073	91.00
		Fitchburg Reservoir	9	0.326 ± 0.088	112.22
				Species mean = 0.305 ± 0.125	

capture was successful. The observed relationship with size and mercury in bass may be related to interspecific variation in the kinetics of mercury bioaccumulation [32]. Largemouth bass are long-lived and have the largest body sizes and probably the lowest rates of growth and metabolism at older ages [14]. They are also the only species studied here that had a positive, significant correlation between mercury and weight. Yellow perch and brown bullhead have smaller body sizes, shorter lifespans (in the case of perch), and, presumably, higher rates of growth and metabolism. The older, slower growing fish had longer times to accumulate and concentrate mercury (as a result of more uptake than excretion), because growth dilution of methylmercury is not sufficiently rapid to offset this effect. In the other two species, the higher growth rates may have resulted in growth dilution of their body burdens of mercury, thereby offsetting possible accelerated mercury uptake due to higher metabolic rates and age-dependent bioaccumulation.

A slight geographic gradient of fish mercury concentration for yellow perch was detectable in our analyses, even across the relatively narrowly defined differences between ecological subregions. Allen-Gil et al. [34] did not note spatial differences in fish species mercury concentrations across geographic regions delineated on the basis of ecological, geological, and climatic factors. Lathrop et al. [35] noted a west to east increase in walleye mercury concentrations across northeastern Minnesota, northern Wisconsin, and southeastern Ontario, Canada, which is possibly related to acidic deposition patterns. Ecoregional differences in Massachusetts are associated with pH differences and may also be overshadowed by other lake-specific factors.

Mercury concentrations in sediment samples ranged from 0.008 mg/kg to 0.425 mg/kg (Table 3). None of the species studied in this project showed a relationship between tissue mercury and sediment mercury or selenium concentrations. Figure 3a shows that sediment mercury and selenium vary independently from fish mercury. Selenium can form highly insoluble complexes with mercury and thereby reduce its biological availability [36]. Under low pH conditions, leaching of sedimentary metals into surface waters and subsequent availability of these metals for bioaccumulation may be facilitated in a complex relationship modulated by the amount and types of particulate and organic matter in the water column and by the pH and Eh of the sediment [37]. In brown bullhead, the source of mercury may not be confined to diet, given the bottom-dwelling habitat of the species and its scaleless, permeable skin. Underlying relationships between sedimentary mercury and selenium may have been obscured with our bulk mercury concentration determination, since mercury is probably preferentially associated with silts and clays, and a normalization to the mass of this size fraction might have been more useful.

Our analyses indicated a clear link between certain environmental characteristics and elevated mercury concentrations in fish. Low pH of the water body was a major correlate to tissue mercury concentrations in brown bullhead and yellow perch (Fig. 3b, c) but not in largemouth bass (Fig. 3a). The association between high mercury concentrations and low pH is clearly delineated by factor analysis. This environmental variable would also seem the most likely to represent subecoregion variability in our analyses. Some of the continuous variables measured in the field (e.g., Secchi disk depth, chlorophyll *a,* DO) represent measures of trophic status that are perhaps better suited for use in the correlation and other association tests than as a coded variable. The factor analysis provided complementary information, scoring mercury in perch highly negative on the same factor as pH. Suns and Hitchin [38] observed a similar relationship in yellow perch from 16 lakes situated on the Precambrian Canadian Shield north of Toronto, Canada.

Low pH has been most consistently documented as being responsible for elevated tissue mercury concentrations in freshwater fish in uncontaminated lakes [2,6]. Possible mechanisms associated with this relationship include [37] (1) mercury entering watersheds with atmospheric deposition; (2) mobilization of existing sediment-bound mercury and mercury present in the surrounding watershed by acidification of surface water runoff and lake water, leading to increases in the amount of mercury available for methylation and bioaccumulation; (3) differential production of the more bioavailable monomethylmercury form of mercury at lower pH; and (4) alteration of rates of mercury methylation and demethylation by microorganisms by acidic conditions. Having reviewed evidence for each of these mechanisms, Richman et al. [37] concluded that they were not mutually exclusive processes and that mercury cycling and uptake into fish tissues was governed

Table 2. Lake water quality characteristics[a]

Lake	pH	Chlorophyll *a* (mg/m^3)	Secchi depth (m)	Depth (m)	Conductivity (mS)	DO (mg/L)	DOC (mg/L)	Cl^- (mg/L)	Ca (mg/L)	SO_4 (mg/L)
Plainfield Pond	7.5	1.2	2.75	2.75	37	8.6	≤MDL	4	2.3	≤MDL
Ashfield Pond	8.5	.5	3.1	5	178	8.87	0.7	28	16	4
Yokum Pond	7.2	.8	2.75	2.9	50.8	8	0.5	1	20	4
Buckley Dunton Reservoir	5.7	5.1	1.2	3.25	29.1	6.36	9.7	2	1.8	2
Center Pond	7.5	2.1	2.75	4.8	114	8.34	0.5	19	28	4
Ashley Lake	7.9	1.9	4	13.8	47.9	8.09	3.1	2	3.8	≤MDL
Bog Pond	6.5	3.7	1.5	2	19.2	7.21	12.1	1	2.7	≤MDL
Crooked Pond	6.7	2.8	2.25	2.75	23	7.13	2.2	≤MDL	1.4	≤MDL
Elders Pond	7.1	14.3	2.9	13.8	117.4	7.85	3.4	21	3	8
West Meadow Pond	7.6	90.8	0.04	1.5	209	2.54	23.3	35	8.3	6
Little Quitticas Pond	7.1	1.5	2.5	3.75	102.8	7.54	8	18	3.4	6
Prospect Hill Pond	10.5	1.9	1.25	2	135.7	9.92	6.1	11	0.8	17
North Watuppa	6.1	1.1	2.75	4.75	93.3	7	4	17	2.9	8
Somerset Reservoir	7.3	2.9	2.5	9.5	101.7	7.39	6	13	6.6	9
Middle Pond	8.9	2.5	2.2	4.5	152.6	7.9	2.5	22	7.7	4
Watson Pond	8.3	40.2	0.6	2.9	101.3	7.32	13	16	5.6	≤MDL
Wampanoag Lake	5.4	1.1	2.5	3.75	79.2	7.84	6.1	18	2.2	2
Upper Naukeag	5.6	.4	7.5	13.75	47.8	7.64	0.1	9	1	≤MDL
Hilchey Pond	7.3	13.2	0.07	2.7	152	7.13	40	14	5.5	4
Sheomet Pond	6.8	1.8	2.25	3.2	37	7.92	4.2	3	2.2	3
Upper Reservoir	4.9	2.3	0.75	1.1	45.8	7.15	58.8	6	1.8	≤MDL
Laurel Lake	6.4	.3	6	7.3	24.7	7.87	5	≤MDL	5.5	2
Gales Pond	6.1	4.4	0.75	1.3	36.7	7.19	37	5	2.6	2
Fitchburg Reservoir	6.3	4.1	5.25	6	73.9	7.99	0.8	14	1.7	4

[a] DO = dissolved oxygen; DOC = dissolved organic carbon; MDL = method detection limit.

Table 3. Lake characteristics

Lake	Sediment		Trophic state[a]	Watershed area (hectares)	Pond area (hectares)	Wetland area (hectares)
	Mercury (mg/kg)	Selenium (mg/kg)				
Plainfield Pond	0.200	1.80	o	170	25.5	9.5
Ashfield Pond	0.172	1.10	o	287	15.8	1.7
Yokum Pond	0.030	0.32	o	161	38.4	2.8
Buckley Dunton Reservoir	0.290	1.34	m	581	58.7	17.1
Center Pond	0.008	0.29	o	256	41.3	9.5
Ashley Lake	0.222	1.26	o	173	44.9	4.2
Bog Pond	0.133	1.27	m	353	15.0	13.8
Crooked Pond	0.250	1.92	m	96	13.8	8.3
Elders Pond	0.029	0.11	e	232	55.4	5.9
West Meadow Pond	0.366	2.81	e	1196	29.1	88.5
Little Quitticas Pond	0.279	1.54	o	417	112.5	52.8
Prospect Hill Pond	0.213	1.62	o	124	17.0	8.7
North Watuppa	0.149	≤MDL	o	2935	700.1	304.5
Somerset Reservoir	0.215	0.76	m	374	66.4	36.7
Middle Pond	0.128	0.76	m	416	9.7	39.9
Watson Pond	0.425	1.98	e	157	29.1	25.7
Wampanoag Lake	0.301	1.14	o	773	90.7	110.3
Upper Naukeag	0.148	2.31	o	495	123.0	27.2
Hilchey Pond	0.282	0.69	e	823	4.9	144.2
Sheomet Pond	0.266	0.95	o	1382	12.5	19.8
Upper Reservoir	0.215	2.05	o	445	16.6	85.9
Laurel Lake	0.274	1.45	o	219	16.6	3.1
Gales Pond	0.356	1.85	m	828	4.5	78.1
Fitchburg Reservoir	0.260	1.06	m	554	60.7	19.1

[a] o = oligotrophic; e = eutrophic; m = mesotrophic; MDL = method detection limit.

by an array of interrelated, variables, the relative importance of which can differ from lake to lake.

Our analyses did not show an association between fish tissue mercury concentrations and the lake TSI. Trophic status and variables associated with it are relatively independent of both fish mercury and pH (Fig. 3). For example, chlorophyll *a* and Secchi disk depth, both associated with lake trophic status, did not partition onto the same factor as species mercury values, indicating that variance in trophic state variables was independent of mercury concentrations in most fish tissue. Other reviews [37] and studies [9,39,40] on this specific relationship have noted that, while the general availability of mercury within aquatic ecosystems may be affected by trophic status, other abiotic factors interfere with and confound the issue.

The ratio of basin area to pond area was not a strong correlate of fish mercury concentrations in any of the species we studied in Massachusetts. The absence of such a relationship does not support the logic that where the basin (watershed) is much larger than the pond, there should be a tendency to have higher mercury concentration in fish tissue, reflective of mercury transport from the watershed [41]. In largemouth bass, however, we did find significant correlations between tissue mercury concentrations and the size of the watershed and the lake area as well as the area in the watershed occupied by wetlands (Fig. 3a). The relative importance of watershed-derived mercury to fish mercury is not consistent in various studies [2,6] and sometimes appears to be a function of the types of water inputs to the lakes. In cases where there has been little surface-water inflow into lakes [6,41], no relationship has been seen between fish mercury concentrations and watershed area to lake volume ratios, whereas positive relationships have been seen in lakes with greater surface-water inputs from drainage basins [38].

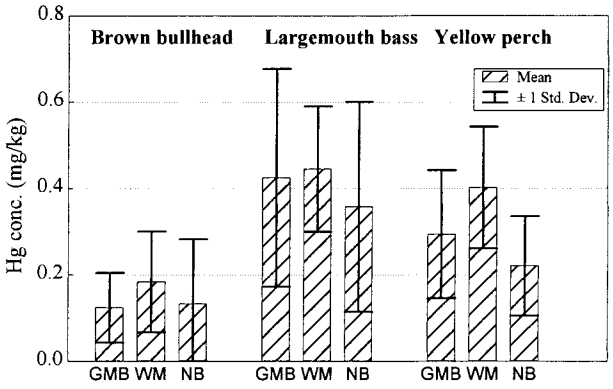

Fig. 2. Mean species mercury concentrations (mg/kg) in Massachusetts subecoregions. GMB = Green Mountain/Berkshire Highlands; WM = Worcester/Monadnock Plateau; NB = Narragansett/Bristol Lowland.

In addition to substantiating the recognized association between fish tissue mercury and acid waters, the principal contributions of the present study include insight into the relative importance of the various biologic, chemical, and geologic factors that may influence fish mercury bioconcentration patterns. Specifically, given that significant ecoregional differences in tissue mercury concentrations only existed in one species, the properties of individual lakes within these narrowly defined regions are more important than are regional variations in determining fish mercury concentrations. The results for largemouth bass, contrasted with those of yellow perch and brown bullhead, suggest that species whose mercury concentrations exhibit major variation associated with size or food-chain position may not be good choices for evaluating the effects of environmental variables. The additional variability introduced by using such species tends to obscure other

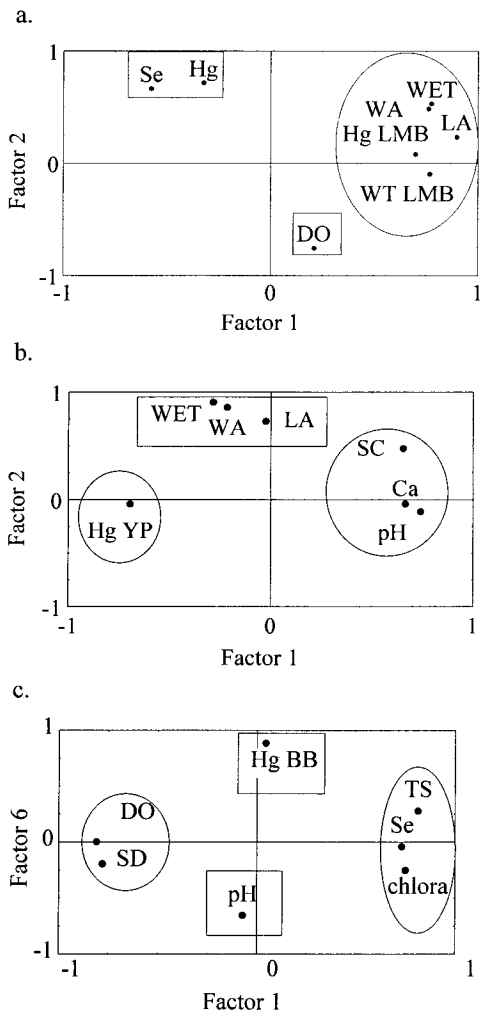

Fig. 3. Rotated factor score plots for: (**a**) largemouth bass, (**b**) yellow perch, and (**c**) brown bullhead. Only variables with scores >|0.65| are shown. Elipses and squares highlight variables grouping on factor 1 or on other factors, respectively. Key: Ca = calcium; chlora = chlorophyll *a*; DO = dissolved oxygen; Hg = sediment mercury; HgBB = mercury in bullhead; HgLMB = mercury in bass; HgYP = mercury in yellow perch; LA = lake area; SC = specific conductance; SD = Secchi disk depth; TS = trophic status; WA = watershed area; WET = wetland area; WTLMB = wet weight of bass.

relationships. This study clearly shows the value of using a specified size range of species that exhibit little size to mercury ratio covariance.

Studies such as this, in which fine-scale ecoregional differences are not usually significant, do not indicate that ecoregional differences are not meaningfully related to fish mercury on larger geographic scales. Indeed, the variables measured in this study may well be important on larger geographic scales and may be beneficially examined in that context. Literature on mercury bioaccumulation is generally dominated by data from waters in regions where bioaccumulation has reached levels of concern, whereas data from areas where bioaccumulation has not been a concern has not been published in the open literature as frequently. Inclusion of this type of data in regional analyses would provide a broader spectrum of conditions for evaluating the importance of ecoregional differences.

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Bioaccumulation of mercury in pelagic freshwater food webs

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Abstract

Current paradigms regarding the bioaccumulation of mercury are rooted in observations that monomethyl mercury (meHg) biomagnifies along pelagic food chains. However, mechanisms regulating the formation of meHg, its initial incorporation at the base of pelagic food chains, and its subsequent trophic transfer remain controversial. Here we use field data from 15 northern Wisconsin lakes, equilibrium aqueous speciation modeling, and statistical modeling to revisit several hypotheses about the uptake, distribution, and fate of inorganic Hg (Hg^{II}) and meHg in aquatic biota. Our field data comprise determinations of total Hg (Hg_T) and meHg in surface waters, sediments, microseston, zooplankton, and small fish in each of the study lakes. For these lake waters, strong positive correlations between DOC and aqueous concentrations of mercury along with negative correlations between DOC and the seston–water partitioning of mercury indicate that organic ligands bind Hg^{II} and meHg strongly enough to dominate their apparent aqueous speciation. In the microseston, zooplankton and fish, meHg concentrations and bioaccumulation factors (BAFs) increased with increasing trophic level while biotic concentrations of Hg^{II} decreased — indicating that meHg was indeed the biomagnified species of mercury. For all trophic levels, meHg concentrations varied positively with the calculated aqueous concentration of $meHg^{+}$ (free ion), especially when coupled with pH, or meHgOH (hydroxide) species but not with $meHgCl^{0}$, the neutral chloride complex. These findings suggest that: (1) the passive uptake of meHg does not control bioaccumulation at the base of aquatic food webs in nature (i.e. phyto- and bacterioplankton); (2) correlation with pH and DOC largely reflect the supply and bioavailability of meHg to lower trophic levels; and (3) meHg concentrations at higher trophic levels reflect uptake at low trophic levels and other factors, such as diet and growth. Low concentrations of meHg in surficial sediments indicate that the fates of biotic Hg^{II} and meHg are different. Most biotic meHg is demethylated rather than buried in lake sediments.

Keywords: Mercury; Methyl mercury; Bioaccumulation; Trace metals; Phytoplankton; Zooplankton; Fish; Sediments

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1. Introduction

The potential determinants of mercury bioaccumulation in natural aquatic ecosystems include environmental factors (such as mercury loading rates, pH, DOC, and temperature), ecological factors (such as productivity and trophic position), and physiological factors (such as respiration and assimilation). Although there is an extensive body of literature examining statistical relationships between such factors and mercury bioaccumulation in fish, large uncertainties remain (Spry and Wiener, 1991; Wiener and Spry, 1996). Survey data show that body size, pH, and DOC often correlate with mercury concentration, but in seemingly inconsistent ways. For example, some studies report a strong negative correlation with pH and a weak or non-significant correlation with DOC (e.g. Lathrop et al., 1989; Lange et al., 1993) while other studies report a strong correlation with DOC and only a weak or non-significant correlation with pH (e.g. McMurty et al., 1989; Fjeld and Rognerud, 1993). Reported correlation with DOC has been positive (e.g. Haines et al., 1994) and negative (Grieb et al., 1990). At least one fish survey reported no significant correlation with either pH or DOC (Driscoll et al., 1995). Such seeming inconsistency suggests a significant degree of interaction among controlling variables and/or multiple effects from single variables.

The opportunity for interaction and multiple effects is clear in Sunda's steady-state model of bioaccumulation (Sunda and Huntsman, 1998):

$$C_{\text{biota}} = V_{\text{net}}/\mu \quad (1)$$

where C_{biota} is the metal concentration in biota, V_{net} is the net metal uptake rate, and μ is the growth rate of the organism (or biodilution term). Although developed for phytoplankton, Sunda's law is a general paradigm for trace metal bioaccumulation across the board in aquatic ecosystems. It holds for phytoplankton, zooplankton, benthic invertebrates and fish — despite the substantial differences in uptake pathways and growth patterns. Various regulatory factors operate through processes related to V_{net}, μ, or both. Since V_{net} and μ comprise many processes, one would anticipate a complex set of dependencies for C_{biota}.

For mercury, DOC of terrestrial origin (i.e. humic matter) can hypothetically affect V_{net} in several ways. For example, co-transport with DOC from the terrestrial watershed can increase the supply of Hg^{II} and meHg to lakes; organic complexation can limit the bioavailability of either chemical form; and light attenuation in dark water lakes can inhibit the photo-destruction of meHg (Lee and Iverfeldt, 1991; Mierle and Ingram, 1991; Driscoll et al., 1995; Sellers et al., 1996). pH may also exert multiple effects on C_{biota}, potentially by depressing μ (since growth rates may be low in acidic waters) and by increasing V_{net} through effects on the net internal production of meHg or on the relative abundance of inorganic bioavailable aqueous species (Winfrey and Rudd, 1990; Gilmour and Henry, 1991; Meili, 1994; Mason et al., 1996).

In this paper, we focus on the relationships between DOC, pH, and the bioaccumulation of mercury by pelagic organisms in small Wisconsin lakes. We measured Hg and meHg in water, microseston (phytoplankton and bacterioplankton), zooplankton, fish, and sediments in lakes that were reasonably well defined hydrologically and that spanned relatively wide ranges of pH and DOC. Our mercury determinations were supported by data on mercury sources, water chemistry, and aquatic biology. Since current paradigms hold that meHg is the chemical species that biomagnifies through trophic transport (May et al., 1987; Meili, 1991; Watras and Bloom, 1992; Suedel et al., 1994; Mason et al., 1996), we emphasize the supply, bioavailability and uptake of meHg with respect to water chemistry and trophic position (i.e. V_{net}). We use field data, equilibrium aqueous speciation modeling of Hg^{II} and meHg, and statistical modeling to revisit several hypotheses.

2. Methods

2.1. Study sites and sampling

Fifteen small lakes in Vilas County, WI (46°N,

Table 1
Morphometric and hydrologic characteristics of the study lakes in northern Wisconsin (Vilas County, 46°N, 89°W)

No.	Lake name	Hydrology[a]	Area (ha)	Volume (10^6 m^3)	$Depth_{max}$ (m)	$Depth_{mean}$ (m)
1.	Little Rock (T)[b]	S	10	0.4	10.3	3.8
2.	Little Rock (R)	S	8	0.3	6.5	3.1
3.	Allequash	D	172	5.2	7.3	3.0
4.	Dorothy Dunn	S	22	0.4	6.7	1.6
5.	Big Musky	S	376	29.4	21.3	7.8
6.	Spruce	S/D	7	0.2	3.8	2.4
7.	Pallette	S	70	6.7	18.3	9.6
8.	Mud	S	5	0.3	14.0	5.0
9.	Russett	S	19	0.8	11.0	3.9
10.	Rock	D	48	1.2	5.0	2.5
11.	Helen	D	27	1.2	16.3	4.4
12.	Red Bass	S	8	0.3	8.3	3.1
13.	Rose	S	2	0.1	13.0	4.9
14.	Helmet	S	3	0.1	10.5	4.9
15.	Boot	S/D	13	0.4	7.3	2.8

Note. Lakes are listed in ascending order of DOC concentration. Most of these lakes are precipitation-dominated seepage lakes.
[a]S, seepage; D, drainage.
[b]T, treatment basin; R, reference basin (Watras and Frost, 1989).

89°W) were selected along a gradient of dissolved organic carbon ranging from 2 to 20 mg C/l (Tables 1 and 2). The lakes are all mesotrophic lakes of glacial origin with little or no human habitation or watershed disturbance. Since the lakes share a common airshed and since atmospheric deposition dominates mercury input, Hg loading was reasonably well constrained at 10

Table 2
Water quality characteristics of the 15 study lakes

Lake no.	DOC (mg/l)	pH	DIC (mg/l)	SPM (mg/l)	Chl *a* (μg/l)	Cond. (μS/cm)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Fe (μg/l)	Mn (μg/l)	SO_4 (mg/l)	Cl (mg/l)
1	1.98	5.32	1.22	1.21	1.26	20.6	1.4	0.4	0.2	120	75	6.1	0.2
2	2.91	5.88	1.34	1.09	1.49	13.8	1.0	0.3	0.2	46	19	2.9	0.3
3	4.11	7.62	11.21	1.62	5.04	96.7	11.7	3.2	1.6	180	25	3.9	0.3
4	3.56	7.09	3.49	1.62	2.08	34.5	3.4	1.1	0.7	169	13	2.8	0.1
5	3.82	7.29	5.50	0.73	1.80	53.0	5.8	1.8	1.0	18	3	3.7	0.3
6	4.67	5.49	1.44	1.88	2.54	12.2	0.8	0.2	0.2	293	24	2.1	0.2
7	5.09	6.73	2.21	1.61	4.64	22.6	2.2	0.6	0.5	27	5	2.5	0.3
8	5.79	6.17	1.36	2.33	3.43	32.6	1.6	0.6	2.4	100	41	2.9	3.7
9	6.92	5.64	1.27	1.37	1.87	16.7	1.3	0.4	0.3	220	29	3.1	0.2
10	9.12	7.23	8.66	2.84	2.62	75.0	9.1	2.6	1.4	310	43	1.6	0.8
11	10.10	6.18	2.60	3.31	4.55	28.5	2.6	0.9	0.8	420	43	2.0	0.9
12	14.39	6.28	1.19	5.90	9.62	25.8	1.8	0.7	1.3	530	71	0.7	2.1
13	16.36	6.38	4.11	3.82	8.20	39.8	4.2	1.3	0.9	345	51	2.6	0.6
14	17.48	5.63	2.45	2.57	1.08	33.0	2.3	0.8	2.2	1200	74	2.8	1.8
15	20.13	4.85	1.37	2.41	1.88	22.7	1.4	0.5	0.4	760	40	1.2	0.3
Mean	8.43	6.25	3.29	2.29	3.47	35.2	3.4	1.0	0.9	316	37	2.74	0.8
S.D.	5.92	0.81	3.01	1.32	2.55	23.5	3.2	0.9	0.7	318	24	1.26	1.0
Min	1.98	4.85	1.19	0.73	1.08	12.2	0.8	0.2	0.2	18	3	0.71	0.1
Max	20.13	7.62	11.21	5.90	9.62	96.7	11.7	3.2	2.4	1200	75	6.06	3.7

Note. Data are mean values for epilimnetic samples from each lake (1992–1994).

$\mu g/m^2$ per year (Fitzgerald et al., 1991). However, interactions with riparian wetland varied between lakes and this likely affected loading to some lakes (e.g. Mierle and Ingram, 1991; St Louis et al., 1994). Yellow perch (*Perca flavescens*) were abundant in the study lakes, with one exception (Rose Lake). Unless otherwise indicated, our sampling platform was a non-metallic boat deployed at the deepest point in each lake during May 1994. Clean technique was followed during all phases of sample collection, storage and analysis.

2.2. Aqueous mercury speciation and water chemistry

All lakes were sampled for total and dissolved Hg, total and dissolved meHg, DOC, DIC, pH, suspended particulate matter (SPM), and Chl *a* during May 1994. Many of the lakes had been sampled previously for these and other analytes during 1992 and 1993 (Watras et al., 1995a,b). Where appropriate, these data have been pooled with the data for May 1994. Water samples were collected from a 2-m depth using a submersible, non-metallic centrifugal pump attached to a 3-m length of 1.3-cm i.d. C-Flex tubing. Unfiltered water for mercury analyses was pumped into 500-ml Teflon bottles through a 64-μm Nitex screen to remove zooplankton. Filtered water for mercury analyses was similarly collected after pumping through an acid-cleaned, Gelman Versaflow filtration capsule (0.45 μm). Samples for dissolved gaseous mercury (DGM) were collected using an overflow technique into 1-l or 2-l Teflon bottles through a narrow tube that extended to the bottom of the collection bottle. The DGM bottle was allowed to overflow for three full volumes before capping without headspace. All samples except those for DGM analysis were preserved with clean 6N HCl to 1% v/v.

Aqueous Hg and meHg were determined according to Bloom and Fitzgerald (1988) and Bloom (1989) as modified by Liang et al. (1994) to incorporate the meHg distillation protocol described by Horvat et al. (1993). Detection limits ranged from 0.03 to 0.18 ng/l for Hg and from 0.03 to 0.06 ng/l for meHg defined as 3 S.D. of reagent blanks. DGM was determined by sparging unfiltered lakewater with Hg-free N_2 gas for 20 min and trapping the liberated Hg vapor on gold (Vandal et al., 1991). DGM samples were sparged within 4 h of collection. The detection limit for DGM ranged from 4 to 20 pg/l defined as 3 S.D. of the sparging blank. Inorganic Hg^{II} was operationally defined as: $Hg^{II} = Hg_T - MeHg - Hg^0$. The aqueous Hg^{II} fraction includes $Hg(OH)_2$, $HgCl_2$, HgOHCl, humic-bound Hg, and potentially some organo-Hg species not quantitatively separated by the ethylation method of Bloom (1989).

Analytical methods for the determination of DOC, DIC, pH, ANC, conductivity, major cations (Ca, Mg, Mn, Na, Fe), and major anions (SO_4, NO_3-N, Cl) followed Watras et al. (1995b). Trace elements (Cd, Cu, Pb, Se, As) were measured using Zeeman-corrected GFAAS with pre-concentration via ultra-clean evaporation (Cd, Cu, Pb) or hydride generation and cryogenic trapping (As, Se).

2.3. Microseston

The microseston in these lakes is primarily phytoplankton, bacterioplankton, and cellular debris. Hg and meHg concentrations in microseston were estimated from the difference between filtered and unfiltered water concentrations ($Hg_P = Hg_T - Hg_D$, where $0.45\ \mu m \leq HgP \leq 64\ \mu m$). Since Hg_P is often small relative to Hg_T and Hg_D (Table 3), the validity of this approach depends, in part, on the precision with which total and dissolved mercury concentrations can be determined. One measure of precision, the CV for replicate analyses, averaged approx. 10% for aqueous Hg and meHg in Wisconsin lakewaters (Bloom et al., 1995).

2.4. Zooplankton

Roughly 100 zooplankton samples were analyzed for Hg and meHg. Zooplankton were collected in replicate vertical hauls of a 20-cm diameter, non-metallic, plankton net (153-μm mesh) at the deepest point in each lake during May 1994. The zooplankton were transported back to a clean laboratory in acid-washed 1-l Teflon jars that were sealed in double, zip-locked plastic bags

Table 3
Concentration of mercury species in surface waters of the 15 study lakes

Lake No.	Hg_T (ng/l)	Hg_D (ng/l)	$MeHg_T$ (ng/l)	$MeHg_D$ (ng/l)	Hg^{II}_T (ng/l)	Hg^{II}_D (ng/l)	Hg^0 (pg/l)
1	0.76	0.44	0.13	0.06	0.63	0.38	23
	(0.17)	(0.12)	(0.08)	(0.04)	(0.21)	(0.15)	—
2	0.92	0.76	0.07	0.03	0.85	0.73	48
	(0.10)	(0.19)	(0.03)	(0.02)	(0.10)	(0.19)	—
3	0.82	0.78	0.05	0.04	0.78	0.74	15
	(0.63)	(0.39)	(0.02)	(0.02)	(0.64)	(0.40)	—
4	0.53	0.54	0.04	0.03	0.49	0.51	14
	(0.27)	(0.16)	(0.03)	(0.00)	(0.24)	(0.15)	—
5	0.63	0.38	0.04	0.02	0.59	0.36	20
	(0.22)	(0.19)	(0.02)	(0.02)	(0.23)	(0.21)	—
6	1.11	0.81	0.10	0.07	1.00	0.74	22
	(0.16)	(0.16)	(0.06)	(0.05)	(0.21)	(0.19)	—
7	0.52	0.43	0.05	0.02	0.47	0.41	10
	(0.15)	(0.14)	(0.02)	(0.01)	(0.13)	(0.15)	—
8	1.25	0.82	0.12	0.08	1.15	0.76	19
	(0.24)	(0.17)	(0.04)	(0.04)	(0.26)	(0.19)	—
9	1.84	1.89	0.55	0.42	1.30	1.47	14
	(0.19)	(1.10)	(0.24)	(0.25)	(0.27)	(1.16)	—
10	2.12	1.80	0.16	0.09	1.96	1.71	—
	—	—	—	—	—	—	—
11	3.07	2.28	0.40	0.34	2.66	1.94	—
	—	—	—	—	—	—	—
12	4.19	4.69	0.45	0.67	3.74	4.02	—
	—	—	—	—	—	—	—
13	2.92	2.39	0.61	0.50	2.31	1.89	—
	(0.07)	(0.14)	(0.14)	(0.03)	(0.21)	(0.11)	—
14	4.11	3.72	0.83	0.73	3.28	3.00	22
	(0.50)	(0.70)	(0.07)	(0.14)	(0.57)	(0.72)	—
15	4.36	3.92	0.60	0.63	3.76	3.29	—
Mean	1.94	1.71	0.28	0.25	1.66	1.46	21
S.D.	1.43	1.42	0.27	0.27	1.20	1.17	11
Min	0.52	0.38	0.04	0.02	0.47	0.36	10
Max	4.36	4.69	0.83	0.73	3.76	4.02	48

Note. Data are mean values for each lake from 1990 to 1994 with S.D. in parentheses. Lakes numbered as in Table 1.
Nomenclature. T, total; D, dissolved (0.45 μm filtered); Hg^0, dissolved gaseous Hg; $Hg^{II} = Hg - MeHg - Hg^0$. Note that the Hg^{II} pool is operationally defined and may also contain organo-Hg species that are not differentiated by the ethylation/GC-separation method of Bloom (1989).

and placed in a plastic cooler. Live zooplankton were then taxonomically sorted and monospecific samples containing 10–150 individuals (0.1–4 mg dry wt.) were put into Teflon micro-vials within 8 h of collection (Watras and Bloom, 1992; Back and Watras, 1995). The sorted live samples were immediately frozen and stored under clean conditions until homogenization and analysis for Hg, meHg and dry weight. Following the method of Back et al. (1995), sample homogenate was digested overnight at 65°C in HNO_3/H_2SO_4 and BrCl for Hg or in KOH/methanol for meHg. Hg digestates were pre-reduced with NH_2OH HCl for 20 min prior to analysis. Detection limits ranged from 4 to 12 pg Hg and from 0.8 to 4.3 pg meHg.

2.5. Fish

Yellow perch (*Perca flavescens*) and golden

shiners (*Notemigonus crysoleucas*) were collected during spring and summer 1994 primarily by mini-fyke net, but shore seining, angling, AC electroshocking, and gill netting were also used when fyke nets were unsuccessful. Fyke nets were set overnight and gill nets were tended every 2 h. Fish were weighed and measured and several scales were collected posterior to the left pectoral fin for age estimation. Because of the large number of fish involved (727 perch, 139 golden shiners, ages <1–7 years), it was not possible to estimate age from otoliths. Fish were individually placed in double zip-lock bags for freezing at -20°C. Individual thawed fish were processed whole, homogenized and analyzed for Hg according to Bloom (1992).

2.6. Sediments

Surficial sediment samples were collected during spring 1994 from six depths spaced along a transect extending from shore to the deepest point in each lake. An Ekman dredge was slowly lowered into the sediment, taking care to minimize disturbance on descent and retrieval. Roughly 30 cm^3 of sediment was removed from the center of the dredge by inserting a clean, plastic scoop to a depth of 3–4 cm. The sample was put into a zip-locked plastic bag and placed on ice in the dark for transport to the lab freezer. Ninety sediment samples were collected in total. Thawed sediment was analyzed for organic content (loss on ignition, LOI) and water content in addition to Hg and meHg. Hg concentrations were determined by the same method used for fish (Bloom, 1992). Methyl mercury concentrations were determined by aqueous distillation, ethylation and CVAFS (Horvat et al., 1993). Corrections for incidental methylation during distillation were not applied, so meHg concentrations in sediments may be over-estimated by 10–20% (Bloom et al., 1997).

3. Results and discussion

3.1. Aqueous mercury

Mean concentrations of Hg_T and $meHg_T$ in the study lakes ranged from 0.5 to 4.4 ng Hg/l and from 0.04 to 0.8 ng meHg/l (Fig. 1A, Table 3). On average, $meHg_T$ constituted approx. 15% of the Hg_T in surface waters, but the meHg fraction ($meHg_T/Hg_T$) was positively correlated with DOC. Dissolved gaseous mercury, largely Hg^0, represented approx. 1% of the total aqueous Hg pool (Table 3). Mercury concentrations were lower than the concentrations of other trace metals and minor elements by 1–2 orders of magnitude (Table 4). These results agree well with previous findings for this region and other temperate areas of North America (Driscoll et al., 1994; Kelly et al., 1995; Watras et al., 1995a,b).

Concentrations of dissolved Hg and meHg were strongly dependent on DOC (Fig. 1B). Linear regression analysis indicated that DOC accounted for 80–85% of the variability in dissolved mercury species. Neither Hg or meHg were correlated strongly with other aqueous constituents, except those trace metals and minor elements that co-varied with DOC (Table 5). Aluminum, copper, iron, Hg and meHg all exhibited strong, positive

Table 4
Concentration of ancillary trace elements in surface waters of the study lakes

Lake no.	Cd (ng/l)	Se (ng/l)	Pb (ng/l)	As (ng/l)	Cu (ng/l)	Al (μg/l)
1	21.1	<10	100	170	80	17.4
2	24.0	<10	340	80	40	12.0
3	<0.1	20	50	180	160	<0.03
4	2.2	20	50	90	110	7.5
5	0.3	40	<10	260	160	6.0
6	12.3	40	170	220	160	25.8
7	0.9	20	20.0	160	50	3.6
8	3.0	<10	<10	50	80	31.8
9	10.1	30	170	270	410	63.1
10	0.7	20	90	200	480	36.0
11	7.2	<10	180	110	450	91.0
12	4.6	30	100	310	640	110.6
13	12.3	40	140	280	440	129.0
14	18.0	70	370	200	810	214.4
15	25.0	70	880	300	770	288.8
Mean	10.1	36.4	204.4	192.2	322.5	74.1
Median	8.7	30.0	139.9	200.2	159.9	33.9
Minimum	0.3	20.0	20.0	50.1	40.0	3.6
Maximum	25.0	70.0	879.2	310.3	809.5	288.8

Note. Lake numbers as on Table 1.

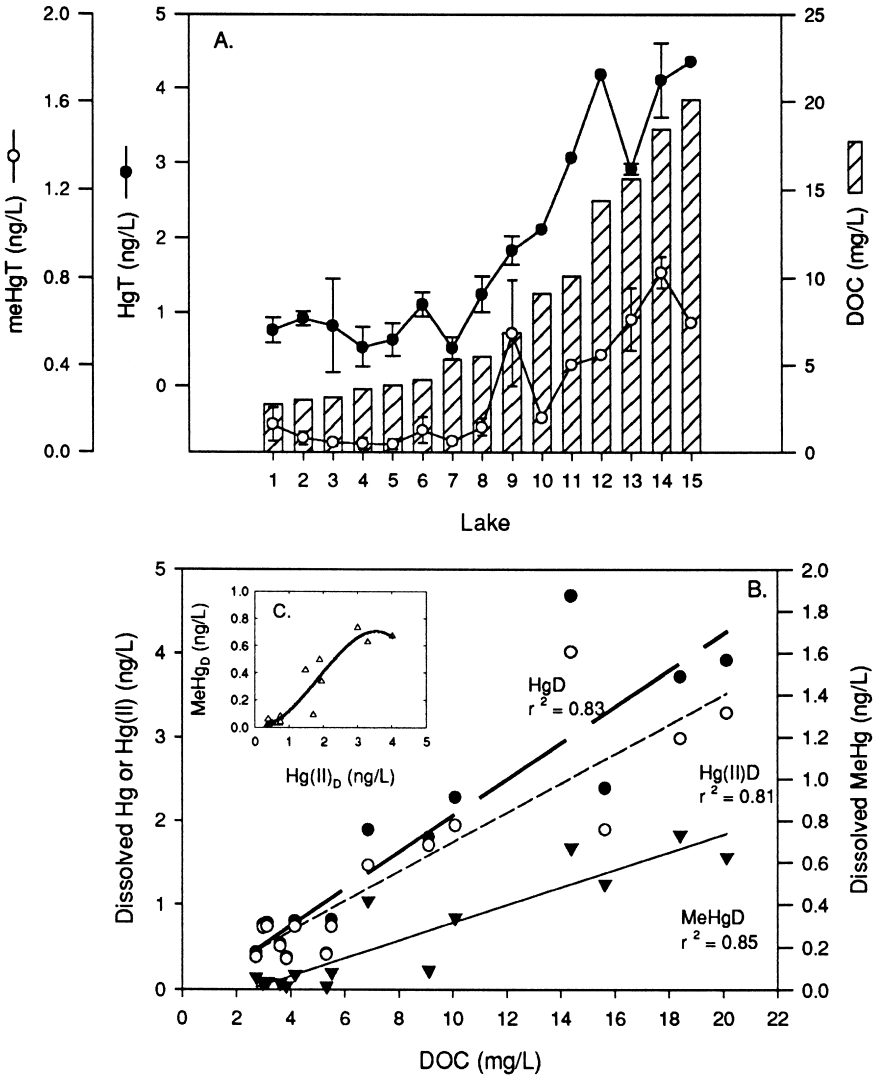

Fig. 1. Relationship between aqueous mercury concentrations and DOC in the 15 WI study lakes. (A) Total Hg and meHg: data are lake averages ± 1 S.D. (1992–1994). Lake numbers from Table 1. (B) Dissolved mercury: first order regression equations are $meHg_D = -0.01 + 0.04$ DOC (solid line, filled triangles); $Hg_D^{II} = -0.02 + 0.17$ DOC (short dashed line, open circles); $Hg_D = -0.12 + 0.22$ DOC (long dashed line, filled circles) — note that we fit a straight line to the meHg data even though there is evidence of curvature at low DOC. (C) Regression equation is $MeHg_D = 0.02 - 0.06\ Hg_D^{II} + 0.20\ Hg_D^{II2} - 0.04\ Hg_D^{II3}$, $r^2 = 0.89$.

DOC dependencies (Fig. 2). Weak negative correlation between aqueous mercury and pH were also observed (Table 5), consistent with previous observations for this region (Watras et al., 1995b).

The strong positive correlations between aqueous mercury and DOC suggest that most of the dissolved Hg^{II} and meHg in these lakewaters is organically complexed — given the relatively constant atmospheric loading of Hg to these lakes and lack of correlation with other aqueous analytes that signify geochemical control. This conclusion is in agreement with numerous field observations (e.g. Meili, 1991; Mierle and Ingram, 1991; Watras et al., 1995b,c; Driscoll et al., 1995), as well as the modeling results of Hudson et al. (1994) which indicated that organic complexes

Table 5
Correlation matrix for aqueous metals and ancillary analytes in the 15 study lakes

	Hg_T	Hg^{II}	meHg	Cu	Al	Fe	Se	Pb	As	Mn	Cd	Mg
Hg^{II}	**0.99**											
meHg	**0.88**	**0.82**										
Cu	**0.96**	**0.94**	**0.88**									
Al	**0.90**	**0.87**	**0.86**	**0.89**								
Fe	**0.86**	**0.83**	**0.83**	**0.90**	**0.87**							
Se	0.69	0.65	0.72	0.71	**0.86**	**0.80**						
Pb	0.57	0.57	0.50	0.56	0.80	0.57	**0.86**					
As	0.52	0.50	0.52	0.60	0.50	0.37	0.45	0.30				
Mn	0.61	0.34	0.61	0.58	0.50	0.62	0.46	0.14	0.23			
Cd	0.30	0.27	0.39	0.24	0.51	0.38	**0.88**	0.72	0.11	0.37		
Mg	−0.15	−0.13	−0.24	−0.02	−0.13	−0.12	−0.42	−0.33	0.05	−0.17	−0.56	
Ca	−0.19	−0.16	−0.28	−0.05	−0.16	−0.15	−0.44	−0.33	0.05	−0.18	−0.53	1.00
Na	0.27	0.28	0.19	0.27	0.22	0.35	0.15	−0.10	−0.16	0.33	−0.34	0.41
DOC	**0.95**	**0.93**	**0.88**	**0.92**	**0.94**	**0.84**	0.74	0.61	0.56	0.53	0.28	−0.09
SPM	0.74	0.77	0.51	0.62	0.43	0.47	0.08	−0.03	0.37	0.60	−0.14	−0.03
Chl *a*	0.34	0.36	0.18	0.19	0.10	0.01	−0.31	−0.67	0.32	0.23	−0.32	0.17
Cond.	−0.14	−0.11	−0.23	−0.01	−0.08	−0.08	−0.37	−0.34	0.03	−0.10	−0.54	0.99
DIC	−0.22	−0.20	−0.29	−0.07	−0.18	−0.15	−0.43	−0.29	0.03	−0.22	−0.50	0.99
ANC	−0.24	−0.21	−0.33	−0.10	−0.24	−0.19	−0.50	−0.33	0.02	−0.24	−0.60	0.99
pH	−0.43	−0.40	−0.51	−0.34	−0.55	−0.43	−0.74	−0.38	−0.18	−0.45	−0.84	0.81
H^+	0.42	0.42	0.37	0.42	0.68	0.42	0.71	0.88	0.36	0.21	0.69	−0.38
SO_4	−0.61	−0.65	−0.34	−0.56	−0.43	−0.41	−0.20	−0.32	−0.28	0.01	0.20	0.08
Cl	0.33	0.35	0.20	0.20	0.15	0.25	0.28	0.02	−0.22	0.43	−0.23	−0.11

Note. Data from Tables 2 to 4. Values are the Pearson correlation coefficient (r). Bold type indicates highly significant correlations ($r > 0.80$)

made up more than 99% of the Hg^{II}_D in a set of seven lakes from this region. It also agrees with the experimental studies of Hintelmann et al. (1996) whose equilibrium constants for the complexation of meHg by dissolved humic matter indicate a similarly high degree of organic complexation.

MeHg increased with increasing Hg^{II}, but the relationship was best described by a third-order polynomial (Fig. 1C). In an earlier study, we concluded that a second-order expression described this relationship well because meHg was weakly dependent on Hg^{II} at low concentrations (Watras et al., 1995b). Our additional data suggest that meHg concentrations are relatively independent of Hg^{II} at both low and high concentrations. The biogeochemical mechanisms underlying this pattern are unclear. We note, however, that meHg concentrations in oxic surface waters rarely exceed 1 ng/l even in ecosystems that are grossly contaminated with inorganic Hg (Suchanek et al., 1993; Jacobs et al., 1995; Saouter et al., 1995).

Although the DOC in dark water lakes (5−>20 mg C/l) comprises humic material exported from riparian wetland, the observed relationship between Hg^{II} and DOC does not necessarily imply that wetlands are a major source of Hg^{II} to lakes. Given the magnitude and regional constancy of atmospheric Hg^{II} loading and the importance of sedimentation and gaseous evasion as Hg^{II} loss terms in seepage lakes (Fitzgerald and Watras, 1989; Fitzgerald et al., 1991; Watras et al., 1994, 1996), the concentration of inorganic Hg^{II} would reach a level where inputs exactly balanced outputs provided rates of loss were controlled by inorganically complexed Hg^{II} while the total Hg^{II} was dominated by organic complexes. At steady-state, the inorganic pool would remain unchanged with respect to DOC but the total Hg^{II} pool would rise in proportion to DOC — yielding a relatively constant ratio Hg^{II}:DOC across lakes, as we observed (170 ± 31 ng Hg/g C, 95% CI). Alternatively, if riparian wetland was a large source of Hg^{II} to lakes, the constant ratio

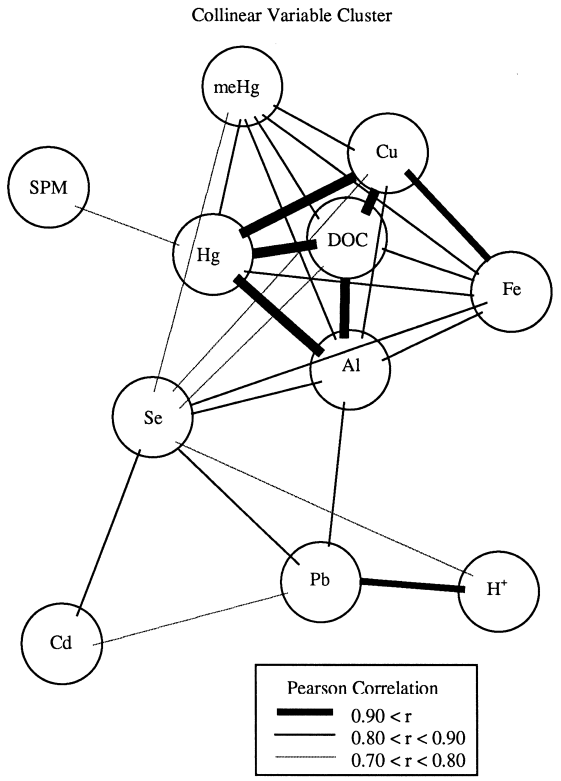

Fig. 2. Diagrammatic representation of the collinearity between Hg, meHg, aqueous metals, and other correlates in the water columns of the 15 WI study lakes. Data from Table 5.

Hg^{II}:DOC across lakes could be explained by similar cycling of carbon and Hg^{II}. In other words, the removal of Hg^{II} from lake water would be linked or parallel to the loss of allochthonous C — perhaps by co-sedimentation or by parallel evasion of Hg^0, CO_2 and CH_4.

A different balance of processes is needed to explain why the ratio meHg:DOC in lake water varied positively with DOC. Although the element Hg is conserved, meHg is produced and destroyed within ecosystems. There is evidence that net meHg input could be affected by DOC in several ways: (1) by the production and export of meHg from riparian wetlands (e.g. Lee and Iverfeldt, 1991; St Louis et al., 1994; Pettersson et al., 1995); (2) by enhanced microbial methylation in-lake due to additional carbon or Hg^{II} substrate (Hudson et al., 1994); and (3) by reduced photodestruction in dark water lakes (Sellers et al., 1996). A variety of mechanisms might be consistent with our observation.

3.2. Microseston

The concentration of Hg^{II} and meHg in microseston averaged 170 ± 44 ng/g dry wt. and 33 ± 14 ng/g dry wt. (95% CI), respectively, across lakes. The concentration of Hg^{II} and meHg in microseston varied independently of DOC (Fig. 3). However, the log K_ds [ratio of Hg in seston (ng/kg dry wt.) to Hg in water (ng/l)] for both Hg^{II} and meHg were negatively correlated with DOC, as expected for strongly complexed metals (Fig. 3). Seston–water partition coefficients were roughly twofold higher for meHg than for Hg^{II} when averaged across all lakes. Without an independent measure, it is unclear whether this difference in K_ds reflects a higher plankton affinity or a lower DOC affinity for meHg. However, conditional stability constants calculated for thiols suggest that DOC has a lower affinity for meHg than for Hg^{II} (Dyrssen and Wedborg, 1991).

Assuming most of the small particulate matter in these lakes consists of living phytoplankton and bacterioplankton, the log K_d may approximate the bioaccumulation factor (BAF) for microplankton. For meHg, we note that detrital organic matter would likely depress observed K_ds below true BAFs since meHg concentrations are low in organic sediments (Watras et al., 1994, 1995d; this paper). Furthermore, even though Fe-oxides have a significant affinity for meHg and Hg^{II}, we estimate that they do not contribute significantly to K_d in the presence of DOC at the levels found in these lakes (Hudson and Watras, in preparation). Assuming that most of the suspended mercury is in living cells and that half of the seston is live biomass, 'true' BAFs would be elevated by roughly 0.3 log units — ranging from 4.7 to 5.9 for Hg^{II} and from 4.8 to 6.2 for meHg. In any case, the magnitude of these BAFs clearly indicate that uptake by the microplankton is a major step in the bioaccumulation process. As shown below, BAFs for higher trophic levels increase further by only a factor of 2–4.

Sestonic meHg increased slightly with decreas-

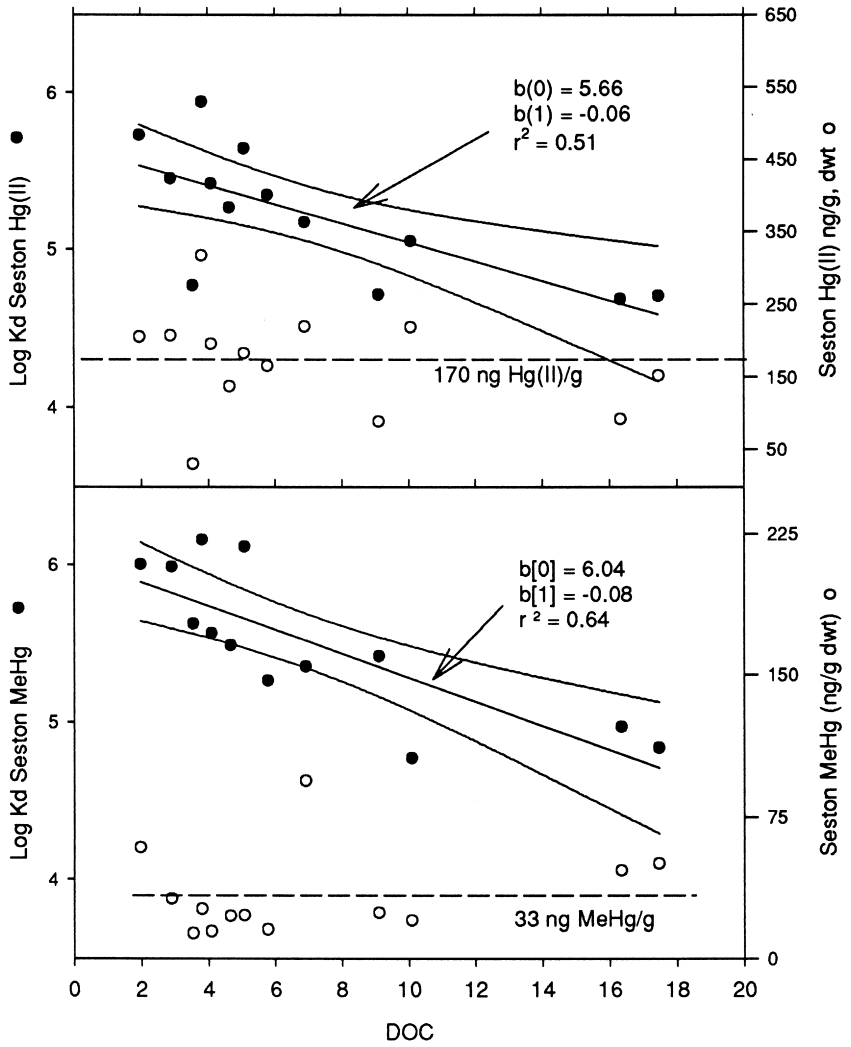

Fig. 3. Dependence of seston–water partition coefficients (log K_d) and sestonic concentrations of Hg^{II} (top) and meHg (bottom) on DOC in the 15 WI study lakes. Solid lines indicate linear regression of DOC vs. log K_d with 95% CI. Regression parameters: $b(0)$ = slope; $b(1)$ = intercept. Dotted lines indicate mean sestonic concentration for all lakes.

ing pH, paralleling the change in dissolved meHg (Fig. 4A,B). This observation is consistent with at least two hypotheses regarding the uptake of meHg at the base of aquatic food webs. Based on earlier field data and modeling results, we previously hypothesized that meHg was bioaccumulated in proportion to supply and that pH affected the supply of meHg to aquatic ecosystems (Bloom et al., 1991; Watras and Bloom, 1992; Hudson et al., 1994). However, the recent experimental data of Mason et al. (1996) suggest an alternative hypothesis: i.e. that meHg uptake by microseston is governed by the passive uptake of neutrally charged $meHgCl^0$ species which increase in concentration as pH decreases — all other things being equal.

Although the passive uptake of $meHgCl^0$ by phytoplankton is indisputable, our field data are not consistent with the hypothesis that passive uptake controls bioaccumulation in nature. For

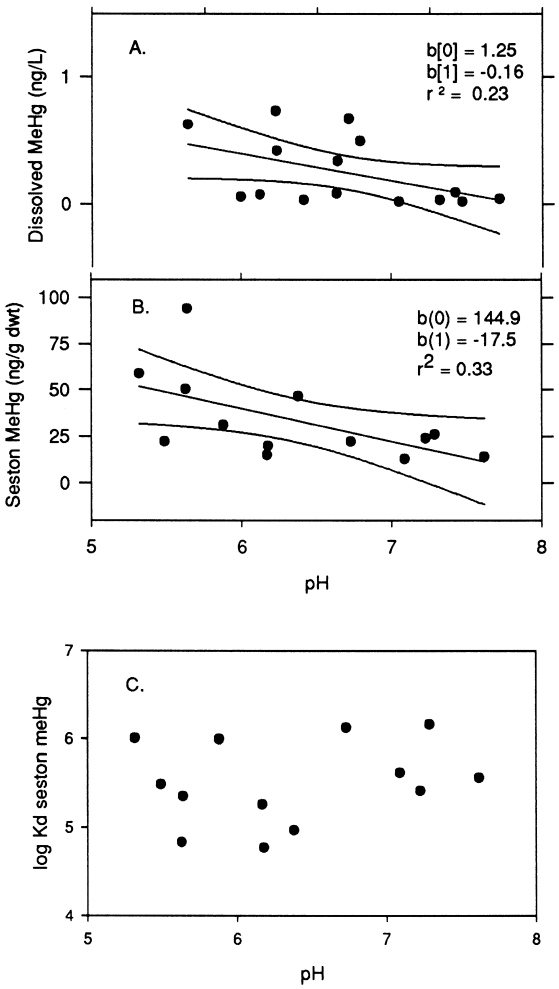

Fig. 4. Dependence of meHg concentration and partition coefficient on pH in the 15 Wisconsin study lakes. (A) Aqueous meHg; (B) seston meHg; and (C) apparent partition coefficient (log K_d). Regression lines and parameters as in Fig. 3.

example, we found that the accumulation of meHg or Hg^{II} by microseston was independent of Cl concentration even though aqueous Cl concentrations varied by a factor of 30 among lakes (Fig. 5). We also observed no correlation between meHg in seston and the ambient $meHgCl^0$ concentration (Fig. 6), which was calculated for each lake from the observed $meHg_D$, Cl, pH and DOC following Hudson et al. (1994). Instead, seston meHg was positively correlated with the calculated aqueous concentration of meHgOH and $meHg^+$ (Fig. 6A,B).

The dependence of seston meHg on either the hydroxide or free ionic meHg species is consistent with the hypothesis that uptake is dominated by active transport into phytoplankton and bacterioplankton. Although meHgOH may be transported passively as a neutral species, its diffusion rate across the cell membrane is only $0.04\times$ the diffusion rate of $meHgCl^0$ (Mason et al., 1996). Further evidence of control by active transport at low pH is provided by the seston–water partition coefficient (K_d). K_d was not correlated with pH for either Hg^{II} or meHg (Fig. 4C). This observation suggests that the negative correlation between sestonic meHg and pH is related to increases in aqueous meHg concentrations at low pH rather than to increases in seston–water partitioning. This conclusion is consistent with earlier findings by Bloom et al. (1991) and Watras et al. (1994) who reported no correlation between pH and seston–water partition coefficients or between pH and perch bioaccumulation factors for meHg in several North American lakes.

3.3. Zooplankton

Mean Hg_T concentrations in zooplankton ranged from 33 to 206 ng/g dry wt. in the 15 study lakes (Table 6). Specific taxa had Hg_T concentrations as high as 484 ng/g dry wt. (e.g. predacious water mites, Table 6). Among crustacean zooplankton, meHg constituted 60–80% of the total Hg on average. These observations are similar to previous findings for zooplankton in remote Canadian lakes (Tremblay et al., 1995; Tsalkiztis, 1995; Wescott and Kalff, 1996), Swedish lakes (Meili, 1991), Finnish lakes (Rask et al., 1994), northern Minnesota lakes (Sorenson et al., 1990) and northern Wisconsin lakes (Watras and Bloom, 1992; Back and Watras, 1995).

Concentrations of meHg and the % meHg were higher in zooplankton than in microseston. However, the average concentration of Hg^{II} was substantially lower in zooplankton than microseston. Thus, within the plankton community we observed biomagnification of meHg but not Hg^{II}. The differential behavior of biotic meHg and Hg^{II} is consistent with previous observations in Little Rock Lake (Watras and Bloom, 1992; Watras et

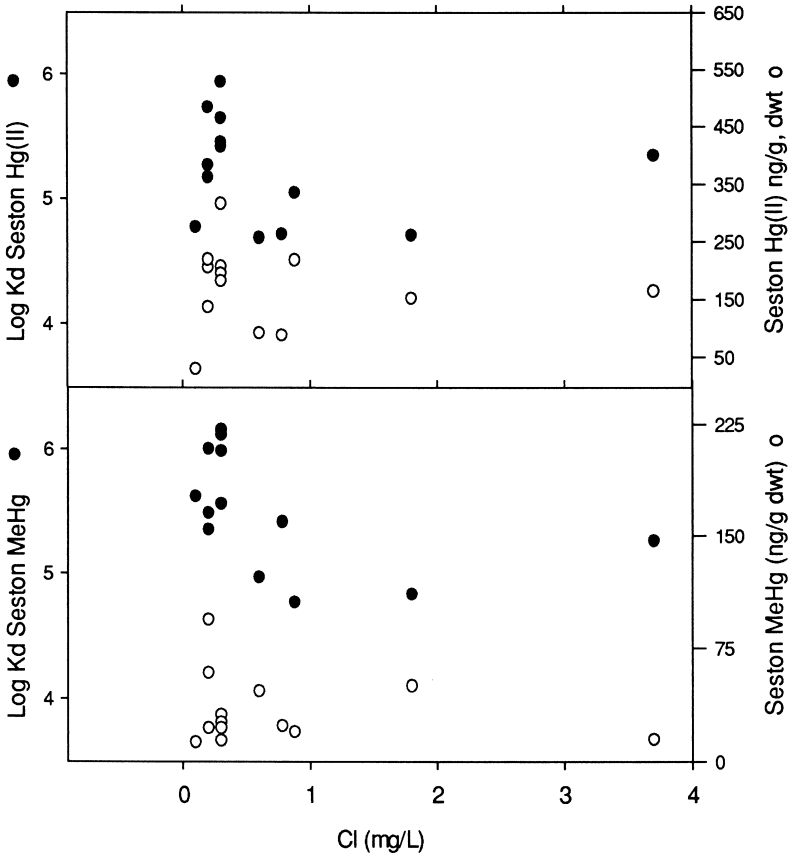

Fig. 5. Aqueous Cl concentration vs. seston–water partition coefficients (log K_d) and sestonic concentrations of Hg^{II} (A) and meHg (B) in the 15 WI study lakes.

al., 1996) as well as observations on other divalent metals in aquatic ecosystems (Suedel et al., 1994).

The meHg concentration in zooplankton was negatively correlated with pH (and pH-related variables) and it was positively correlated with DOC and dissolved meHg (Fig. 7A). The strength of correlation varied with the level of taxonomic resolution applied to the zooplankton community. When all species were lumped together for a given lake (i.e. 'zooplankton I' on Fig. 7A), correlation coefficients were low. For individual zooplankton genera (i.e. *Diaptomus*), correlation coefficients were substantially higher. This result is parallel to numerous observations on fish which clearly show the importance of taxonomic, morphometric, and ontogenic characteristics on mercury bioaccumulation (Spry and Wiener, 1991; Wiener and Spry, 1996).

As observed with sestonic meHg, zooplankton meHg was more strongly dependent on aqueous meHgOH and $meHg^+$ than $meHgCl^0$ regardless of the level of taxonomic resolution (Fig. 7B). For Crustacea, the dependence on aqueous meHgOH was strongly linear and there was no dependence on $meHgCl^0$ (Fig. 8). Crustacean meHg was also strongly correlated with seston meHg (Fig. 9A) and it showed a dependence on pH similar to that observed with seston (cf. Fig. 9B and 5B). These observations are consistent with the trophic transfer and biomagnification of meHg from seston to crustacean zooplankton. Zooplankton may also accumulate some meHg directly from solution

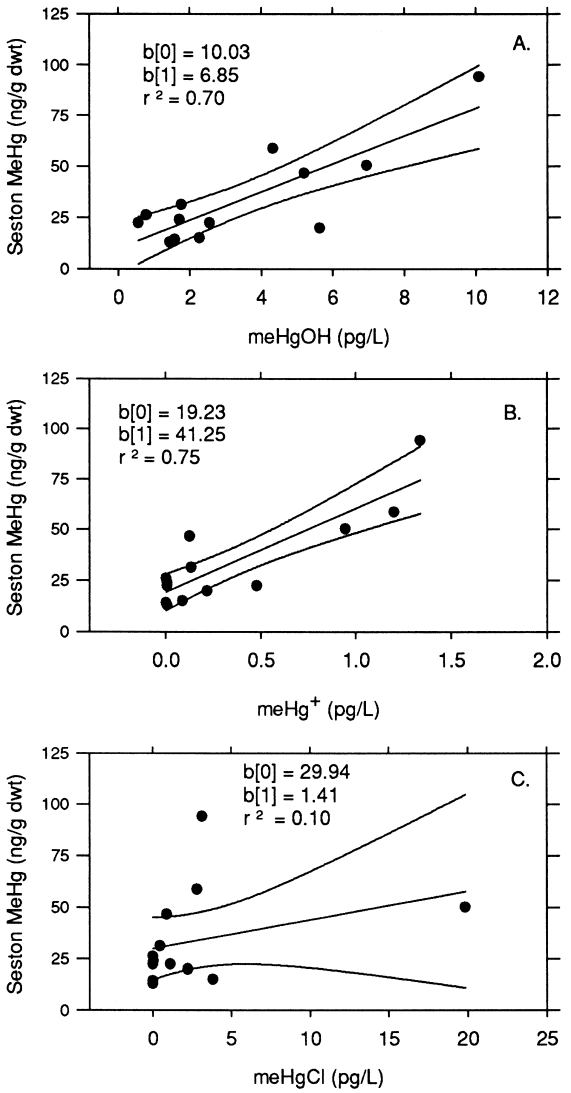

Fig. 6. Dependence of seston meHg concentration on aqueous meHgOH (A), $meHg^{+}$ (B) and $meHgCl^{0}$ (C). Regression parameters as in Fig. 3. Concentration of aqueous meHg species were calculated from known concentrations of $meHg_D$, Cl, DOC and pH in surface waters according to the assumptions of Hudson et al. (1994).

and the intercept on Fig. 9A may approximate direct uptake.

3.4. Fish

Mercury concentrations in 223 yellow perch ranged from 19 to 544 ng/g w/w (Fig. 10). Fish length and fish weight varied widely between samples but a strong relationship between length and weight across all fish suggested similarity in growth between lakes (Fig. 10A). However, consistent allometry among lakes does not guarantee that similar size fish will be collected from each lake. Indeed, there was evidence that bigger fish were collected from low pH lakes. Given the extensive body of literature documenting a positive relationship between fish Hg and body size (Scott and Armstrong, 1972; Abernathy and Cumbie, 1977; MacCrimmon et al., 1983; Wren et al., 1983; Mathers and Johnsen, 1985; Skurdal et al., 1985; Wren and MacCrimmon, 1986; Lathrop et al., 1989; Sorenson et al., 1990; Jackson, 1991; Gutenmann et al., 1992; Glass et al., 1993; Suchanek et al., 1993; Lange et al., 1993), an analysis of covariance was performed to factor-out (or standardize) the effect of body size on fish Hg so that valid inter-lake comparisons could be made. Note that the allometric relationship in Fig. 10 implies that either length or weight could be used to standardize fish Hg concentrations. We chose fish weight since it is logically consistent with Hg concentrations measured on a weight–weight basis.

An analysis of covariance (ANCOVA) was performed using a log-transformation of the following expression:

$$\mathrm{meHg}_{\mathrm{perch},j} = LS_{\mathrm{perch},j} \times W_{\mathrm{perch}}^{A_{\mathrm{perch}}}$$

where $\mathrm{meHg}_{\mathrm{perch},j}$ is the concentration of meHg in yellow perch from lake j, W_{perch} is the weight of the sampled fish, and $LS_{\mathrm{perch},j}$ is a categorical variable that is used to factor out the effects of the particular lake (Wente, 1997). Note the weight coefficient A_{perch} was assumed to be consistent between lakes. Therefore the model assumes that size-related variation in meHg bioconcentration is a characteristic of the yellow perch rather than its environment. This approach differs from fitting individual log–log regressions for each lake — a procedure that would allow the size-related variation in bioaccumulation to vary by lake. The ANCOVA indicated that (log) yellow perch Hg concentrations (and therefore, bioaccumulation factors) varied directly with (log) weight (Fig. 11, $A_{\mathrm{perch}} = 0.27$, $P < 0.0001$). The results support our

Table 6
Concentration of mercury in zooplankton from the Wisconsin study lakes

Taxon	*n*	Hg_T (ng/g dry wt.)	Hg^{II} (ng/g dry wt.)	$meHg_T$ (ng/g dry wt.)	% meHg
All zooplankton	15	83 (33–206)	29 (10–48)	53 (6–161)	57 (11–83)
Crustacea	13	78 (23–179)	24 (10–47)	54 (13–143)	70 (52–83)
Cladocera	10	110 (50–197)	36 (8–79)	73 (35–148)	70 (50–87)
Daphnia	5	81 (54–143)	16 (10–31)	65 (41–112)	80 (76–87)
Holopedium	5	130 (64–251)	42 (10–67)	88 (47–184)	68 (57–83)
Bosmina	5	105 (46–158)	40 (5–79)	65 (29–88)	67 (50–90)
Copepoda	10	60 (23–144)	16 (2–32)	45 (13–132)	71 (52–97)
Diaptomus	7	67 (19–144)	14 (2–41)	52 (14–132)	76 (50–97)
Cyclopoida	8	46 (12–84)	18 (3–43)	28 (9–46)	62 (46–92)
Insecta	11	52 (31–90)	33 (15–48)	19 (4–74)	30 (9–82)
Chaoborus	11	49 (21–90)	29 (15–48)	20 (4–74)	32 (9–82)
Chironomidae	2	114 (95–133)	109 (92–126)	5 (3–7)	5 (4–5)
Arachnoida					
Hydracarina	3	339 (189–484)	67 (59–82)	272 (107–425)	76 (56–88)

Note. Data are grand means for *n* lakes with range between lakes in parentheses.

assumption that size-related variation in meHg bioconcentration is a characteristic of the fish rather than its environment. A 30-g perch was selected as the standard fish.

For the standard 30-g perch, Hg concentration was more strongly dependent on pH ($r^2 = 0.72$) than on DOC ($r^2 = 0.33$) (Fig. 12). This result is consistent with our observations on microseston and zooplankton where pH was also the dominant correlate of meHg concentration. The strength of the pH correlation was higher for fish than for microseston or crustacean zooplankton, but similar to that observed with *Diaptomus* (Fig. 7A) — perhaps reflecting again the importance of taxonomic resolution. We did not find evidence that fish age influenced the correlation with pH or DOC. When the mean Hg concentration in 3-year-old perch from each lake was used as the dependent variable (107 fish total), results were similar to those obtained with the standard 30-g perch.

The dependence of biotic meHg on the free ion or hydroxide species observed with seston and zooplankton carried over to the perch (Fig. 13). Since fish are several trophic levels above seston, other factors such as diet influence meHg accumulation. Nonetheless, our data indicate that direct meHg uptake at low trophic levels ripples through the aquatic food web.

3.5. Sediments

The Hg_T content of organic, surficial sediments ranged from 12 to 398 ng/g dry wt. (Table 7),

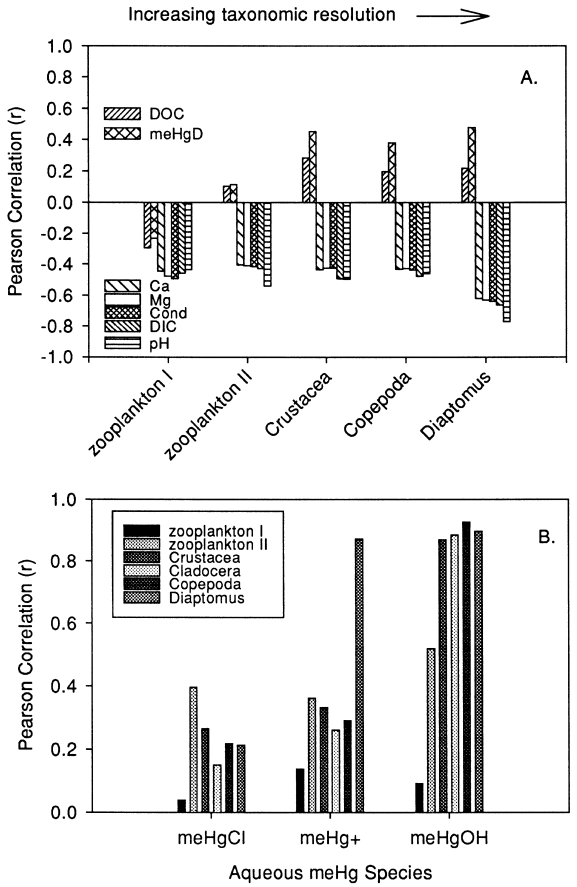

Fig. 7. Correlations between zooplankton meHg and several aqueous constituents in the Wisconsin study lakes. (A) The strength of correlations between zooplankton meHg and either pH-related variables (negative r) or DOC-related variables (positive r) depends on the taxomomic specificity of the zooplankton data. (B) Correlations between zooplankton meHg and the 'available' meHg species in lake water for all taxonomic groupings. Data are mean values for each lake. Zooplankton I are all taxa pooled for a given lake. Zooplankton II are all taxa except water mites (*Hydracarina*). Concentration of aqueous meHg species calculated as in Fig. 6.

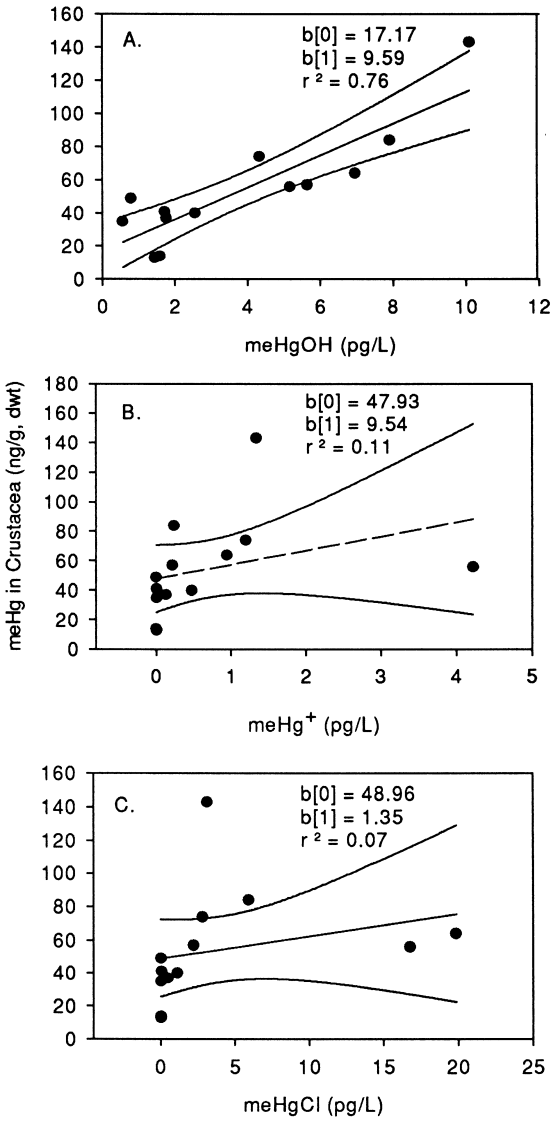

Fig. 8. Dependence of meHg concentration in crustacean zooplankton on the concentration of aqueous meHg species in the Wisconsin study lakes. Zooplankton data are mean values for individual lakes. Concentration of aqueous meHg species calculated as in Fig. 6. Regression parameters as in Fig. 3.

which is within the range reported earlier from a smaller set of northern Wisconsin lakes (Rada et al., 1993). The meHg content of all surficial sediments was low, averaging 2.6 ± 1.8 ng/g dry wt. across lakes. On average meHg constituted 1.5% of the Hg_T in surficial sediments, ranging from 0.1 to 5.4% (Table 7).

Since organic sediments largely comprise material settled from pelagic waters, they contain information about the fate of biotic mercury. The Hg_T content of sediments was similar to that observed in plankton, but meHg concentrations in sediments were much lower than in pelagic organisms. This observation indicates that biotic meHg is lost prior to sediment deposition. Rein-

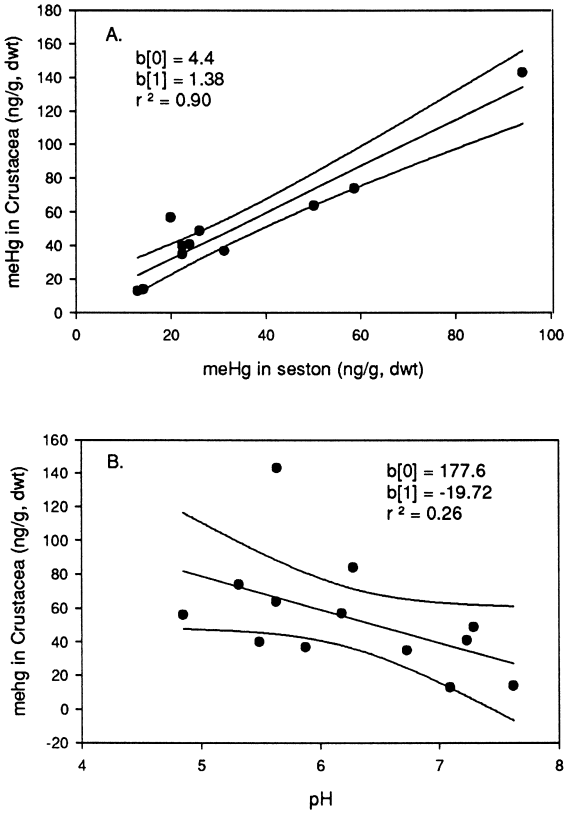

Fig. 9. Relationship between meHg in crustacean zooplankton and meHg in microseston (A) or pH (B) in the Wisconsin study lakes. Regression parameters as in Fig. 3.

felder and Fisher showed that many pelagic trace metals are biologically recycled rather than directly removed to sediments via settling detritus (Reinfelder and Fisher, 1991; Fisher and Reinfelder, 1995). Although recycling extends the residence time of trace elements in surface waters, it cannot defer their fate indefinitely. Biotic meHg may also be recycled in surface waters, but our sediment data indicate that most of it is eventually demethylated.

Sediment Hg_T was positively correlated with four water column variables: aqueous mercury, SPM, DOC and aqueous Fe (Table 8). The dependence of sediment Hg on these variables was not linear, however. Exponential expressions provided the best fit to these data (Fig. 14). A nonlinear regression model with aqueous Hg_T as the independent variable accounted for 70% of the

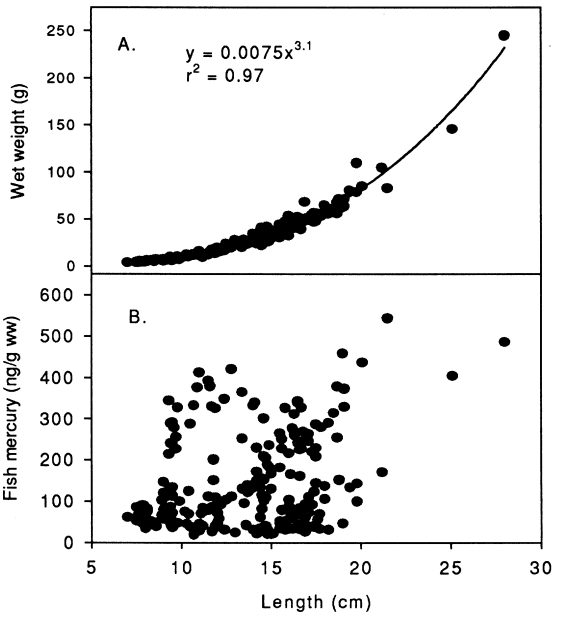

Fig. 10. Morphometric data and mercury concentrations for 223 individual yellow perch from 14 Wisconsin study lakes. All ages combined.

variability in mean sediment Hg among the 15 lakes (Fig. 13A). Sediment meHg was positively correlated with seston Hg concentration and negatively correlated with pH (Table 8). Sediment

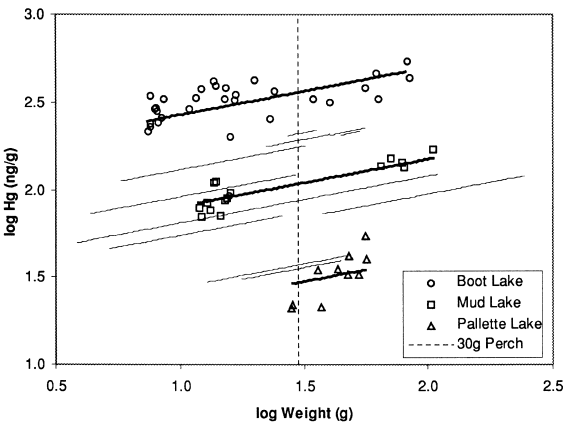

Fig. 11. Relationships between weight and mercury content of yellow perch from 14 of the study lakes. Each sloping line depicts the best estimate for a lake and its horizontal extent indicates the range of fish weights sampled from that lake. Individual fish data are shown from three lakes for illustrative purposes. The vertical line marks the 30-g standard weight.

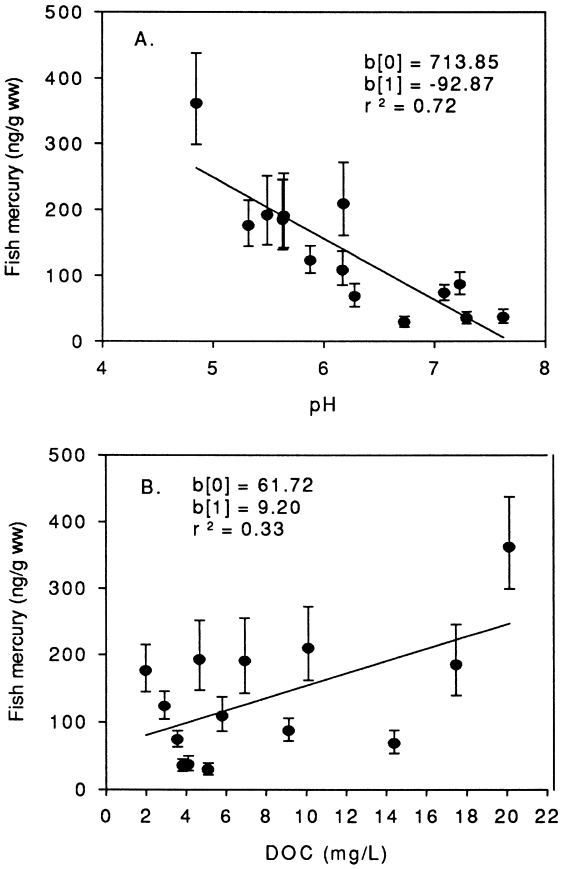

Fig. 12. Relationship between fish mercury and pH (A) or DOC (B) in the Wisconsin study lakes. Data are estimates for 3-year-old yellow perch weighing 30 g in each lake ±1 S.D. Regression parameters as in Fig. 3.

meHg was not dependent on DOC or SPM in the water column (Fig. 15).

4. Synthesis

The above observations highlight the complex interplay between the concepts of chemical speciation and bioaccumulation in aquatic ecosystems. Chemical speciation includes both the different chemical forms of an element (e.g. Hg^{II}, Hg^{0} and meHg) and different aqueous species (e.g. $meHg^{+}$, meHgCl and organically-complexed meHg), which all differ in their tendency to bioaccumulate. Similarly, bioaccumulation involves two distinct processes — uptake from water into biota at

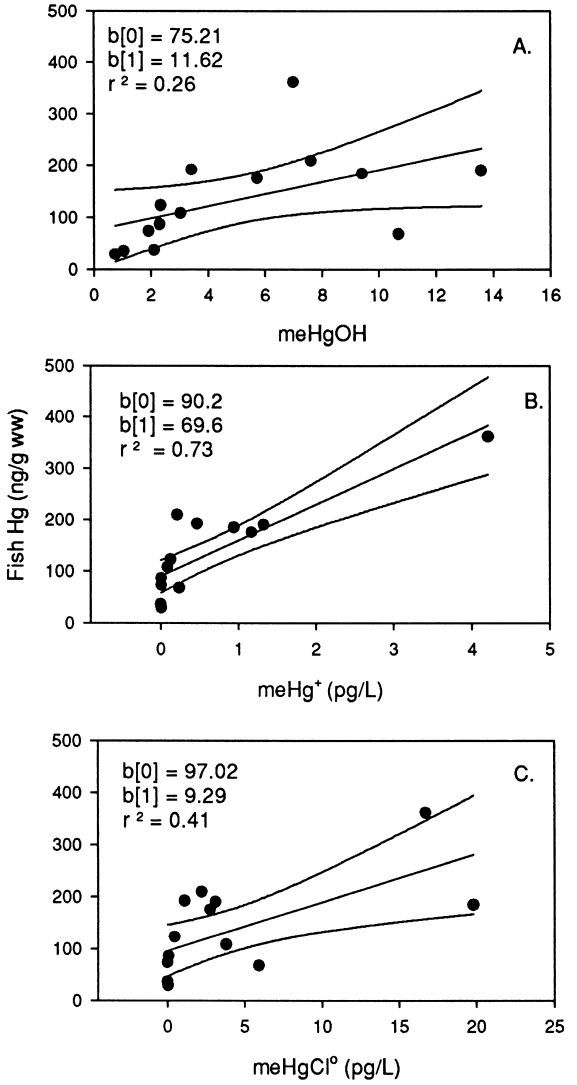

Fig. 13. Dependence of meHg concentration in fish (yellow perch) on the concentration of aqueous meHg species in the Wisconsin study lakes. Fish data are mean values for individual lakes. Concentration of aqueous meHg species calculated as in Fig. 6. Regression parameters as in Fig. 3.

lower trophic levels and transfer between trophic levels — that are influenced by chemical speciation to different degrees. In what follows, we consider these two processes and the influence of speciation on them. Examining the relative bioaccumulation of different forms of Hg between trophic levels illustrates the concept of biomagnification; examining the dependence of meHg

Table 7
Mercury in surficial sediments of the Wisconsin study lakes

Lake	*n*	Hg_T (ng/g dry wt.)	$meHg_T$ (ng/g dry wt.)	% meHg	Water content (%)	Volatile matter (%)
1	5	132 (52–191)	1.8 (0.3–4.3)	1.3 (0.3–2.2)	91.9 (87.0–95.6)	55.6 (43.9–60.7)
2	6	142 (87–192)	0.7 (0.5–0.9)	0.5 (0.3–0.8)	87.0 (80.4–92.6)	48.2 (37.6–55.3)
3	6	77 (12–119)	0.7 (0.1–1.2)	0.9 (0.5–1.2)	92.9 (90.6–95.4)	52.0 (40.1–69.3)
4	6	158 (120–215)	3.3 (1.5–4.8)	2.2 (0.8–3.1)	95.4 (94.8–96.0)	61.3 (56.6–67.2)
5	4	69 (28–144)	0.9 (0.3–2.3)	1.3 (0.4–1.9)	94.3 (92.7–96.6)	57.2 (47.5–70.0)
6	4	200 (138–285)	3.9 (0.8–5.8)	1.8 (0.6–2.8)	94.4 (92.4–96.3)	62.2 (55.7–70.3)
7	6	63 (0.3–156)[a]	0.5 (0.06–1.9)	1.3 (0.1–2.6)	57.5 (21.3–97.7)	29.0 (0.4–58.0)
8	6	192 (150–254)	3.8 (0.5–8.7)	2.2 (0.2–4.5)	93.9 (90.6–96.4)	53.6 (50.5–56.5)
9	6	191 (93–273)	7.4 (3.9–12.2)	3.9 (1.4–5.4)	91.9 (89.8–94.4)	52.5 (39.5–70.4)
10	5	220 (203–231)	1.9 (1.0–3.1)	0.9 (0.4–1.4)	91.2 (85.2–93.8)	40.4 (38.3–42.4)
11	6	289 (218–398)	4.0 (2.5–8.3)	1.5 (0.7–3.1)	95.1 (94.1–96.2)	51.0 (47.3–52.7)
12	4	242 (151–368)	1.8 (1.1–2.5)	0.8 (0.6–1.0)	94.4 (93.4–95.3)	56.9 (53.8–63.7)
13	6	224 (97–362)	1.4 (0.7–1.7)	0.6 (0.5–0.7)	95.0 (93.4–96.6)	62.7 (56.8–74.7)
14	5	238 (215–251)	2.5 (0.9–5.7)	1.1 (0.4–2.5)	95.1 (94.1–96.2)	51.0 (74.3–52.7)
15	5	200 (92–334)	3.8 (1.2–4.8)	2.7 (0.4–4.6)	91.0 (86.6–94.1)	46.0 (36.8–54.2)
Mean		176	2.6	1.5	90.4	51.1
S.D.		68	1.8	0.9	9.4	9.6
n	80	15	15	15	15	15
Min		63	0.5	0.5	57.5	29.0
Max		289	7.4	3.9	95.4	62.7

Values are the mean of *n* samples taken along a littoral–profundal transect in each lake, with range in parentheses.
[a] Low value = sand.

bioaccumulation on solution speciation illustrates the concept of bioconcentration.

4.1. Biomagnification

Biomagnification is defined here as the increasing concentration of a contaminant at successively higher trophic levels of a food web. As observed by Suedel et al. (1994), there is sparse evidence for biomagnification among the metallic elements in aquatic ecosystems. Indeed, most elements become progressively less concentrated at higher trophic levels, perhaps because the increasing ratio of body volume to surface area decreases the relative rate of uptake from the water and because the trophic transfer of most metals is inefficient (see Reinfelder et al., 1998). Although the term biomagnification is not neces-

Table 8
Environmental correlates of mean sediment mercury concentrations in the Wisconsin study lakes

Correlate	Sediment Hg	Sediment meHg
Hg_T, water column	0.75	0.21
SPM	0.71	−0.02
$meHg_T$, water column	0.67	0.38
DOC, water column	0.65	0.13
Iron, water column	0.61	0.18
Sediment meHg	0.45	–
pH, water column	−0.41	−0.47
Chloride, water column	0.40	0.08
ANC, water column	−0.38	−0.42
Chl *a*, water column	0.29	−0.26
Seston meHg	0.27	0.07[a]
% volatile, sediment	−0.25	−0.03
Seston Hg	0.085	0.444

Note. Pearson product moment correlations, (r), for pairwise comparisons with $n = 15$ for each. Samples with organic matter > 30% (LOI) only (i.e. three sandy samples omitted).
[a]One outlier omitted.

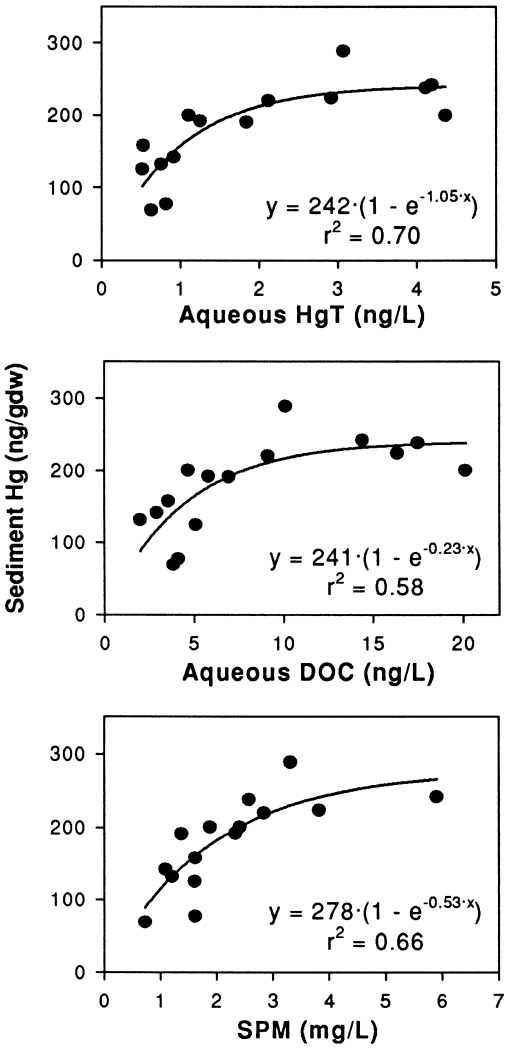

Fig. 14. Relationship between mean sediment Hg_T and mean aqueous Hg, DOC or suspended particulate matter (SPM) in the water column of the 15 WI study lakes.

sarily tied to a specific uptake mechanism, observation of this phenomenon has been interpreted as de facto evidence of trophic transport. Biomagnification results from trophic transport when consumers absorb contaminants from carbon sources (food) and then respire carbon at a rate faster than they depurate the contaminant.

Our data clearly show that meHg increased with increasing trophic level in the 15 Wisconsin study lakes while Hg^{II} did not (Table 9). In fact, Hg^{II} concentrations decreased as trophic level increased, leading to the u-shaped behavior of total Hg in the biota. This finding is consistent with earlier observations on the pelagic biota of Little Rock Lake (Watras and Bloom, 1992) and several Scandinavian lakes (Surma-Aho et al., 1986; Meili, 1991) and with the observations of increasing meHg fraction ($meHg/Hg_T$) between marine algae, mussels, and fish reported by May et al. (1987). It also helps to explain the earlier conclusions of Knauer and Martin (1972) and Williams and Weiss (1973) that the biomagnification of Hg_T does not occur in pelagic marine communities.

Dissolved organic carbon competes with organisms for Hg^{II} and meHg. However, on a unit carbon basis, the biota has a substantially stronger affinity for meHg. Assuming organisms are roughly 50% C (dry wt.), we find that microseston, zooplankton and fish are enriched in meHg by factors of 3, 5 and 20 (respectively) relative to DOC (Table 9). This enrichment corresponds to biomagnification factors ranging from 1.6 to 4 between trophic levels.

The effect of DOC on bioaccumulation and biomagnification is shown across three trophic

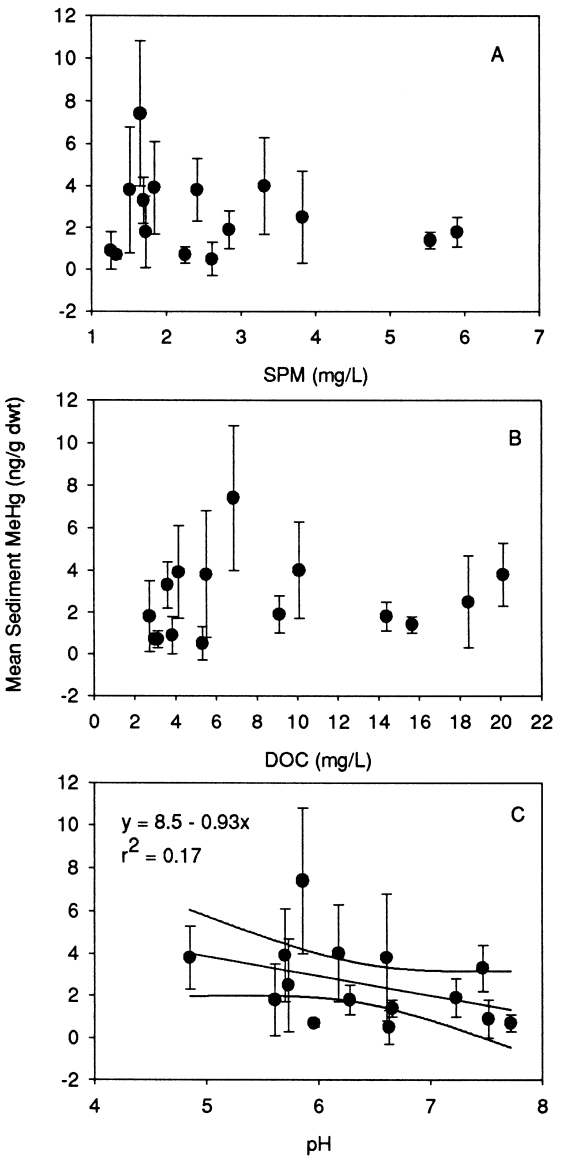

Fig. 15. Relationship between meHg in surficial sediments and SPM, DOC, or pH in surficial waters of the 15 WI study lakes. Data are means ± 1 S.D. for each lake.

levels on Fig. 16. The bioaccumulation factors (BAF) observed in this study lie within the range observed earlier on Little Rock Lake (Watras and Bloom, 1992), but the variability among the 15 lakes is high in part because of the uncorrected effects of variables like DOC (Fig. 16A). Compared across all 15 lakes, the effect of DOC on BAFs is similar for all three trophic levels on Fig. 16B. The regression slopes are statistically indistinguishable and the difference in elevation reflects the degree of biomagnification between trophic levels.

4.2. Bioconcentration

Bioconcentration refers to the tendency of a substance to accumulate in biota relative to water. Typically, bioconcentration is quantified by the ratio of the dissolved concentration of the substance to its concentration in a particular biota b of interest

$$\mathrm{BCF}_{b,j} = \mathrm{meHg}_b / [\mathrm{meHg}_D] \tag{2}$$

where the subscript j refers to the lake or system from which the water and biota were sampled. For metals such as Hg^{II} and meHg, bioconcentration factors vary widely between lakes. Here, we wish to examine how much of this variability between lakes can be accounted for via modeling the equilibrium aqueous speciation of meHg.

Since uptake via different mechanisms can lead to different metal species controlling uptake rates (Hudson, 1998), we must first define a bioconcentration factor with respect to rate-controlling species $\mathrm{meHg_i}$:

$$\mathrm{BCF}^{\mathrm{i}}_{b,j} = \frac{\mathrm{meHg}_{b,j}}{[\mathrm{meHg_i}]_j} = f(\mathrm{chem}_j, \mathrm{biota}_j) \tag{3}$$

where f expresses any remaining dependencies on lake chemical and biological parameters. For organisms that acquire most of their meHg directly from water, this expression implies that $\mathrm{meHg_i}$ controls the uptake rate while f reflects the ratio uptake rate constant:specific growth rate (or $V_{\mathrm{net}}/[\mathrm{meHg_i}] \times u$ in Eq. 1). For organisms that take up meHg primarily from food, the dependence on species $\mathrm{meHg_i}$ would reflect uptake from water into the lower trophic levels while f would contain terms expressing both food web interactions and organism-specific factors (cf. Cabana et al., 1994). In both cases a direct proportionality between concentrations in water and

Table 9
Bioaccumulation of mercury and biomagnification of methylmercury in the lower trophic levels of pelagic food webs

Compartment	Marine ecosystem[a] Hg_T (ng/g dwt)	Freshwater ecosystems[b]				
		Number of lakes	Hg_T (ng/g dry wt.)	Hg^{II} (ng/g dry wt.)	meHg (ng/g dry wt.)	% meHg
DOC[c]		15	193 (84–326)	170 (77–279)	23 (3–61)	11[d] (4–22)
Microseston	410	15	202 (43–343)	170 (30–316)	34 (13–94)	18 (7–34)
Zooplankton	130	15	83 (33–206)	29 (10–48)	53 (6–161)	57 (11–83)
Small fish	720	14	512 (131–924)	27 (7–48)	485 (124–876)	95[e]

Note. Data are mean values of the 15 Wisconsin lakes with range in parentheses.
[a] Data from Knauer and Martin (1972).
[b] Data from this paper (for fish, wet wt.:dry wt. = 3.85).
[c] Assumes all aqueous mercury is organically complexed.
[d] % meHg positively correlated with DOC.
[e] % meHg in small fish from Grieb et al. (1990), Bloom (1992) and Watras (unpublished).

biota are predicted. (Note that in order to consider concurrent uptake of different species, a hybrid concentration would need to be defined.)

One way to test these models is to check for correlations between the concentrations of meHg in the biota and the aqueous meHg species of interest, as implied by rearranging Eq. (3). In doing so, one must be cautious to retain the direct proportionality between mercury in biota and water. In other words, strong correlations only support the hypothesized controlling species if they have a slope of near unity [log-transform of (4) or an intercept of nearly zero (linear form)]. Taking the log transform of Eq. (3) is a convenient means of forcing the proper relationship and it also has the advantage of being consistent with the typical proportionality between the mean and variance of these samples (log-normal distribution). Once the bioconcentration factors are computed for each hypothesis, we can then examine them to see if they are correlated with water quality or biological parameters in order to explore the nature of the function f. The test criterion is the ability to account for variability in meHg bioconcentration factors observed between lakes at different trophic levels.

As noted above, standard bioconcentration factors are calculated using $meHg_D$ in the denominator of log-transformed Eq. (3). Since no uptake mechanism is intended when one uses this approach, we may regard it as the null hypotheses — i.e. that chemical speciation has no effect on uptake. We may then test alternative hypotheses based on the uptake mechanisms and speciation models proposed for other metals where there is evidence that the different aqueous species are taken up at different rates (e.g. free ion, hydroxide, chloride and organic complexes). The hypotheses under consideration may be summarized as follows:

1. $meHg_D$: all species are equally available. This assumption could apply to an actual mechanism if all meHg complexes are kinetically labile and if uptake is strongly limited by diffusion or occurs via a kinetically controlled transporter.
2. $meHgCl/OH^0$: passive absorption of neutral $meHgCl^0$ and $meHgOH^0$. We use a mixed concentration that is defined according to the ratio of the passive permeability coefficients of these species (Mason et al., 1996):

$$[meHgX^0] \equiv [meHgCl^0] + 0.041 \times [meHgOH^0]$$

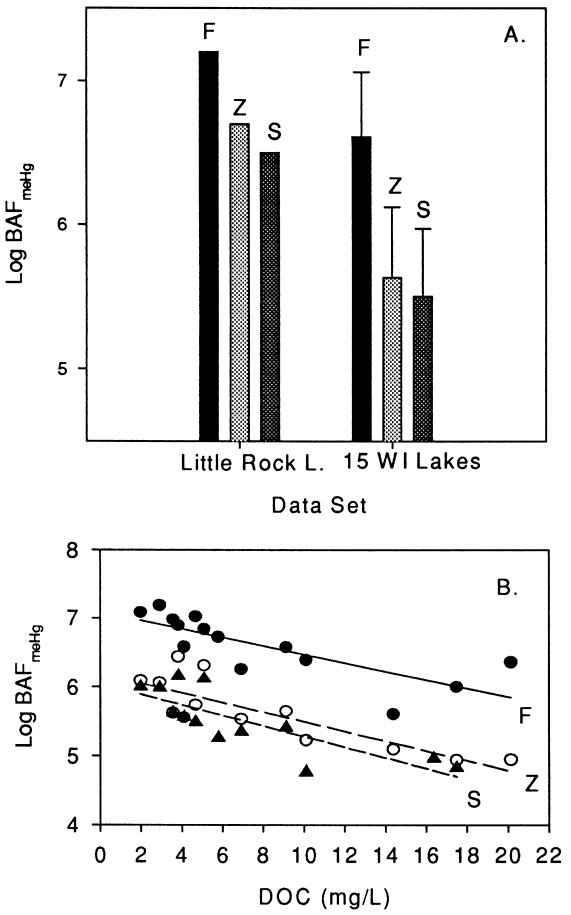

Fig. 16. Comparison of bioaccumulation factors for meHg in fish, zooplankton, and microseston in northern Wisconsin lakes (log BAF_{meHg} = log C_b/log C_w, where C_b is the meHg concentration in biota on a dry weight basis and C_w is $meHg_D$). (A) Comparison between earlier data from Little Rock Lake [modified from Watras and Bloom (1992)] and data from this study; bars show mean value ± S.D. (B) Dependency of log BAF_{meHg} on DOC for microseston (S, filled triangles, short dash), crustacean zooplankton (Z, open circles, long dash), and fish (F, filled circles, solid line). Data are mean values for the 15 study lakes. Regression equations are: fish: $y = 7.09 - 0.06x$, $r^2 = 0.61$; zooplankton: $y = 6.19 - 0.07x$, $r^2 = 0.70$; microseston: $y = 6.04 - 0.08x$, $r^2 = 0.64$.

3. $meHg^+/X_{transporter}$: free ion control of facilitated uptake. MeHg uptake would require two steps:

$$meHg^+ + X_{transporter} \overset{\text{Binding}}{\longleftrightarrow} meHgX^+_{transporter}$$

$$meHgX^+_{transporter} \overset{\text{Internalization}}{\longrightarrow} meHg_{cell} + X_{transporter}$$

4. $meHg^+/HX_{transporter}$: free ion control of facilitated uptake via a protonated transporter site. The binding reaction in this case is:

$$meHg^+ + HX_{transporter} \longleftrightarrow meHgX_{transporter} + H^+$$

which is equivalent to meHgOH uptake:

$$meHgOH + HX_{transporter} \longleftrightarrow meHgX_{transporter} + H_2O.$$

More relationships between speciation and uptake are possible (Hudson et al., 1994; Hudson, 1998), but will not be considered here.

To test these hypotheses, we applied the logarithmic form of equation (3) to the lake-averaged data for: (1) microseston; (2) crustacean zooplankton; and (3) yellow perch using aqueous concentrations of the various meHg species calculated according to the assumptions of Hudson et al. (1994). The reactions considered include:

$$meHg^+ + OH^- \longleftrightarrow meHgOH^0$$

$$meHg^+ + Cl^- \longleftrightarrow meHgCl^0$$

$$meHg^+ + Y^-_{DOM} \longleftrightarrow meHgY_{DOM}$$

$$H^+ + Y^-_{DOM} \longleftrightarrow HY_{DOM}$$

where Y_{DOM} is an approximation for the meHg-binding moieties of aquatic DOM. The mean BCF and variance were computed for each meHg species and the correlations between BCF and pH, DOC and other solutes were determined (Table 10a–c). The main test criterion was the variance of $BCF^i_{b,j}$, which should be lowest for the best model. Correlations between BCF and other analytes indicate which factors might further reduce the variance of BCF.

As shown on Table 10a–c, the lowest variability

Table 10
Correlations between BCF and pH, DOC and other solutes

Species *i*	Log BCF		Correlates					
	Mean	S.D.	pH		log DOC		Other	
			Slope	*r*	Slope	*r*	Solute	Slope/*r*
(a) Seston meHg bioconcentration factors (BCF, l / kg dry wt.: see text)								
$meHg_D$	5.5	0.46	0.14	0.23	−1.5	−0.81	SPM	−2.0/−0.83
							Cl	−0.60/−0.59
$meHg^+$	8.7	0.93	1.10	0.95	−0.48	−0.01	Ca	2.0/0.83
meHgOH	**6.9**	**0.30**	**0.11**	**0.27**	**−0.34**	**−0.37**	**SPM**	**−1.0/−0.66**
$meHgX^0$	7.6	0.77	0.70	0.73	−1.1	−0.17	SO_4	1.2/0.60
(b) Crustacean meHg bioconcentration factors (BCF, l / kg dry wt.: see text)								
$meHg_D$	5.6	0.49	0.20	0.36	−1.3	−0.82	SPM	−1.6/−0.78
$meHg^+$	8.7	1.00	0.94	0.93	−0.48	−0.17	Ca	2.0/0.83
							Mg	2.0/0.80
meHgOH	**7.1**	**0.30**	**0.11**	**0.31**	**−0.34**	**−0.36**	**SPM**	**−0.65/−0.51**
$meHgX^{0A}$	7.7	0.78	0.68	0.81	−1.1	−0.46	Mn	−1.2/−0.60
(c) Perch (3-year-old) meHg bioconcentration factors (BCF, l / kg dry wt.: see text)								
$meHg_D$	6.7	0.45	0.09	0.14	−1.4	−0.83	SPM	−1.8/−0.79
							SO_4	1.7/0.74
$meHg^+$	9.8	0.85	0.83	0.86	−0.63	−0.24	Ca	1.9/0.79
							Mg	1.8/0.74
meHgOH	**8.2**	**0.26**	**−0.006**	**−0.02**	**−0.49**	**−0.46**	**SPM**	**−0.88/−0.62**
							Chl *a*	**−0.73/−0.60**
$meHgX^{0A}$	8.7	0.69	0.58	0.66	−1.2	−0.50	Mn	−1.1/−0.66

Note. Data are the mean values and standard deviation (S.D.) calculated using Eq. (3).

in BCFs (reported as standard deviation, S.D.) was consistently associated with either $meHg^+$ or meHgOH species, but not with $meHgX^0$, which is mainly the neutral chloride complex. The meHg species which resulted in the least variable BCFs, also had the lowest correlation with ancillary variables like pH and DOC. This result indicates that normalizing biotic concentrations of meHg to that particular aqueous species of meHg effectively removed the influence of the ancillary variable. In other words, the effect of the ancillary variable was to reduce the bioavailability of the important meHg species in water.

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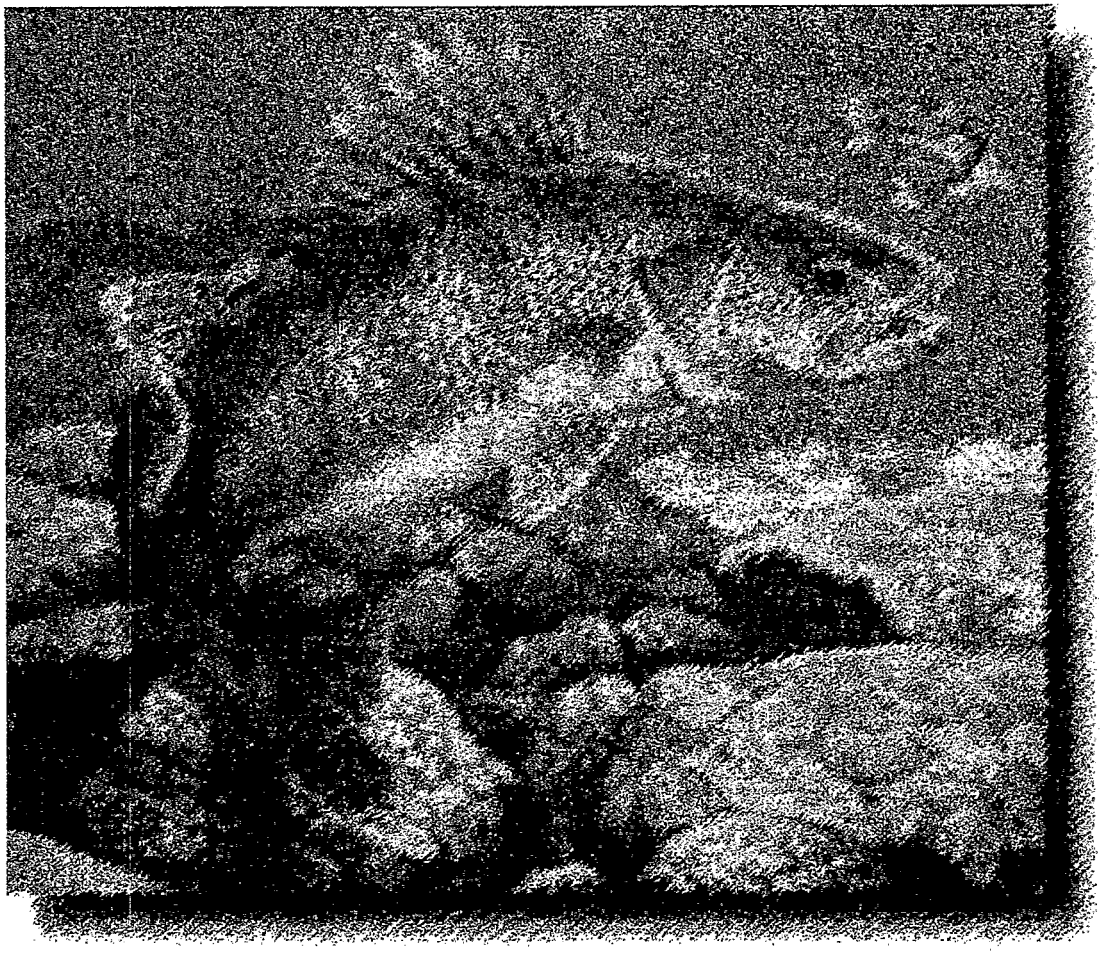

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Potential areas for conflict of interest were investigated via direct inquiry with the peer reviewers and review of their current affiliations. No conflicts of interest were identified.

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EXECUTIVE SUMMARY

About This Document

This document is the basis for a human health Ambient Water Quality Criterion (AWQC) for methylmercury. This AWQC replaces the AWQC for total mercury in published in 1980 and partially updated in 1997. Under Section 304(a) of the Clean Water Act, EPA must periodically revise criteria for water quality to accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects of pollutants on human health.

This document uses new methods and information described in the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) (2000 Human Health Methodology) (U.S. EPA, 2000a,b). These new methods include updated approaches to determine toxicity dose-response relationships for both carcinogenic and noncarcinogenic effects, updated information for determining exposure factors, and new procedures to determine bioaccumulation factors.

The Mercury Study Report to Congress (MSRC) (U.S. EPA, 1997), an eight-volume report prepared by the U.S. Environmental Protection Agency (EPA) and submitted to Congress in 1997, serves as a primary information source on methylmercury. However, as the state of the science for methylmercury is continuously and rapidly evolving, the information from the MSRC has been supplemented by inclusion of published information since 1997.

Exposure to Methylmercury

The major pathway for human exposure to methylmercury is consumption of contaminated fish. Dietary methylmercury is almost completely absorbed into the blood and is distributed to all tissues including the brain; it also readily passes through the placenta to the fetus and fetal brain.

Major Health Effects of Methylmercury

Methylmercury is a highly toxic substance with a number of adverse health effects associated with its exposure in humans and animals. Epidemics of mercury poisoning following high-dose exposures to methylmercury in Japan and Iraq demonstrated that neurotoxicity is the health effect of greatest concern. These epidemics led to observation of methylmercury effects on the fetal nervous system. High-dose

human exposure results in mental retardation, cerebral palsy, deafness, blindness, and dysarthria in utero and in sensory and motor impairment in adults. Although developmental neurotoxicity is currently considered the most sensitive health endpoint, data on cardiovascular and immunological effects are beginning to be reported and provide more evidence for toxicity from low-dose methylmercury exposure.

Three large prospective epidemiology studies in the Seychelles Islands, New Zealand, and the Faroe Islands were designed to evaluate childhood development and neurotoxicity in relation to fetal exposures to methylmercury in fish-consuming populations. Prenatal methylmercury exposures in these three populations were within the range of some U.S. population exposures. No adverse effects were reported from the Seychelles Islands study, but children in the Faroe Islands exhibited subtle developmental dose-related deficits at 7 years of age. These effects include abnormalities in memory, attention, and language. In the New Zealand prospective study, children at 4 and 6 years of age exhibited deficiencies in a number of neuropsychological tests.

In addition to the three large epidemiological studies, studies on both adults and children were conducted in the Amazon; Ecuador; French Guiana; Madeira; Mancora, Peru; northern Quebec; and Germany. Effects of methylmercury on the nervous system were reported in all but the Peruvian population.

Other Health Effects of Methylmercury

Methylmercury causes chromosomal effects but does not induce point mutations. The MSRC concluded that because there are data for mammalian germ-cell chromosome aberration and limited data from a heritable mutation study, methylmercury is placed in a group of high concern for potential human germ-cell mutagenicity. There is no two-generation study of reproductive effects, but shorter term studies in rodents, guinea pigs and monkeys have reported observations consistent with reproductive deficits. There are no data to indicate that methylmercury is carcinogenic in humans, and it induces tumors in animals only at highly toxic doses. Application of the proposed revisions to the Guidelines for Cancer Risk Assessment (EPA 1999)leads to a judgment that methylmercury is not likely to be carcinogenic for humans under conditions of exposure generally encountered in the environment.

Quantitative Risk Estimate for Methylmercury

The quantitative health risk assessment for a noncarcinogen relies on a reference dose (RfD). This is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious health effects during a lifetime. To derive an RfD, one first establishes a no adverse effect level (NOAEL) for a particular endpoint. This can be done by inspection of the available data or by using a mathematical modeling procedure to estimate the NOAEL; the latter approach was used for methylmercury. Next the NOAEL is divided by a numerical uncertainty factor to account for areas of variability and uncertainty in the risk estimate.

There has been considerable discussion within the scientific community regarding the level of exposure to methylmercury that is likely to be without an appreciable risk of deleterious health effects during a lifetime. In 1999, the Congress directed EPA to contract with the National Research Council (NRC) of the National Academy of Sciences to evaluate the body of data on the health effects of methylmercury. NRC was to concentrate on new data since the 1997 MSRC, and to provide recommendations regarding issues relevant to the derivation of an appropriate RfD for methylmercury. NRC published their report, *Toxicological Effects of Methylmercury*, in 2000. EPA generally concurred with the NRC findings and recommendations. The NRC document was used as a resource in determining the EPA RfD for methylmercury documented here.

Choice of Study

The adverse effect of methylmercury observed at lowest dose is neurotoxicity, particularly in developing organisms. The brain is considered the most sensitive target organ for which there are data suitable for derivation of an RfD. There is an extensive array of peer-reviewed, well-analyzed data from human studies of low-dose exposure to methylmercury. NRC and EPA considered three epidemiologic longitudinal developmental studies suitable for quantitative risk assessment: the Seychelles Child Development Study (SCDS); the ongoing studies of children in the Faroe Islands; and the study of children in New Zealand. All cohorts consisted of children exposed in utero through maternal consumption of mercury-contaminated fish or marine mammals. In all studies there were biomarkers of maternal exposure (hair), and in the Faroes study cord blood was also used as an additional measure of fetal exposure. The SCDS yielded no evidence of impairment related to methylmercury exposure, but the two other studies have found dose-related adverse effects on a number of

neuropsychological endpoints. EPA chose to base the RfD on data from the Faroes study. The SCDS has no findings of effects associated with methylmercury exposure, and thus is not the best choice for a public health protective risk estimate. While the New Zealand study does show mercury-related effects it relatively small by comparison to the other two. Advantages of the Faroes study include these:

- Large sample size ($n > 900$ for some measures)
- Good statistical power as calculated by conventional means
- Use of two different biomarkers of exposure
- Comprehensive and focused neuropsychological assessment
- Assessment at an age and state of development when effects on complex neuropsychological functions are most likely to be detectable
- Statistically significant observations which remain after adjusting for potential PCB effects
- Extensive scrutiny in the epidemiological literature

The Faroe Islands study was used for derivation of the RfD.

Estimation of the No Adverse Effect Level

A benchmark dose analysis was chosen as the most appropriate method of quantifying the dose-effect relationship. The level chosen was a Benchmark Dose Lower Limit (BMDL); this was the lower 95% limit on a 5% effect level obtained by applying a K power model ($K \geq 1$) to dose-response data based on mercury in cord blood. The BMDL was chosen as the functional equivalent of a no-adverse-effect level for calculation of the RfD.

Choice of Endpoint

Several endpoints are sensitive measures of methylmercury effects in the Faroese children. EPA considered the recommendations of the NRC and EPA's external scientific peer review panel in coming to a decision as to the appropriate endpoint. The NRC recommended the use of a BMDL of 58 ppb mercury in cord blood from the Boston Naming Test (BNT). The external peer panel felt that the BNT scores showed an effect of concomitant PCB exposure in some analyses. They preferred a PCB-adjusted BMDL of 71 ppb mercury in cord blood for the BNT. A difficulty with this choice is that this BMDL is based on scores from only about one-half of the total cohort. The peer panel further suggested using a composite index across several measures in the Faroes data set. EPA prepared a comparison of the

endpoints recommended by NRC and peer reviewers; this also included the BMDLs from the NRC integrative analysis and geometric means of four scores from the Faroes. These BMDLs and corresponding estimates of ingested methylmercury are within a very small range. Rather than choosing a single measure for the RfD critical endpoint, EPA considers that this RfD is based on several scores. These test scores are all indications of neuropsychological processes related to the ability of a child to learn and process information.

Calculation of Ingested Methylmercury Dose

In the risk assessment discussion EPA uses the NRC-recommended BMDL of 58 ppb mercury in cord blood as an example in the dose conversion and RfD calculation. The BMDL in terms of mercury in cord blood was converted to an estimate of ingested methylmercury. This was done by use of a one-compartment model similar to that used in the MSRC. Single-parameter estimates were used rather than a distributional approach. It was assumed that the cord blood methylmercury level was equal to maternal blood level. The ingested dose of methylmercury that corresponds to a cord blood level of 58 ppb is 1.081 μg/kg bw/day.

Uncertainty Factor

Several sources of variability and uncertainty were considered in the application of a composite uncertainty factor of 10. This included a factor of 3 for pharmacokinetic variability and uncertainty; one area of pharmacokinetic uncertainty was introduced with the assumption of equivalent cord blood and maternal blood mercury levels. An additional factor of 3 addressed pharmacokinetic variability and uncertainty. Other areas of concern include inability to quantify possible long-term sequelae for neurotoxic effects, questions as to the possibility of observing adverse impacts (such as cardiovascular effects) below the BMDL, and lack of a two-generation reproductive effects assay.

Methylmercury Reference Dose

The RfD derived in this assessment is 0.1 μg/kg bw/day or $1x10^{-4}$ mg/kg bw/day. The RfD for methylmercury was not calculated to be a developmental RfD only. It is intended to serve as a level of exposure without expectation of adverse effects when that exposure is encountered on a daily basis for a lifetime. In the studies so far published on subtle neuropsychological effects in children, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling.

That is, there are currently no data that would support the derivation of a child (vs. general population) RfD.

Relative Source Contribution

The assessment of methylmercury exposure from common media sources (e.g., diet, air) and relative source contribution (RSC) estimates follows the 2000 Human Health Methodology. The RSC is used to adjust the RfD to ensure that the water quality criterion is protective, given other anticipated sources of exposure. The exposure assessment characterizes the sources of methylmercury exposure in environmental media, providing estimates of intake from the relevant sources for children, women of childbearing age, and adults in the general population. Based on available data, human exposures to methylmercury from all media sources except freshwater/estuarine and marine fish are negligible, both in comparison with exposures from fish and compared with the RfD. Estimated exposure from ambient water, drinking water, nonfish dietary foods, air, and soil are all, on average, at least several orders of magnitude less than those from freshwater/estuarine fish intakes. Therefore, these exposures were not factored into the RSC. However, ingestion of marine fish is a significant contributor to total methylmercury exposure. For the methylmercury criterion, the RSC is the estimated exposure from marine fish intake. This is subtracted from the RfD when calculating the water quality criterion. One hundred percent of the mercury in marine fish was assumed to be present as methylmercury. The estimated average exposure to methylmercury from marine fish is 2.7 x 10-5 mg/kg-day. This exposure represents almost 30% of the RfD.

Methylmercury Bioaccumulation

Methylmercury is a chemical that bioaccumulates and biomagnifies in aquatic food webs. The fates of mercury and methylmercury in the environment are complex processes affected by numerous biotic and abiotic factors that are subjects of ongoing research. Methylation of mercury is a key step in the entrance of mercury into food chains. The biotransformation of inorganic mercury forms to methylated organic forms in water bodies can occur in the sediment and the water column. Inorganic mercury can be absorbed by aquatic organisms but is generally taken up at a slower rate and with lower efficiency than is methylmercury. Methylmercury continues to accumulate in fish as they age. Predatory organisms at the top of aquatic and terrestrial food webs generally have higher methylmercury concentrations because methylmercury is typically not completely eliminated by organisms and is

transferred up the food chain. Nearly 100% of the mercury that bioaccumulates in upper-trophic-level fish (predator) tissue is methylmercury.

Numerous factors can influence the bioaccumulation of mercury in aquatic biota. These include, but are not limited to, the acidity (pH) of the water, length of the aquatic food chain, temperature, and dissolved organic material. Physical and chemical characteristics of a watershed, such as soil type and erosion or proportion of area that is wetlands, can affect the amount of mercury that is transported from soils to water bodies. Interrelationships among these factors are poorly understood and are likely to be site-specific. No single factor (including pH) has been correlated with extent of mercury bioaccumulation in all cases examined. Two lakes that are similar biologically, physically, and chemically can have different methylmercury concentrations in water, fish, and other aquatic organisms.

The Methylmercury Criterion is a Fish Tissue Residue Criterion

EPA concluded that it is more appropriate at this time to derive a fish tissue (including shellfish) residue water quality criterion for methylmercury rather than a water column-based water quality criterion. This decision considered issues of mercury fate in the environment, the NRC report on the toxicological effects of mercury, and in particular the methylmercury peer review comments. EPA believes a fish tissue residue water quality criterion is appropriate for many reasons. Such a criterion integrates spatial and temporal complexity that occurs in aquatic systems and that affects methylmercury bioaccumulation. A fish tissue residue water quality criterion is more closely tied to the CWA goal of protecting the public health because it is based directly on the dominant human exposure route for methylmercury. The concentration of methylmercury is also generally easier to quantify in fish tissue than in water and is less variable over the time periods in which water quality standards are typically implemented in water quality-based. Thus, the data used in permitting activities can be based on a more consistent and measurable endpoint. A fish tissue residue criterion is also consistent with how fish advisories are issued. Fish advisories for mercury are based on the amount of methylmercury in fish tissue that is considered acceptable, although they are usually issued for a certain fish or shellfish species in terms of a meal size. A fish tissue residue water quality criterion should enhance harmonization between these two approaches for protecting the public health.

The methylmercury water quality criterion is, thus, a concentration in fish tissue. It was calculated using the criterion equation in the 2000 Human Health Methodology rearranged to solve for a protective concentration in fish tissue rather than in water.

$$TRC = \frac{BW \times (RfD - RSC)}{\sum_{i=2}^{4} FI_i}$$

Where:

TRC = Fish tissue residue criterion (mg methylmercury/kg fish) for freshwater and estuarine fish

RfD = Reference dose (based on noncancer human health effects) of 0.0001 mg methylmercury/kg body weight-day

RSC = Relative source contribution (subtracted from the RfD to account for marine fish consumption) estimated to be 2.7×10^{-5} mg methylmercury/kg body weight-day

BW = Human body weight default value of 70 kg (for adults)

FI = Fish intake at trophic level (TL) i (i = 2, 3, 4); total default intake is 0.0175 kg fish/day for general adult population. Trophic level breakouts for the general population are: TL2 = 0.0038 kg fish/day; TL3 = 0.0080 kg fish/day; and TL4 = 0.0057 kg fish/day.

The resulting Tissue Residue Criterion is 0.3 mg methylmercury/kg fish. This is the concentration in fish tissue that should not be exceeded based on a total fish and shellfish consumption-weighted rate of 0.0175 kg fish/day. EPA strongly encourages States and authorized Tribes to develop a water quality criterion for methylmercury using local or regional data rather than the default values if they believe that such a water quality criterion would be more appropriate for their target population.

1.0 INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document provides guidance to States and Tribes authorized to establish water quality standards under the Clean Water Act (CWA) to protect human health, pursuant to Section 304(a) of the CWA. Under the CWA, States and authorized Tribes are to establish water quality criteria to protect designated uses. While this document constitutes the U.S. Environmental Protection Agency's (EPA's) scientific recommendations regarding concentrations of methylmercury in fish and shellfish that protect human health, this document does not substitute for the CWA or EPA's regulations, nor is it a regulation itself. Thus, it cannot impose legally binding requirements on EPA, States, Tribes, or the regulated community, and may not apply to a particular situation based upon the circumstances. State and Tribal decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance when appropriate. EPA may change this guidance in the future.

This document establishes a water quality criterion for methylmercury. The U.S. Environmental Protection Agency (EPA) originally published an Ambient Water Quality Criterion (AWQC) for total mercury in 1980. That AWQC was partially updated in 1997 to incorporate a change in the reference dose (RfD). As required under Section 304(a) of the Clean Water Act, EPA must periodically revise criteria for water quality to accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on human health from the presence of pollutants in any body of water. The criterion uses new methods and information described in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (2000) (2000 Human Health Methodology) and in the Methodology's accompanying *Federal Register Notice* (U.S. EPA, 2000a,b). These new methods include updated approaches to determine toxicity dose-response relationships for both carcinogenic and noncarcinogenic effects, updated information for determining exposure factors, and new procedures to determine bioaccumulation factors.

Development of a methylmercury criterion involves some unique considerations compared with many of EPA's past efforts in the water quality criteria program. Traditionally, EPA has established recommended 304(a) criteria to protect human health as ambient concentrations in water. For those pollutants that bioaccumulate, such as methylmercury, exposure through the food pathway is estimated by using a bioaccumulation factor (BAF). However, following review of available data and

recommendations made by external peer reviewers (U.S. EPA, 2000c), EPA determined that it is more appropriate to base the methylmercury criterion on a fish tissue residue concentration than on an ambient water concentration. This determination was partly based on the current scientific understanding of the fate of mercury and methylmercury in aquatic ecosystems. Another factor was the limited information on sources of mercury and the conversion to methylmercury (and its bioavailability). Additional considerations were the difficulty in measuring methylmercury in the water column and relating it to concentrations in aquatic organisms. EPA believes that the latest data and science on methylmercury exposure, effects, and environmental fate support the derivation of a fish tissue residue criterion.

1.2 PRIMARY DATA SOURCE

Much of the information in this document has been taken from the *Mercury Study Report to Congress* (MSRC) (U.S. EPA, 1997b-h). This comprehensive, eight-volume study was prepared by EPA and submitted to Congress in 1997 to fulfill the requirements of section 112(n)(1)(B) of the Clean Air Act, as amended in 1990. The MSRC provides an assessment of the magnitude of U.S. mercury emissions by source, the health and environmental implications of those emissions, and the availability and cost of control technologies. As the state of the science for methylmercury continues to evolve, information from the MSRC has been supplemented by data and analyses published since 1997. The health effects information used in the derivation of the reference dose (RfD) for the fish tissue residue concentration is based on the recommendations of the National Academy of Sciences National Research Council report, *Toxicological Effects of Methylmercury* (NRC, 2000). For additional discussion on the NRC recommendations, see Section 4 of this criteria document. The comments of the methylmercury RfD scientific peer review panel also guided the risk assessment.

1.3 CHEMICAL AND PHYSICAL PROPERTIES

The water quality criterion is being derived for methylmercury (CAS No. 22967-92-6). Synonyms for methylmercury include MeHg, methylmercury ion, methylmercury ion (1+), methylmercury (1+), methyl mercury, and methylmercury(I) cation (Prager, 1997). A commonly occurring form of methylmercury is methylmercuric chloride ($CH_3Hg^+Cl^-$), a stable salt form that exists as a white crystal. This compound is often used in laboratory dosing experiments investigating the toxicological properties of methylmercury. Because methylmercury exists as a free ion only in minute quantities (Prager, 1997), the chemical and physical data provided below are for the chloride salt.

The table below presents available chemical and physical data for methylmercuric chloride (ATSDR, 1999; Kaufman, 1969).

Chemical formula	CH_3HgCl
Chemical structure	$CH_3—Hg^+ Cl^-$
Molecular weight	251.10 (g/mol)
Physical state (25°C)	White crystal
Boiling point (at 25 mm Hg)	No data
Melting point	170°C
Density (25°C)	4.06 g/mL
Vapor pressure (25°C)	0.0085 mm Hg
Water solubility (21°C)	<100 mg/L
Log octanol/Water partition coeff.	No data
Odor threshold (air)	No data
Conversion factors (air)	1 ppm = 10.27 mg/m^3; 1 mg/m^3 = 0.0974 ppm

2.0 TOXICOKINETICS

This section presents information on the absorption, distribution, metabolism, and excretion of methylmercury in humans and animals. This information is summarized from Volume V, Chapter 2 of the *Mercury Study Report to Congress* (MSRC) (U.S. EPA, 1997e).

2.1 ABSORPTION

2.1.1 Oral Absorption

Methylmercury is efficiently absorbed from the gastrointestinal tract following ingestion. Approximately 94%-95% of methylmercury in fish ingested by volunteers was absorbed from the gastrointestinal tract (Aberg et al., 1969; Miettinen, 1973). Aberg et al. (1969) found uptake of greater than 95% of radiolabeled methylmercuric nitrate administered in water to human volunteers.

Data from studies on rats, cats, and monkeys support these absorption estimates (ATSDR, 1999). Studies on rats indicate rapid and complete absorption of inhaled methylmercury vapor into the bloodstream (Fang, 1980). Female cynomolgus monkeys administered 0.5 mg mercury per kilogram of methylmercuric chloride by oral gavage experienced complete absorption within 6 hours (Rice, 1989).

2.1.2 Absorption via Other Routes

Limited information is available on absorption via inhalation and dermal routes. There is one reported human dermal exposure when a 48-year-old chemistry professor inadvertently spilled drops (0.4-0.5 mL) of dimethylmercury from her pipette into her latex gloves. Penetration of dimethylmercury through the gloves occurred instantaneously. Mercury hair level was elevated to almost 1,100 ppm, with a half life of 74.6 days. Five months after exposure, the woman experienced severe neurotoxicity and died 9 months later (Blayney et al., 1997; Nierenberg et al., 1998).

Skog and Wahlberg (1964) evaluated the dermal absorption of the methylmercuric cation in guinea pigs. The test material was applied as the dicyandiamide salt. Absorption was estimated by disappearance of the applied compound and by appearance of mercury in kidney, liver, urine, and blood. Approximately 3% to 5% of the applied dose was absorbed during a 5-hour period.

Indirect evidence in animals indicates that inhaled methylmercury vapor is absorbed readily through the lungs. Fang (1980) showed a correlation between tissue mercury levels and both exposure level and exposure duration in rats exposed to radioactively labeled methylmercury vapor. The percent absorbed was not quantified.

2.2 DISTRIBUTION

After absorption from the gastrointestinal tract, methylmercury is readily absorbed into the blood and distributes to all tissues, including the brain and fetus. The fraction of the absorbed dose that is found in the blood has been estimated in three studies. Kershaw et al. (1980) reported an average fraction of 0.059 of the absorbed dose in total blood volume, based on a study of five adult male subjects who ingested methylmercury-contaminated tuna. In a group of nine male and six female volunteers who had received ^{203}Hg-methylmercury in fish, approximately 10% of the total mercury body burden was present in 1 L of blood in the first few days after exposure; this dropped to approximately 5% over the first 100 days (Miettinen et al., 1971). Sherlock et al. (1984) derived an average value of 1.14% for the percentage of absorbed dose in 1 kg of blood from data on subjects who consumed a known amount of methylmercury in fish over a 3-month period. Average daily intake in the study ranged from 43 to 233 µg/day. There was a dose-related effect on percentage of absorbed dose that ranged from 1.03% to 1.26% in 1 L of blood. Each of these values was multiplied by 5 to yield the total amount in the blood compartment, as there are approximately 5 L of blood in an adult human body.

Methylmercury in the blood is found predominantly in the red cells (Kershaw et al., 1980; Thomas et al., 1986). It is distributed throughout the body following absorption from the gastrointestinal tract into the blood (Clarkson, 1972; Hansen, 1988; Hansen et al., 1989; Nielsen and Andersen, 1992; Soria et al., 1992; Suzuki et al., 1984). Although the distribution of methylmercury in the body is generally uniform, at least one animal study indicates that high levels can be found in the kidney. Rice (1989b) administered 0.025 or 0.05 mg mercury/kg-day as methylmercuric chloride in apple juice to cynomolgus monkeys for approximately 2 years. Kidney tissue concentrations of mercury ranged from 10 to 28 ppm in the cortex and 1 to 10 ppm in the medulla when assessed more than 200 days after cessation of treatment. In contrast, mercury concentration was less than 2 ppm in the other tissues evaluated.

Methylmercury easily penetrates the placental barrier in humans and animals (Hansen, 1988; Hansen et al., 1989; Nielsen and Andersen, 1992; Soria et al., 1992; Suzuki et al., 1984). Several studies

have demonstrated mercury in newborn cord blood. The relationship to maternal blood is variable (Grandjean et al., 1999). Information on this relationship is discussed in Section 4.5.4.1.

The distribution of methylmercury in animals may vary by age and sex (Thomas et al., 1982,, 1986, 1988). Female rats exposed to methylmercury had higher peak levels of mercury in the kidney (primarily as methylmercury) than males; inorganic mercury levels did not differ significantly between the sexes (Thomas et al., 1986). Accumulation of mercury was found to be higher in the bodies of neonatal rats (Thomas et al., 1988) than in adult rats (Thomas et al., 1982). Ten days after administration of methylmercury, 94% of the dose was still detected in neonates while approximately 60% was retained in adults (Thomas et al., 1988). The longer retention of mercury in neonates may result from multiple factors, including the high levels of mercury accumulated in the pelt of neonates owing to lack of clearance (Thomas et al., 1988) and the lack of a fully developed biliary transport system in neonates (Ballatori and Clarkson, 1982).

2.3 METABOLISM

The time required for methylmercury metabolism to inorganic mercury may account for the latent or silent period observed in epidemiological studies from methylmercury poisoning incidents in Japan and Iraq. During the latent period (both during and after the cessation of exposure) the patient feels no untoward effects. It is possible that a number of biochemical changes may take place in parallel during this period, and some may not be causatively related to the clinical outcome. Ganther (1978) hypothesized that the carbon-mercury bond in methylmercury undergoes homolytic cleavage to release methyl free radicals. The free radicals are expected to initiate a chain of events involving peroxidation of lipid constituents of the neuronal cells. The onset of symptoms is delayed for the period of time that cellular systems are able to prevent or repair effects of lipid peroxidation. When the cellular defense mechanisms are overwhelmed, rapid and progressive degeneration of the tissue results. In the Iraqi poisoning incident, the latent period before toxic signs were noted varied from a matter of weeks to months. In contrast, the latency observed in the Japanese poisoning incident was as long as a year or more. The difference in duration may in part be due to the presence of selenium in the fish ingested by the Japanese population.

Rat liver microsomes can metabolize methylmercury into inorganic mercury via the NADPH-cytochrome P-450 reductase, also known to control hydroxyl radical production in liver microsomes (Suda and Takahashi). To a lesser degree, an oral dose of methylmercuric chloride may also be

converted into inorganic mercury via the intestinal flora (Nakamura et al, 1977; Rowland et al., 1980). The intestinal wall is poor in absorbing the inorganic mercury, thus almost all of it is excreted. Studies in mice appear to indicate that toxicity from exposure to dimethylmercury results from the biotransformation of dimethylmercury to methylmercury (Ostland, 1969). Following acute exposure to methylmercury, most of the mercury in the brain is in the organic form; however, with chronic exposures, a greater amount is in the inorganic form, suggesting that the rate of demethylation increases with long-term exposure (Aschner and Aschner, 1990). Rice (1989a, 1989) demonstrated that tissue half-life of methylmercury in the brain may be significantly longer than the blood half-life.

In rats, methylmercury in the body is relatively stable and is only slowly demethylated to form mercuric ion (Norseth and Clarkson, 1970). The demethylation appears to occur in tissue macrophages (Suda and Takahashi, 1986), intestinal microflora (Nakamura et al., 1977; Rowland et al., 1980), and fetal liver (Suzuki et al., 1984).

2.4 EXCRETION

In humans, approximately 90% of the absorbed dose of methylmercury is excreted in the feces (U.S. EPA, 1997e). Excretion via the urine is relatively minor but slowly increases with time; at 100 days after dosing, urinary excretion of mercury accounted for 20% of the daily amount excreted. The urinary excretion of mercury may reflect the deposition of demethylated mercury in the kidneys and its subsequent excretion. In humans the major routes of excretion are via the bile and feces.

Feces are also the predominant route of methylmercury elimination in adult animals (Farris et al., 1993; Hollins et al., 1975; Thomas et al., 1987). Biliary excretion of methylmercury and its demethylation in gastrointestinal flora have been reported in rats (Farris et al., 1993). After a single oral dose of methylmercury, the major elimination route was the feces (65% of the administered dose as inorganic mercury and 15% of the administered dose as methylmercury) and the minor route was urine (1% of the administered dose as inorganic mercury and 4% of the administered dose as methylmercury) (Farris et al., 1993). Following administration of methylmercuric nitrate, 33% of the administered dose was excreted in 49 days; 0.18% to 0.27% excretion in the urine in 10 days and 3.3% urinary excretion in 49 days. This continued for up to 71 days postingestion (Miettinen, 1973). Forty to 50 days postingestion, <0.12% of the administered dose of mercury was found per gram of hair. The half-life for methylmercury appeared to be 70-74 days. In humans the whole body half-life of methylmercury was estimated to be between 70 and 80 days (Aberg et al., 1969; Miettinen, 1973; Bernard and Purdue, 1984).

Mercury is excreted into the hair of methylmercury-exposed humans and animals. Incorporation of mercury into hair is irreversible, and hair analysis is thus a useful tool for monitoring exposure to methylmercury. Segmental analysis of hair may be used to provide a historical record of exposure patterns.

Methylmercury is excreted in breast milk (Bakir et al., 1973; Sundberg and Oskarsson, 1992). The ratio of mercury in breast milk to mercury in whole blood was approximately 1:20 in women exposed to methylmercury via contaminated grain in Iraq between 1971 and 1972 (Bakir et al., 1973). Evidence from the Iraqi poisoning incident also showed that lactation decreased blood mercury clearance half-times from 75 days in males and nonlactating females to 42 days in lactating females; the faster clearance due to lactation was confirmed in mice (Greenwood et al., 1978). In mice, of the total mercury in the breast milk, approximately 60% was estimated to be methylmercury. Skerfving (1988) has found that 16% of mercury in human breast milk is methylmercury. Studies in animals indicate that the mercury content of breast milk is proportional to the mercury content of plasma (Sundberg and Oskarsson, 1992; Skerfving, 1988).

In rat and monkey neonates, excretion of methylmercury is severely limited (Lok, 1983; Thomas et al., 1982). In rats dosed prior to 17 days of age, essentially no mercury was excreted (Thomas et al., 1982). By the time of weaning, the rate of excretion had increased to adult levels. The failure of neonates to excrete methylmercury may be associated with the inability of suckling infants to secrete bile (Ballatori and Clarkson, 1982) and the decreased ability of intestinal microflora to demethylate methylmercury during suckling (Rowland et al., 1977).

Currently, five studies report clearance half-lives for methylmercury. Three studies suggest a half-life of approximately 70 to 80 days (Aberg et al., 1969; Bernard and Purdue, 1984; Miettinen, 1973). Smith et al. (1994) reported a half-life of 44 days in a study of seven adult males treated intravenously with methylmercury. In this study, methylmercury and inorganic mercury concentrations in blood and excreta were determined separately based on differential extractability into benzene. The predominant species in the blood was methylmercury; there was no detectable methylmercury in the urine. Al-Shahristani and Shihab (1974) calculated a "biological half-life" of methylmercury in a study of 48 male and female subjects who had ingested seed grain contaminated by organic mercurials. The half-life, determined from distribution of mercury along head hair, ranged from 35 to 189 days with a mean of 72 days.

The relatively long half-life of methylmercury in the body results partly from reabsorption of methylmercury secreted into the bile (hepatobiliary cycling) (Norseth and Clarkson, 1971). In this cycle, methylmercury forms a complex with glutathione in the hepatocyte and the complex is secreted into the bile via a glutathione carrier protein (Clarkson, 1993). The methylmercury-glutathione complex in the bile may be reabsorbed from the gallbladder and intestines into the blood. This cycle is terminated when intestinal microorganisms demethylate methylmercury to form mercuric ion (Rowland et al., 1980). Mercuric mercury is poorly absorbed from the intestines and the fraction that is not reabsorbed is excreted in the feces. As noted above, approximately 90% of the absorbed dose of methylmercury is ultimately excreted in the feces as mercuric mercury.

2.5 BIOLOGICAL MONITORING

Distribution of methylmercury to hair and blood provides a means for biological monitoring of methylmercury exposure. This section provides an overview of the use of hair and blood for assessing exposure and outlines the available methods for quantitation.

2.5.1 Blood

Methylmercury distributes freely throughout the body, and thus blood is a good medium for estimating short-term exposure. Blood levels may not necessarily reflect methylmercury intake over longer periods, as an individual's intake may fluctuate (Sherlock et al., 1982; Sherlock and Quinn, 1988).

The characteristic partitioning of mercury in the blood permits identification of the form of mercury to which an individual has been exposed. Measurements of blood hematocrit and mercury concentrations in both whole blood and plasma can be used to calculate the red blood cell to plasma mercury ratio. In the case of methylmercury, examination of this ratio enables estimation of interference from exposure to high levels of elemental or inorganic mercury (Clarkson et al., 1988).

2.5.2 Hair

Scalp hair is a useful indicator for estimating methylmercury exposure (Phelps et al., 1980). Mercury is incorporated into scalp hair at the hair follicle in proportion to its content in blood. The hair-to-blood ratio in humans has been estimated as approximately 250:1 expressed as μg mercury/g hair to mg mercury/l blood. Uncertainty in measurements, interindividual variation in body burden, differences

in hair growth rates, and variations in fresh and saltwater fish intake have led to estimates ranging from 190:1 to 370:1 and higher (Birke et al., 1972; Skerfving, 1974; Phelps et al., 1980; Turner et al., 1980; Sherlock et al., 1984). Once incorporated into the hair, the mercury is stable, and can give a longitudinal history of blood methylmercury levels (Phelps et al., 1980; WHO, 1990). The identity of the predominate chemical species (inorganic or methylmercury) depends on exposure patterns and the extent of methylmercury demethylation.

Chemical analyses to determine mercury content of hair assay total mercury rather than chemical species of mercury. As a result, the fraction of hair mercury that is methylmercury is an estimate based on knowledge of environmental and occupational exposure patterns (U.S. EPA, 1997f). Analysis of hair mercury levels may be confounded by several factors, including adsorption of mercury vapor onto the hair strands, natural hair color, hair treatment, and growth rate (Francis et al., 1982; Suzuki, 1988).

Analysis of mercury in maternal hair has been utilized to estimate the fetal burden. This approach has been validated by Cernichiari et al. (1995), who collected blood samples and autopsy brains from terminally ill neonates in a population exposed to methylmercury via fish consumption. Maternal blood and hair samples were also obtained. The concentrations of total mercury in six major brain regions of the neonates were highly correlated with the concentration of mercury in a 1-cm segment of maternal hair next to the scalp (correlation coefficients 0.6 to 0.8, $p<0.01$). These correlations were confirmed by a series of comparisons utilizing maternal hair, maternal blood, neonate blood, and neonate brain tissue.

2.5.3 Methods of Analyzing Mercury Concentrations in Biological Samples

The most common methods used to determine mercury levels in biological media include atomic absorption spectrometry, neutron activation analysis, X-ray fluorescence, and gas chromatography. Another method is anodic stripping voltammetry (Liu et al., 1990). Gas chromotography-electron capture is the only method capable of differentiating methylmercury from other species, whereas cold vapor atomic absorption spectrometry will detect mercury at parts per billion in both urine (Magos and Cernik, 1969) and blood samples (Magos and Clarkson, 1972). Mercury content in hair has been measured by cold vapor atomic absorption spectrometry, atomic fluorescence spectrometry, X-ray fluorescence, and neutron activation analysis (Zhuang et al., 1989).

Another method for analyzing biological samples containing methylmercury is with the use of *Pseudomonas putida* strain FB1. The method is considered very reliable and specific for methylmercury

quantification because chemical inference is negligible. The *Pseudomonas putida* bacteria is capable of converting methylmercury to methane gas and elemental mercury (Baldi and Filippelli, 1991), thus allowing the detection of 15 ng of methylmercury in 1 g of biological tissue with a coefficient of variation of 1.9%.

New methods, such as inductively coupled plasma-mass spectrometry (Kalamegham and Ash, 1992) for analyzing mercury in biological samples are being developed, but are considered very costly and unaffordable by many laboratories. For additional detail on other methods, please refer to the Toxicological Profile for Mercury (Update) (ATSDR, 1999) and in the World Health Organization (WHO) report Methylmercury (IPCS, 1990).

2.6 PHARMACOKINETIC MODELS

A number of extrapolations are generally required in risk assessments, including high-dose to low-dose extrapolations, route-to-route extrapolations, cross-species extrapolations, and extrapolations for varying exposure durations. Physiologically based pharmacokinetic (PBPK) modeling can increase the accuracy of these extrapolations if one has data to use in the model parameters. (Clewell and Andersen, 1985, 1989; Clewell, 1995a; Andersen et al., 1995).

For methylmercury, PBPK modeling in the risk assessment process is used to estimate the relationship between the measure of exposure used in epidemiological studies (mercury in hair and blood) and the daily ingested dose used to determine a reference dose. Several human PBPK models have been developed (Luecke et al., 1994, 1997; Smith et al., 1994; Gearhart et al., 1995; Clewell et al., 1999) to address this issue. Two animal models (Farris et al., 1993; Gray, 1995) were also developed to describe the disposition and metabolism of methylmercury and its major metabolite, mercuric mercury, in rats. A brief description of the pharmacokinetic models developed for methylmercury is presented here.

A PBPK model was developed by Farris et al. (1993) to simulate the disposition of methylmercury and its primary metabolite, inorganic or mercuric mercury, in the adult rat. Farris et al. (1993) also conducted metabolism and distribution studies in rats to collect the data needed to understand the processes that influence the pharmacokinetics of both methylmercury and mercuric mercury. This model incorporated time-dependent compartment volume changes, compartment volume-dependent clearance rates, and the recycling of mercury as a result of hair ingestion during grooming. The Farris model served as the foundation for several subsequent models developed for methylmercury.

On the basis of the modeling results reported by Farris et al. (1993), Smith et al. (1994) developed a simple human PBPK model. Smith et al. (1994) assumed that methylmercury behaved as a single pool while the behavior of its metabolite (inorganic mercury) varied in different tissues. Smith et al. (1994) also conducted experimental studies in human volunteers to monitor levels of methylmercury and inorganic mercury in the blood, urine, and feces following a single intravenous injection of a tracer dose of methylmercury. The modeling results indicated that inorganic mercury accumulated in the body and was the predominant form of mercury present at longer times following administration. The biological half-life of methylmercury in the body was estimated to be 44 days, with an estimated 1.6% of the body burden excreted each day.

Gray (1995) developed a PBPK model for methylmercury in the rat that could be used to evaluate the developmental toxicity observed following *in utero* exposure to methylmercury. The model consists of a maternal model with a fetal submodel. This model can be used to obtain fetal and maternal organ methylmercury concentration-time profiles for any maternal dosing regimen, including the dosing patterns used in rat developmental neurobehavioral studies.

Luecke et al. (1994) developed a generic PBPK model for human pregnancy that was applied (Luecke et al., 1997) to both rat and human kinetic data for methylmercury. This model consists of four submodels and incorporates the changes observed in both the mother and the fetus during the time course of pregnancy. Both rat and human data have been simulated using the model following various routes of exposure to methylmercury.

Stern (1997) identified data on the distribution of parameters in the one-compartment model from the published literature. Available data specific to women between the ages of 18 and 40 were used; data between men and women were also used to determine statistical differences, if any. Blood volume and body weight were assumed to be correlated. A similar approach was used by Swartout and Rice (2000). In that analysis, however, some of the parameters are described by different distributional shapes or by distributions from different data sources than those used by Stern (1997).

Swartout and Rice (2000) performed an uncertainty analysis of the estimated ingestion rates used to derive the methylmercury reference dose. The uncertainty arising from the calculation of ingestion dose levels in mg/kg per day corresponding to measured concentrations of mercury in hair is estimated through a Monte Carlo analysis of the EPA dose conversion model. The Monte Carlo model was modified to include a methylmercury elimination concentration that was converted to an equivalent half-

life, and a term was added to account for measurement error of hair-mercury concentrations. The authors assumed correlations between several pairs of parameters: the hair-to-blood ratio and the elimination-rate constant, body weight and blood volume, and the fraction of the absorbed dose in the blood and body weight. Applying the results of this analysis and assuming the input correlations to the benchmark dose of 11 ppm mercury in hair used in the derivation of the methylmercury RfD results in a lower 95% confidence limit of 4.07×10^{-4} mg/kg-day. The dose conversion factor simulation is 8.0×10^{-5} with a 90% confidence interval of 3.7×10^{-5} to 1.6×10^{-4}. The corresponding dose conversion value used in the derivation of the methylmercury reference dose is 9.8×10^{-5}. The 90% confidence interval spans a three fold to five fold range of ingestion doses for any given concentration of mercury in hair. The hair-to-blood mercury concentration ratio contributed to the variance of the output.

Gearhart et al. (1995) developed a multicompartment adult and fetal model to analyze epidemiological data for a methylmercury risk assessment. This model was recently reparameterized by Clewell et al. (1999) for use in a Monte Carlo variability and sensitivity analysis. The model structure, a modification of the model developed by Farris et al. (1993), consists of a maternal model with a fetal submodel. Changes in both maternal and fetal tissues during gestation are described. The model has the capability to estimate maternal hair and blood concentrations following ingestion of methylmercury, as well as the resulting fetal cord blood concentrations. This model was used to address the relationship between mercury in maternal hair and daily ingested dose, which has been identified as a major issue in conducting a risk assessment for methylmercury. The results of Monte Carlo analysis using the model provided an estimate of the variability in ingestion rates associated with a measured hair concentration. The predicted variability (ratio of median to 5th percentile equals 1.5) is comparable to similar analyses performed using a simple compartmental model (U.S. EPA, 1997e; Stern, 1997). The results of a sensitivity analysis of the model suggest that the most important determinants of pharmacokinetic variability for methylmercury are the hair:blood partition, body weight, and hair growth rate.

3.0 TOXICOLOGICAL BASIS FOR CRITERIA

This section of the *Water Quality Criteria for the Protection of Human Health* document for methylmercury relies heavily on information provided in the *Mercury Study Report to Congress* (MSRC) (U.S. EPA, 1997e) for summaries of studies published before 1997. Data published after 1997 are summarized in this chapter. The *Water Quality Criteria for the Protection of Human Health* document for methylmercury is not intended to be an exhaustive survey of the voluminous health effects literature available; rather, it includes detailed information on studies that form the basis for EPA's hazard identification and dose-response assessment. The database on neurodevelopmental effects of methylmercury is quite extensive. Developmental neurotoxicity is currently considered the most sensitive health endpoint. Data on cardiovascular and immunological effects are beginning to be published and may provide a more sensitive endpoint for low-dose methylmercury effects. This chapter will focus on developmental neurotoxic, cardiovascular, and immunological toxic effects of methylmercury exposure. The reader is referred to the MSRC for information on other toxic effects of methylmercury.

3.1 INTRODUCTION

Methylmercury is a highly toxic substance with a number of adverse health effects associated with its exposure in humans and animals. Human exposure following high-dose poisonings in Japan and Iraq resulted in effects that included mental retardation, cerebral palsy, deafness, blindness, and dysarthria in individuals who were exposed *in utero* and sensory and motor impairment in exposed adults. Chronic, low-dose prenatal methylmercury exposure from maternal consumption of fish has been associated with more subtle endpoints of neurotoxicity in children. Results from animal studies also show effects on cognitive, motor, and sensory functions. The following section focuses on studies reporting neurotoxicity as an endpoint for methylmercury exposure.

3.2 NEUROTOXICITY

3.2.1 Human Studies

3.2.1.1 Minamata and Niigata, Japan

Minamata Bay, Japan

The first documented widespread human methylmercury poisoning occurred in Minamata, Japan, between 1953 and 1960. Over time the source of the poisoning was traced to consumption of contaminated fish and seafood from Minamata Bay. An industrial plant was found to have discharged waste containing mercury directly into the waters of the bay. The initial cases of what was later called Minamata disease were two young women with what appeared to be encephalitis. Public awareness of the situation grew after the sudden deaths of cats in the surrounding area. Cats were brought into Minamata in February 1957 to study the possible health impact of environmental exposure to methylmercury. Within 32 to 65 days after arrival, all developed similar symptoms (e.g., excessive salivation, violent rotational movements, inability to walk in a straight line, and collapsing death or voluntarily jumping into the sea to drown) (Harada, 1995). This episode revealed the potential neurotoxic effects on humans exposed to methylmercury.

Adult Minamata Disease

Officially, approximately 2,200 persons have Minamata disease. Many other cases of the disease have either not been reported or were misdiagnosed. Many had eaten contaminated fish and shellfish for quite some time before the symptoms appeared (Iwata et al., 1975). In human patients, the early stage of Minamata disease brought gross disturbance of the central nervous system, which affected approximately 88 people living in the area around Minamata Bay. Of those 88 people, 12 died within 100 days, while the others had permanent disability. Among those with permanent disability, symptoms included appallic symptoms and idiotic disorders, with nervous symptoms resulting from widespread disturbance of brain cortices. In those with advanced illnesses from moderate poisoning, symptoms included tremor, disturbance of sensation, severe generalized ataxia, dysarthria, concentric constriction of the visual fields, and difficultly in hearing (Takeuchi et al., 1975).

The most common clinical signs observed in adults were paresthesia, ataxia, sensory disturbances, tremors, impairment of hearing, and difficulty in walking. Examination of the brains of severely affected patients who died revealed marked atrophy of the brain (55% normal volume and weight), with lesions in the cerebral cortex and cerebellar cortex, and changes in the nerve fibers, cystic cavities, and spongy foci (Harada, 1995). Microscopically, entire regions of the brain were devoid of neurons, granular cells in the cerebellum, Golgi cells, and Purkinje cells. In addition to effects on the brain, methylmercury is known to have direct effects on the visual field. Korogi et al. (1997) presented results from a study on the comparison of magnetic resonance imaging findings of the striate cortex with visual field deficits in patients with Minamata disease. Results from this study indicated that the central 10° and 15° of vision represent 20% and 30% of the surface area of the striate cortex, respectively. The central portion of the visual fields occupied the posterior area as well as a greater proportion of the striate cortex. The visual field deficits in patients with Minamata disease correlated well with the magnetic resonance findings of the striate cortex. In severe cases of Minamata disease, the visual fields are identical with bilateral homonymous hemianopsia, with sparing of central vision (Korogi et al., 1997).

Delayed Onset-Type Minamata Disease

Mercury content in the hair and blood samples of Minamata patients was not analyzed until 1959. This was due in large part to the latency of the disease; the Minamata incident had apparently continued for such a protracted period that symptoms were delayed in appearing. In some cases, symptoms appeared more than 5 years after methylmercury intake ceased. Symptoms of delayed Minamata also were complicated by other diseases or aging. In the case of maternal exposure, symptoms usually did not appear until 5 to 8 years after the birth of the child. At this time, hair samples from mothers ranged from 1.82 to 191 ppm, while that of their offspring (congenital patients) ranged from 5.25 to 110 ppm (Harada, 1995).

Congenital Minamata Disease

Awareness of the developing fetus as a sensitive subpopulation came to light when a number of children were born with congenital cerebral palsy. These patients experienced symptoms such as mental retardation, primitive reflex, cerebellar ataxia, disturbances in physical development and nutrition, dysarthria, deformity of the limbs, hyperkinesia, hypersalivation, paroxysmal symptoms, strabismus, and pyramidal symptoms. Pathological findings of congenital Minamata disease patients include general atrophy and hypoplasia of the brain cortex and abnormality of the cytoarchitecture, remaining matrix

cells, hypoplasia of the corpus callosum, intramedullary preservation of the nerve cells, and dysmyelination of the pyramidal tract. In the cerebellum, hypoplasia of the granular cell layer and other layers as well as degeneration of granular cells were observed (Harada, 1995).

In a small fishing village called Yudo, 7 cases of cerebral palsy and 10 cases of infantile Minamata disease were found in a total of 50 households. Between 1955 and 1958, there were 188 births in the small fishing villages of Yudo, Tsukinowa, and Modo, with a 9.0% incidence of cerebral palsy, while the overall national incidence ranged from 0.2% to 2.3% (Harada, 1995).

Extensive investigations of congenital Minamata disease were undertaken and 20 cases that occurred over a 4-year period were documented. The exact number of congenital Minamata disease patients is not known, as some undiagnosed patients were already deceased. At present, 64 cases have been confirmed as congenital Minamata disease. In all instances congenital cases showed a higher incidence of symptoms than did the cases where exposure occurred as an adult. The congenital patients are unable to perform ordinary functions of living (Harada, 1995).

From 1950 to 1969, a total of 151 umbilical cords were collected from residents of the Minamata area. Included in this pool were 25 patients with congenital Minamata disease. Levels of methylmercury in the umbilical cords ranged from 0.35 ppm in 1952 to 0.96 ppm in 1955. The methylmercury levels in the cords from patients with congenital Minamata disease showed higher values than the cords of patients who had Minamata disease (0.72 ppm), mental retardation (0.74 ppm), other diseases (0.22 ppm), and no symptoms (0.28 ppm) (Harada et al., 1999).

Kinjo et al. (1993)

A case-control study examined the relationship between health complaints of patients with Minamata disease and exposure to methylmercury. A total of 1,144 Minamata disease patients older than 40 years of age were surveyed. A control group was also established; this group included nonexposed people living in neighboring towns, matched by age and sex. A questionnaire was used to obtain information on subjective complaints and activities of daily living (ADL). Results from analysis of the data indicated that Minamata disease patients had significantly higher rates of all complaints than did controls. Subjective complaints of Minamata disease patients, overall, were more prevalent than in controls. The results remained unchanged with age when the subjective complaints were categorized into two groups: those where frequency increased with age and those related to sensory disturbance. The

authors noted that the reason for the high prevalence rate of sensory disturbance among current Minamata disease patients is unclear. The data from the ADL questionnaire, when analyzed, were used to estimate functional capability in the elderly. Results indicate that ADL was significantly lower for Minamata disease patients aged 60 and over in comparison with controls. The authors conclude that ADL disability in Minamata disease patients is accelerated by aging. Overall, the prevalence of deficits was relatively greater in cases compared with controls as a function of increasing age.

Harada et al. (1998)

In 1995, Harada et al. (1998) measured mercury concentration in hair samples from 191 fishermen and family members living in mercury-polluted areas in the Minamata region of Japan. The study participants fished for a living and had previously consumed methylmercury-contaminated fish and shellfish caught in this region. Estimates of fish consumption were not provided. The study population comprised 83 men and 108 women who ranged in age from 32 to 82 years. Data on subjective symptoms and lifestyle factors were collected by questionnaire. In addition, each participant was administered relevant neurological tests (test details not provided) by a group of neurologists. Mercury concentrations in hair were less than 10 ppm in 185 out of 191 subjects. The mean concentrations were 5.0 ± 3.4 ppm and 2.1 ± 1.1 ppm for men and women, respectively. All six subjects with hair concentrations greater than 10 ppm were men. The mean concentration for men in the study was only slightly higher than the mean value of 4.6 ppm for normal nonexposed Japanese men. There appeared to be an upward trend in hair mercury concentration associated with increased frequency of fish consumption. Although the hair mercury concentrations approached what was considered normal (≤10 ppm in hair samples), the study participants exhibited a high incidence of a variety of neurological conditions. More than 85% of subjects reported subjective symptoms including numbness, forgetfulness, pain in the extremities, focal cramps, headache, and motor disturbances. Clinical findings included sensory disturbance, ataxia, speech impediment, hearing impairment, constriction of visual fields, and tremor. "Stocking and glove" sensory disturbance (a hallmark of Minamata disease) occurred in 69% of the participants. A dose-response relationship between clinical symptoms and hair concentration was not evident, indicating that hair level data were of limited use for diagnosis of chronic Minamata disease.

Fukuda et al. (1999)

A study was completed in Kumamoto, Japan, near Minamata City, to evaluate the relationship between the number of neurological complaints from symptoms and methylmercury exposure. A total of

1,304 exposed adults living in a methylmercury-polluted area and 446 nonexposed age-matched adults, living in an area not known to be polluted with methylmercury, participated in an interview and questionnaire survey. The data from 64 participants of the survey were analyzed by comparison of prevalence, factor analysis, and cluster analysis. Results indicated that the exposed population had more neurological complaints in comparison with those not exposed. The factor analysis proposed four factors: arthritic, muscular, sensory, and nonspecific complaints. All four were higher in the exposed population in comparison with the nonexposed. The authors suggest that the increased neurological and nonspecific complaints may be due to past exposure to methylmercury.

Futatsuka et al. (2000)

A case-control study was conducted to estimate the role of various risk factors, including methylmercury exposure, for diseases such as liver disease, renal disease, and diabetes mellitus. The study population included 1,500 subjects over 40 years of age living in the town of Tsunagi since 1984. The town of Tsunagi was methylmercury polluted, with 36.9 diagnosed Minamata disease patients for every 1,000 population. Urine, blood, physical, and ultrasonographic examinations were administered to determine evidence of liver disease, renal disease, and diabetes mellitus. Personal interviews were conducted to collect information on risk factors and specific details on the complaints. Results from this study indicated that prevalence of disease, liver disease, renal disease, and diabetes mellitus was not higher in the methylmercury-polluted area compared with other areas in Japan. However, subjects in the polluted area had more complaints than those in the nonpolluted area. The authors concluded that past exposure to methylmercury may have influenced these results.

Niigata, Japan

From 1963 to 1965, patients with Minamata disease-like symptoms were reported in the basin of the Agano River in Niigata. Methylmercury, a residual product from acetoaldehyde synthesis, was released from a manure factory located 70 km up the river. Untreated wastewater from the factory drained into the Agano River, contaminating the fish and shellfish population. By 1973, 325 patients with Minamata disease were identified. This poisoning was later named "Niigata Minamata disease." Similar to the incident in Minamata, the symptoms progressed even after cessation of exposure. Numbness in the extremities and in the perioral area was the most frequently reported (Iwata et al., 1975). In the Niigata incident, the maternal hair mercury concentration immediately after giving birth to a congenital patient was 293 ppm. The maternal symptoms associated with this level of exposure were

mild, with sensory disturbances and other Minamata disease-related symptoms. The level of mercury exposure required to initiate the onset of Minamata disease was established at 50 ppm maternal mercury hair level. Because of the previous experience in Minamata with methylmercury poisoning, women with hair mercury levels above 50 ppm were advised not to become pregnant. As a consequence, there was only one case of congenital Minamata disease in the Niigata incident (Harada, 1995).

3.2.1.2 Iraq Outbreak

In fall 1971, 90,000 metric tons of methylmercury-treated seed grain were imported through the southern seaport of Basra, Iraq, and distributed freely throughout the countryside. Because the grain was delivered at planting time, residents of the area baked the grain into bread. There are no records on the size of the population who consumed grain treated with methylmercury fungicide. Nor are there reliable estimates of the number of people who ate methylmercury-treated grain and developed signs and symptoms but did not seek medical attention. It was not until late December 1971 that the first case of methylmercury poisoning was recorded. Within 2 months, 6,530 hospital admissions and 459 hospital deaths were recorded from methylmercury ingestion. Included in this exposed population were pregnant women (Bakir et al., 1973). Children exposed *in utero* manifested severe sensory impairments such as blindness and deafness, general paralysis, hyperactive reflexes, cerebral palsy, and impaired mental development (Amin-Zaki et al., 1974).

A study was conducted by Marsh et al. (1987) to investigate the relationship between methylmercury exposure, as measured by maternal hair concentrations during pregnancy, and associated adverse effects in offspring. A total of 81 mother-infant pairs participated; maternal hair mercury levels served as the index for prenatal exposure and were measured by x-ray fluorescent spectrometric analysis to range from 1 to 674 ppm. Clinical evaluations were conducted along with interviews with the mother about labor, delivery, any abnormalities at birth, size of the baby, early childhood development, and age at which infants achieved developmental milestones. These milestones included sitting without support, standing and walking unaided, and speaking two or three meaningful words. Developmental retardation was indicated by the child's inability to walk a few steps unsupported by 18 months of age or to speak two or three meaningful words by 24 months of age. Additional questions included any observations of involuntary movements, seizures, impaired vision or hearing, lack of coordination, and the mother's general impression of the child's physical and mental development. The interview was limited by the mothers' recall of the age of their children; moreover, this culture did not use Western calendars to record family events. The physical examination of the child included observation; head circumference

and body length measurements; cranial nerve signs; speech; limb tone, strength; deep tendon reflexes; plantar responses; coordination; dexterity; primitive reflexes; sensation; posture; and ability to sit, stand, walk, and run. Neurological examinations scored 0 to indicate normal functions and 3 to indicate definite abnormality. Unclear readings were denoted with points for borderline findings, whereas scores of 0-3 reflect no definite abnormality. The highest score in the most severely affected child was 11.

The impact of methylmercury on neurological function of infants exposed *in utero* during the Iraqi poisoning incident is described in a series of reports by Amin-Zaki et al. (1974, 1976, 1979, 1981), Marsh et al. (1980, 1981, 1987), and Seafood Safety (1991). The major symptoms observed in this epidemic closely resembled those recorded in Minamata, Japan. The predominant symptom noted in adults was paresthesia, and it usually occurred after a latent period of 16 to 38 days following initiation of exposure. Additional dose-dependent symptoms observed in the more severely affected individuals included ataxia, blurred vision, and constriction of the visual field leading to blindness in severe cases, slurred speech and hearing difficulties. Fatalities from methylmercury exposure usually resulted from failure of the central nervous system (Bakir et al., 1973). Of the 28 children with the highest exposures, 7 had seizures, whereas none of the 53 children with the lowest exposures experienced seizures. Maternal hair mercury levels for those seven children ranged between 78 and 674 ppm.

Results indicate that boys appeared to be more severely affected than girls. Statistically significant differences were apparent for regressions for boys and girls, where boys had the steeper slope to indicate increased severity in late walking and talking than girls.

Cox et al. (1989) performed an analysis of the Iraqi data to identify the threshold for adverse neurodevelopmental effects if one existed. A variety of statistical models such as logit, hockey-stick, and nonparametric kernel-smoothing methods were used in the attempt. Analyses were limited by the lack of data on the background prevalence of poor outcomes among Iraqi children. The authors estimated a population threshold of approximately 10 ppm for the outcomes investigated. The uncertainty associated with such an estimate, however, is highly dependent upon the assumed background prevalence of poor outcomes (e.g., motor retardation, neurological abnormality) (Cox et al., 1989). In another attempt at reanalyzing the data, Crump et al. (1995) reported that the estimate of the population threshold was highly dependent on the choice of the model and highly sensitive to the definition of abnormality. For example, delayed walking was heavily influenced by four cases of delayed walking among children with corresponding maternal hair mercury levels below 150 ppm. Crump et al. (1995) concluded that the statistical upper limit of the threshold could be as high as 255 ppm. Furthermore, their maximum

likelihood estimate of the threshold using a different parametric model was said by the authors to be virtually zero.

Cox et al. (1995) analyzed the Iraqi data on late walking in children exposed to methylmercury *in utero*. The results indicated that dose-response analyses based on late walking endpoints were unreliable because of four influential observations in the group of responders with hair mercury levels below 150 ppm. Based on visual interpretation of the plot of the data, the four observations are isolated from the remainder of the responders and would be expected to have considerable influence on the threshold estimate. No quantitative sensitivity analysis was performed to further investigate the effect of removing one or more of these data points. The authors point out that if the four data points were to represent background, the threshold for late walking would be greater than 100 ppm. This is, however, considered unlikely given that no responses were observed in the 37 individuals with lower levels of exposure.

3.2.1.3 Peru

A prospective study (Marsh et al., 1995) was conducted in Mancora, Peru, between 1981 and 1984 but not published until 1995. Mancora was selected as the study site based on a number of criteria, but mainly for its dependence on marine fish as a large source of dietary protein. A diet high in seafood was presumed to be associated with methylmercury exposure. Study participants consisted of 369 pregnant women and 194 of their children. Maternal hair samples were collected from the final group of 131 mother-infant pairs to analyze for methylmercury content. The geometric mean hair level was 7.05 ppm, with a range of 0.9 to 28.5 ppm. The peak maternal hair methylmercury levels during pregnancy ranged from 1.2 to 30 ppm, with a geometric mean of 8.3 ppm. Neurological examinations were administered to children. Frequencies were reported for tone decreased; tone increased; limb weakness; reflexes decreased; Babinski's sign, which is an indicator of a pyramidal-tract abnormality; primitive reflexes; and ataxia. This study identified no significant relationship between maternal hair methylmercury levels and measures of infant development or neurological signs. The authors suggested that marine fish may contain elements, such as selenium, that reduce the toxicity of methylmercury, thereby masking any neurological effects associated with methylmercury exposure.

3.2.1.4 Northern Quebec, Canada

A cross-sectional study of 234 Cree Indian children between the ages of 12 and 30 months on July 1, 1978, was conducted by McKeown-Eyssen et al. (1983). These children resided in four northern

Quebec communities known to have the highest levels of methylmercury exposures within Quebec. Maternal hair mercury level was the index to reflect prenatal exposure. Methylmercury levels of the hair were measured in alternate 1-cm segments, beginning with the scalp-end segment. The average maternal hair methylmercury concentration was 6 ppm, with only 6% of the samples exceeding 20 ppm. Physical and neurologic examinations were administered to the children, with the additional measures of special senses, cranial nerve function, sensory function, muscle tone, stretch reflexes, coordination, persistence of Babinski's response, and a summary of signs for the absence or presence of neurologic abnormality. At 4 years of age, four measures of the Denver Developmental Scale (gross and fine motor development, language development, and personal and social skills) were administered to assess the child's development. Associations between exposure and neurological outcome were analyzed by multiple regression analyses adjusted for alcohol and caffeine intake, tobacco use, age of mother, and multiparity.

No significant association between methylmercury exposure and neurological deficits was identified in girls. Abnormality of tendon reflexes was evidenced in 11.4% of the boys and 12.2% of the girls, but was only significantly associated with maternal hair mercury in boys. The prevalence of abnormality of muscle tone or reflexes was found to increase seven times with each increase of 10 ppm of the prenatal exposure index. However, the authors caution the interpretation of the results on boys because the abnormality of muscle tone or reflexes tended to consist of isolated abnormalities of mild severity that are of doubtful clinical importance. In addition, there was no dose-response relationship.

3.2.1.5 Seychelles Islands

The Seychelles Child Development Study (SCDS) was initiated in 1981 to examine the effects of low-dose fetal exposure to methylmercury from maternal consumption of fish. The SCDS was planned and conducted in two separate stages. The preliminary cross-sectional stage of the study sought to provide additional detail and guidance on how to design the main study. The main study, started in 1989, was a double-blind, prospective, longitudinally designed study that followed a cohort of infant-mother pairs from 6 months to 66 months postgestation.

Demographics

The Seychelles Islands is a Westernized archipelago in the middle of the Indian Ocean, more than 1,500 kilometers from the eastern coast of mainland Africa. The Seychellois population is of African and European origin with some minority groups from India and China. English, French, and Creole are

the three official national languages, with Creole being the most popular language at home. A majority (~85%) of the population consume a high amount of marine fish on a daily basis. In general, the Seychellois population is considered quite healthy, with easy access to good health care and education (Marsh et al., 1995).

Cross-Sectional Pilot Study (Myers et al., 1995b,c)

From 1987 to 1988, a cohort of 789 mother-infant pairs was selected after exclusion criteria were exercised. The fetal exposure index used was maternal hair total mercury. The levels ranged from 0.59 to 36.4 ppm, while the median level in this study was 6.6 ppm total mercury. The Denver Developmental Screening Test-Revised (DDST-R) was administered and a medical and neurological examination was performed for each child between 5 and 109 weeks of age. Covariates were selected for statistical analysis because of their potential to bias the assessment of the association between maternal mercury and developmental outcomes. These covariates included gender, birth weight, Apgar score, age at testing, and medical history. Mother's age, use of alcohol and tobacco, and medical history also were used. When DDST-R scores of questionable and abnormal results were grouped, mercury effects were seen and were more pronounced in boys and declined as age of testing increased. In general, males had higher response rates on the DDST-R than females, independent of mercury level. No association, however, was observed between mercury exposure and overall neurological examination results. The authors cautioned the interpretation of the results because the developmental association with fetal mercury exposure disappeared when DDST-R scores of "questionable" were treated in the standard manner as passes.

A subset (217 children) of the children from the pilot study cohort (Myers et al., 1995a) was tested at 66 months of age with the same battery of tests as planned for the main study at similar age. Maternal hair mercury levels during pregnancy ranged from 1.0 to 36.4 ppm, while the median level was 7.1 ppm. Nine endpoints were evaluated in this second evaluation: the McCarthy Scales of Children's Abilities that yield the general cognitive index (GCI), perceptual performance, memory, and motor ability; the Preschool Language Scale that yields total language score and subscores for verbal ability and auditory comprehension; and the letter-word identification and applied problems subscales of the Woodcock-Johnson Tests of Achievement. The association between maternal hair mercury concentration and outcome was assessed by multiple regression analysis. Prenatal mercury exposure correlated with outcomes at 66 months on the McCarthy GCI and perceptual performance subscale and with total language and auditory comprehension scores. After removing outliers and influential points, however,

mercury effects were no longer significant except for the Preschool Language Scale auditory comprehension subscale.

Prospective Longitudinal Main Study

A double-blinded, prospective longitudinal study was initiated with a new cohort of 740 mother-infant pairs that were selected between 1989 and 1990. These participants resided on the island of Mahe, which is one of the largest islands in the archipelago of the Seychelles where 90% of all Seychellois citizens live. Maternal hair mercury level was used as the marker of fetal mercury exposure. The levels ranged from 0.5 ppm to 26.7 ppm, with a median of 5.9 ppm. The cohort was followed from ages 6.5 months to 66 months, with evaluations occurring uniformly at four critical periods (6.5, 19, 29, and 66 months of age) (Myers et al., 1995). Tests of 7-year-old children have also been done, but results are not yet published. Age-appropriate tests were administered at the time points indicated in Table 3-1.

6-Month Evaluation (Myers et al., 1995c)

At 6 months of age, all children were administered a standardized test of visual recognition memory (Fagan Infantest); a standardized screening test to measure personal-social, fine motor adaptive, language, and gross motor development (DDST-R); and a general medical and neurological examination. Covariates of this main study included those evaluated in the pilot study, with the addition of birth order, gestational age of the child, primary caregiver intelligence, maternal and paternal educational levels, history of breastfeeding, language spoken at home, and family income. Medical conditions related to poor neurodevelopmental outcomes were also included as covariates in the statistical analysis. The study results indicate no association at 6 months of age with DDST-R, neurological examination, and Fagan Infantest. However, males had lower scores on both tests than females.

19- and 29-Month Evaluations (Davidson et al., 1995)

At 19 months of age, children were evaluated with the Bayley Scales of Infant Development (BSID), while the primary caregiver was administered the Raven Standard Progressive Matrices. The cohort was evaluated again at 29 months. Infant intelligence was measured by BSID Mental and Psychomotor Scales. To measure adaptive behaviors, a modified version of the BSID Infant Behavior Record was completed at 29 months. Between the ages of 42 and 56 months, children were administered

Table 3-1. Developmental domains evaluated and tests applied in the Seychelles Islands Child Development Main Study

Developmental Domain	Age of Child (months)			
	6.5	19	29	66
Marsh et al. (1995)				
Global-cognitive	DDST-R	BSID MDI	BSID MDI	MSCA GCI
Visual-perceptive	—	Kohen-Raz	Kohen-Raz	Bender-Gestalt MSCA Perceptual
Speech-language	DDST-R	—	—	MSCA Verbal PLS Total Language Aud. Comprehension Verbal Ability
Memory	Fagan Infantest	—	—	MSCA Memory
Visual attention	Fagan Infantest	—	—	—
Neuromotor exam	Neurological DDST-R	BSID PDI	BSID PDI	Bender-Gestalt MSCA Motor
Behavioral	DDST-R	—	BSID IBR	CBCL
Learning-achievement	—	—	—	Woodcock-Johnson
Auditory response	—	—	—	Audiometry Tympanometry
Davidson et al. (1998)				
Global-cognitive	—	—	—	MSCA GCI
Visual-perceptive	—	—	—	Bender-Gestalt
Speech-language	—	—	—	PLS Total Score
Behavioral	—	—	—	CBCL
Learning-achievement	—	—	—	Woodcock-Johnson Letter and Word Recognition, Applied Problems

Symbols and Abbreviations: — = No test administered; BSID = Bailey Scales of Infant Development; IBR = Infant Behavior Record; MDI = Mental Developmental Index; PDI = Psychomotor Developmental Index; CBCL = Child Behavior Checklist; DDST-R = Denver Developmental Screening Test - Revised; GCI = General Cognitive Index; MSCA = McCarthy Scales of Children's Abilities; PLS = Preschool Language Scale.
Source: Marsh et al. (1995); Davidson et al. (1998).

the Pre-School Caldwell-Bradley Home Observation for Measurement of the Environment (HOME). Hair samples were collected from all children at both 19 and 29 months of age for analysis of total mercury concentration to determine postnatal exposure. The median maternal hair mercury concentration during pregnancy for the 738 mother-infant pairs in the cohort at 19 months was 5.8 ppm. Twenty-two percent of the children at 19 months had child hair mercury levels ≥ 10 ppm (Myers et al., 1997). The same covariates and modeling strategy were used as in the primary analysis. No effects of mercury were detected on the BSID scores at either age. Results of this study indicate that one functional behavior—the examiner's subjective rating of the child's test session activity level—was related to maternal hair mercury levels in the mothers of male children: activity level decreased as maternal hair mercury level increased. Independent of mercury exposure; activity level was rated higher in males. Authors of this study conclude that these two results suggest that prenatal exposure to mercury may lower activity level in males. This result should be interpreted with caution as it is not yet clear whether the lower activity in males is a direct result of increased mercury exposure.

19-Month Evaluation of Walking and Talking (Myers et al., 1997)

The 19-month cohort was selected for evaluations of two developmental milestones. Data for age of first walking (n = 720) and talking (n = 680) were obtained from the primary caregiver of each child. Age at walking was defined as the age when the child was able to walk without support, while age at talking was defined as the age the child first said words other than "mama" and "dada." The mean age for walking was 10.7 months for girls and 10.6 months for boys, while for talking it was 10.5 months for girls and 11.0 months for boys. Multiple regression analysis was used to assess the relationships between each developmental milestone, maternal hair mercury levels, and covariates. Covariates evaluated are the same as those included in the study reported by Davidson et al. (1995) described in the previous paragraph. In this study, there was a marginally significant relationship between prenatal mercury exposure from eating fish and the age at which males started to walk, but this depended on four statistical outliers. No association between prenatal mercury exposure and either the age at which females started to walk or either gender started to talk was found.

Semiparametric Modeling of the 19-Month Data (Axtell et al., 1998)

In addition to the multiple regression analysis used in the prospective longitudinal main study of the SCDS, a semiparametric generalized additive model was used to identify nonlinearities in the relationship between prenatal methylmercury exposure and developmental milestone achievements. The

specific milestones evaluated in the main SCDS cohort at 19 months of age (n = 738 children) were age that children walked and said words. Walking was defined as the number of steps without support and talking was any word except "mama" or "dada." Maternal hair total mercury was used as an index of fetal exposure. No significant nonlinear relationships with mercury were identified in any of the models for age at talking; this implies that the original linear regression models were appropriate for this analysis. A General Additive Model analysis indicated that the relationship between maternal hair mercury level and age at walking may not be linear. Walking appeared at a later age as exposure increased in the range from 0 to 7 ppm. Walking appeared slightly earlier with increasing mercury levels above 7 ppm. However, there was no evidence from any models that higher levels of mercury exposure resulted in further delays in walking. There is no biological or developmental hypothesis to explain the increase in age of walking at lower levels and not at higher levels.

66-Month Evaluation (Davidson et al., 1998)

An evaluation was conducted on 711 mother-child pairs at 66 months of age. At this age, six neurobehavioral tests were administered: McCarthy Scales of Children's Abilities, the Preschool Language Scale, the Woodcock-Johnson Applied Problems and Letter and Word Recognition Tests of Achievement, the Bender Gestalt Test, and the Child Behavior Checklist (CBCL). Maternal hair mercury and child hair mercury were measured. Mercury exposure was assessed by total mercury in segments of maternal hair representing growth during pregnancy. The mean maternal hair total mercury level was 6.8 ppm while the mean child hair total mercury level at age 66 months was 6.5 ppm. The covariates evaluated include all those included in the previous study period, in addition to hearing status of the child and Hollingshead socioeconomic status of the family. Two multiple linear regression analyses were performed for each of the six primary measures. Secondary analyses tested the hypothesis that associations between developmental outcomes and total mercury exposure might be nonlinear. Four of the six measures (all except for Bender Gestalt and Woodcock-Johnson Applied Problems Tests of Achievement) showed better scores in the highest methylmercury groups compared with lower groups for both prenatal and postnatal exposure. For both prenatal and postnatal methylmercury exposure, no adverse developmental effects were reported for toddlers. Postnatal exposure at 66 months, however, was associated with a small but statistically significant increase on several developmental outcomes even though there is no reason to suppose that such effects are associated with exposure to methylmercury. There are studies, however, that indicate the methylmercury levels in the infant were surrogate for the length of breastfeeding, which is reported to have a positive association with developmental outcomes (Grandjean et al. 1992).

New Analysis—CBCL Main Cohort 66 Months (Myers et al., 2000)

No effect of mercury was identified on the Child Behavior Check List (CBCL) at 66 months of age in the main cohort of the Seychelles study as determined by the total T score (Davidson et al., 1998). The CBCL is a report inventory scored by the caregiver that assesses eight domains: withdrawn, somatic complaints, anxious/depressed, social problems, thought problems, attention problems, delinquent behavior, and aggressive behavior. An analysis of these subscales was performed on the 711 children assessed on this test (Myers et al., 2000). No effect of mercury was identified on individual subscales.

New Analysis—Main Cohort 66 Months (Axtell et al., 2000; Palumbo et al., 2000)

The investigators performed additional analyses of the 66-month data to evaluate the possibility of nonlinear relationships associated with mercury exposure (Axtell et al., 2000). Endpoints included the six primary variables analyzed previously: McCarthy GCI, Preschool Language Scale (PLS), Wodcock-Johnson Applied Problems, Woodcock-Johnson Letter/Word Recognition, Bender copying errors, and CBCL total T score. Generalized additive models, which make no assumptions about the relationship between exposure and test score, were used. Maternal hair levels during pregnancy were used as a measure of prenatal exposure and child's hair mercury at 66 months was used for postnatal exposure. Nonlinearities were identified between prenatal exposure and PLS and CBCL, and between postnatal exposure and McCarthy GCI. For the PLS the trend involved a decrement of 0.8 points (poorer performance) from 0-10 ppm and an increase of 1.3 points above 10 ppm. For the CBCL there was an increase (representing a poorer score) between 0 and 15 ppm and a decrease above 10 ppm. The GCI increased (improved) by 1.8 points through 10 ppm mercury in the child's hair and declined by 3.1 above 10 ppm. Although these results are difficult to interpret, they provide limited evidence of an adverse effect of mercury exposure below 10 ppm maternal hair on two measures, and a somewhat greater association of adverse effects with child's hair mercury above 10 ppm on the GCI. As pointed out by the authors, there are fewer data points above 10 ppm (this is especially true for child's hair mercury), and therefore trends above this level are estimated less precisely.

The investigators in the Seychelles study further examined by multiple linear regression the results of the McCarthy GCI administered at 66 months (Palumbo et al., 2000). They analyzed the standard MSCA subscales and also constructed subscales to approximate the domains of cognitive functioning assessed in the Faroe Islands study: attention, executive function, expressive language, receptive language, nonverbal memory, visuospatial ability, visuomotor ability, and gross motor ability. They

found a positive association between child's hair mercury at 66 months and the standard memory subscale, with no other associations identified. As with all previous analyses of these variables, the raw scores were converted to "normative" scores. As pointed out by an OSTP panel (NIEHS 1998, Section 3.5 of the Confounders and Variables Section), the applicability of U.S. norms to this population is unclear, and the use of standardized scores may decrease sensitivity by collapsing different raw scores to one standard score.

Pilot Cohort Analysis at 108 Months (Davidson et al., 2000)

Further evaluation was performed on a portion of the Seychelles pilot cohort at 108 months of age (Davidson et al., 2000). Eighty-seven children were tested on five subtests of the WISC-III (Information, Block Design, Vocabulary, Digit Span, and Coding), California Verbal Learning Test (CVLT), Boston Naming Test (BNT), Beery-Buktenica Development Test of Visual Motor Integration (VMI) (copying geometric figures), Finger Tapping, grooved pegboard, Trailmaking (tracing the correct route through a form with a pencil), and the design memory subtest of the Wide Range Assessment of Memory and Learning (WRAML) (drawing each of four geometric designs from memory). Performance on BNT, VMI, and grooved pegboard showed a positive association (better performance) related to mercury exposure in males, with no effects identified in females. There were trends toward poorer performance related to mercury exposure for grooved pegboard in females ($p = 0.07$) as well as marginal p values on the full model that were not further analyzed (Finger Tapping, digit span). The investigators did not report power calculations, but with such a small number of subjects the power was probably quite low, so these largely negative results need to be interpreted with caution.

Benchmark Analysis (Crump et al., 2000)

A benchmark analysis (Crump et al., 2000) was conducted on data from the SCDS, with the goal of providing an alternative basis for deriving an appropriate human exposure level for methylmercury. The data modeled included responses from the neurological test batteries conducted at 6.5, 19, 29, and 66 months of age. In addition, data for developmental milestones (age first walked and age first talked) were analyzed. Maternal hair mercury concentrations measured in this study ranged from 0.5 to 26.7 ppm and averaged 6.8 ppm.

Most of the measured endpoints in the SCDS were recorded as continuous responses, and the k-power model, the Weibull model, and the logistics models for continuous data were applied. Test scores

below a predetermined value, $P_0 = 0.05$, were considered abnormal. For this analysis, the BMR was defined as 10% (BMR = 0.1). (For a description of modeling terms see Section 4.3).

In cases where responses were recorded as quantal responses (abnormal/normal), the data were modeled using the Weibull dose-response model for quantal data. Quantal responses reported in children in the Seychelles study included deep tendon reflexes, limb tone, overall neurological responses, and psychomotor index. In addition, each continuous response was converted to a quantal response by considering a response abnormal if it was more than 2 standard deviations away (in the adverse direction) from the mean response of the entire cohort, and then analyzed using the Weibull model. In these analyses, the BMD was defined in the same way as in the analyses of the continuous response.

The analyses of continuous response were conducted without covariates. Analyses with P_0 specified were conducted using both an expanded set and a reduced set of covariates for the children: sex, birth weight, birth order, whether or not the child was breastfed, medical history, maternal age, maternal smoking and alcohol use during pregnancy, maternal medical history, language spoken in home, score from home visit, Raven group (caregiver's intelligence quotient), maternal and paternal education level, family income, gestational age, Hollingshead socioeconomic scale, auditory scores, and the child's mercury level. Covariates were not included in the analyses of quantal responses or in the analyses of continuous responses in which x_0 was specified.

Parameter estimates were obtained using the maximum likelihood method, and statistical confidence bounds were computed by the profile likelihood method. The BMDL was defined conventionally as the 95% statistical lower confidence bound on the BMD. Results indicated that the most reliable analyses were represented by 144 calculated lower statistical bounds on the BMD (BMDL, or the lower statistical bound on maternal mercury hair level corresponding to an increase of 0.1 in the probability of an adverse response) derived from the modeling of continuous responses.

The results of BMD modeling are shown in Table 3-2. The average value of the BMDL in these 144 analyses was 25 ppm mercury in maternal hair, with a range of 19 to 30 ppm. With the exception of the linear model, which produced larger BMDLs, the dose-response models applied to continuous end points all produced comparable BMDLs.

Table 3-2. BMDL values (expressed as ppm mercury in maternal hair) for neurological responses and developmental milestones from the Seychelles Child Development Study

Endpoint	Model						
	Weibull				*K*-Power		
	P_0[a]		χ_0[b]	Quantal	P_0[a]		χ_0[b]
	None	Exp.[c]	None	None	None	Exp.	None
6.5 Months							
Deep tendon reflexes	—	—	—	22.8	—	—	—
Limb tone	—	—	—	20.9	—	—	—
Overall neurological	—	—	—	15.8	—	—	—
Fagan visual recognition memory	26.0	26.0	27.4	19.7	26.0	26.0	26.9
Fagan attention	25.7	25.9	27.0	23.7	25.5	25.6	26.4
19 Months							
Mental development index	23.7	23.4	26.0	22.6	24.3	24.1	25.6
Psychomotor index	—	—	—	22.3	—	—	—
29 Months							
Mental development index	24.1	24.4	25.7	21.9	24.0	24.2	24.8
Psychomotor index	—	—	—	22.5	—	—	—
66 Months							
Bender gestalt errors	26.9	26.7	28.5	22.7	26.7	26.7	27.5
Child behavior checklist total	27.2	27.2	29.0	19.4	20.0	26.9	27.8
McCarthy general cognitive index	24.4	24.2	26.5	22.7	24.7	24.6	25.9
Preschool language total score	25.2	25.1	26.8	22.7	24.7	24.7	25.5
Woodcock-Johnson							
Applied problems	23.1	23.5	25.3	22.7	23.9	24.3	25.5
Letter-word recognition	23.7	23.7	25.3	22.7	23.8	23.9	24.7
Developmental milestones							
Age first walked unassisted	24.9	24.0	25.9	22.7	24.4	23.2	26.8
Age first talked	24.6	23.5	25.9	20.3	25.0	24.1	25.9

[a] Abnormal defined as a response >2 standard deviations in adverse direction from mean response of entire cohort.
[b] Abnormal defined so that 5% of responses are abnormal ($p_0 = 0.05$).
[c] Exp. denotes use of an expanded range of covariates.

Source: Crump et al., 2000.

3.2.1.6 New Zealand

A study was conducted in the northern New Zealand islands to study the effects of prenatal methylmercury exposure on children exposed *in utero* from maternal fish consumption. Between 1982 and 1983, 11,000 mother-infant pairs were requested to submit hair samples and fill out a detailed diet questionnaire. Of those 11,000 pairs approximately 1,000 of these mothers had consumed fish more than three times per week for the 9 months of pregnancy. Seventy-three had hair mercury levels above 6 ppm, with the highest level being 86 mg/kg. This study was conducted in two stages.

Preliminary Tests at Age 4 (Kjellstrom et al., 1986)

From the 73 mothers with high mercury exposure (> 6 ppm) during pregnancy, a total of 31 matched pairs were selected to participate in a study on the effects of prenatal methylmercury exposure on children exposed *in utero* from maternal consumption of fish. A reference child matched for mother's ethnic group, age, and child's birthplace and birth date was located for each child selected from the high-fish-consumption group. Mercury exposure during gestation was determined from maternal hair analysis. The average hair concentrations for high-exposure mothers and the reference group were 8.8 ppm and 1.9 ppm, respectively. At 4 years of age, the children were tested using the DDST. Standardized vision tests and sensory tests were also performed to measure development of these components of the nervous system. The prevalence for developmental delay in children was 50% for progeny of high-mercury mothers and 17% for progeny of mothers of the control group. These results were statistically significant. Analysis of the DDST results by sector showed that developmental delays were most commonly noted in the fine motor and language sectors, but the differences between the experimental and control groups were not significant. The authors concluded that children born to mothers with mean hair mercury levels above 6 ppm have twice the risk of delayed development, as tested by the DDST, in comparison with the control group.

Psychological Tests at Age 6-7 (Kjellstrom et al., 1989)

In 1985 when the children were 6 to7 years of age, a follow-up study was conducted. In this study, 61 of the 74 high-exposure children were compared with three control groups with lower prenatal mercury exposure. Average maternal hair mercury concentrations in the control groups were 3 to 6 ppm and 0 to 3 ppm, respectively. The high-exposure group, with maternal hair mercury levels ranging from 6 to 86 ppm, was matched with controls for maternal ethnic group, age, smoking habits, residence, and sex

of the child. Each child was tested with a battery of 26 scholastic, psychological, and behavioral tests, which included Test of Language Development (TOLD), the Wechsler Intelligence Scale for Children (WISC), and McCarthy Scale of Children's Abilities as described in Table 3-3. Confounding factors such as language used at home, maternal and paternal occupation, maternal alcohol consumption, and number of children in the household were controlled using linear multiple regression analysis.

Table 3-3. Developmental domains evaluated and tests applied in studies of New Zealand children with prenatal exposure to mercury from fish

Developmental Domain	Age of Child (years)	
	4	6
General cognitive	—	MSCA general WISC-R Performance IQ, Total IQ
Visual-perceptual	Sheridan-Gardiner Letter Matching test Miniature Toy Test	MSCA perceptual
Speech-language	DDST	TOLD Spoken Language Quotient MSCA Verbal WISC-R Verbal Peabody Picture Vocabulary Test (1981)
Memory	—	MSCA memory
Motor	DDST	MSCA motoric
Learning-achievement	—	Clay Diagnostic Survey Concepts, Letter Test, and Word Test MSCA quantitative Burt Word Recognition Test Key Math Diagnostic Arithmetic Test
Personal-social	DDST	Everts Behaviour Rating Scale

Symbols and Abbreviations: — = No test administered; DDST = Denver Developmental Screening Test; MSCA = McCarthy Scales of Children's Abilities; TOLD = Test of Language Development; WISC-R = Wechsler Intelligence Scale for Children - Revised.
Source: Kjellström et al., 1986; 1989.

An average hair mercury level of 13 to 15 ppm during pregnancy was consistently associated with decreased test performance. Results of the psychological test variables were influenced by ethnic background and social class. After controlling for confounding factors and eliminating outliers, the association between prenatal methylmercury exposure and decreased performance in psychological tests remained unchanged. The children who had the poorest performance in the WISC IQ test at age 6 also had a high prevalence of abnormal or questionable DDST scores at age 4, indicating that the effects evidenced in this follow-up study confirm those found in the preliminary study at age 4. The authors

conclude that effects of methylmercury leading to developmental delays may later lead to deficits in psychological tests.

Benchmark Modeling of the 1985 Data (Crump et al., 1998)

Crump et al. (1998) performed a reanalysis and BMD modeling of the Kjellstrom et al. study results. Crump et al. used actual hair mercury levels as opposed to an indicator variable for mercury level in hair; additional confounding factors, such as parent's education and age at which the child was tested were also controlled for. They also and evaluated all 26 scholastic and psychological tests (illustrated in Table 3-4) administered to the 237 6 to 7-year old children. No significant associations between mercury exposure and children's test scores were identified. This finding, however, was highly influenced by one child whose mother's hair mercury level was 86 ppm, fourfold higher than observed for any other mother. When this outlier was omitted, scores on six tests were found to be significantly associated with maternal hair mercury concentrations: Clay reading test-concepts, Clay reading test-letter test, McCarthy-general cognitive test, McCarthy-perception, TOLD-grammar completion, and TOLD-grammar understanding. BMDs calculated from five tests (TOLD-spoken language quotient, WISC-performance IQ, WISC-full scale IQ, McCarthy perceptual, and McCarthy-motoric) ranged from 32 to 73 ppm and BMDL of 17 to 24 ppm, respectively. When the child with the highest maternal hair mercury was excluded, the BMDs ranged from 13 to 21 ppm with BMDLs spanning 7.4 to 10 ppm (Table 3-4).

Table 3-4. BMD and BMDL values (expressed as maternal hair mercury concentration, ppm) for neurobehavioral endpoints in New Zealand children evaluated at 6 to 7 years of age

Test	All New Zealand children		Child with highest maternal mercury concentration omitted	
	BMD[a]	BMDL[b]	BMD	BMDL
TOLD – spoken language	45	20	15	9.5
WISC – performance IQ	73	24	15	10
WISC–full-scale IQ	51	21	15	10
McCarthy–perception	32	17	13	7.4
McCarthy–motoric	55	21	21	9.8

[a] A background prevalence (P_0) of abnormal response of 5% and a benchmark response of 10% were used for these calculations.
[b] 95% lower confidence bound on BMD.
Abbreviations: TOLD = Test of Language Development; WISC = Wechsler Intelligence Scale for Children.
Source: Crump et al. (1998).

3.2.1.7 Faroe Islands

A large human prospective longitudinal study was conducted in the Faroe Islands to determine if increased methylmercury exposure is related to decreased neurobehavioral function. Before the prospective study, a pilot study was conducted to assess the magnitude of fetal mercury exposure in the Faroes. At 12 months of age, a follow-up evaluation was conducted and then a prospective study was initiated with children born at consecutive deliveries within a 22-month period at nearby hospitals.

Demographics

The Faroes is a group of 18 islands located in the North Atlantic between Scotland and Iceland. The Faroese population is homogenous with respect to cultural and socioeconomic factors. The culture is mainly Scandinavian, with a traditional stable family unit that has easy access to good health care, education, and social systems. Dietary deficiencies are virtually nonexistent, alcohol intake is low, rate of preterm delivery of low-birth-weight infants is also low, and rate of breastfeeding is high for at least 12 months (Budtz-Jorgensen et al., 2000). Seafood constitutes a major part of the average diet in fishing communities in the North Atlantic like the Faroe Islands (Grandjean et al., 1995). The major source of methylmercury exposure is pilot whale, which according to ancient tradition was hunted and distributed within the community (Grandjean et al., 1997). Other components of the Faroese diet include lamb, potatoes, dairy products, and foods imported from other countries (Steurwald et al., 2000).

Pilot Study (Grandjean et al., 1992)

A pilot study was conducted by Grandjean et al. (1992) to assess the magnitude of fetal mercury exposure in the small fishing village of Lorvik, Faroe Islands. Blood samples were collected from a group of 53 women of fertile age, between 20 and 50, identified through a municipal register. Between 1986 and 1987, 1,023 umbilical cord blood samples were also collected at consecutive deliveries at three local hospitals. Women had a median blood mercury level of 12.1 µg/L, with values that ranged from 2.6 to 50.1 µg/L. The median mercury concentration in cord blood for all 250 samples exceeded 40 µg/L, while 20 samples had levels higher than 100 µg/L. Hair samples had mercury content that exceeded 10 ppm, and five samples exceeded 25 ppm. In 34 hair samples the measured mercury levels exceeded 15 ppm. Mercury concentrations tended to be 20% to 65% higher in cord blood than in the venous blood of mothers. Highly increased mercury concentrations in maternal hair and umbilical cord blood were related to maternal consumption of pilot whale.

12-Month Evaluation (Grandjean et al., 1995b)

At 12 months of age, 583 children were selected for further evaluation. These children were followed for 1 year after birth. Three age-appropriate developmental milestones were evaluated: sitting, creeping, and standing. The age at which the child achieved a developmental milestone was not associated with indices of prenatal mercury exposure, either from cord blood (average of 174 μg/L) or maternal hair (approximately 15% of mothers had concentrations above 50 nmol/g). Infants who reached the milestone criteria early had significantly higher mercury concentrations in their hair at 12 months than those who did not. The child's hair mercury concentration was found to be highly correlated to the period of breastfeeding. Breast milk may transfer contaminants such as methylmercury, but it is also known to confer certain advantages such as maternal antibodies. The authors concluded that if methylmercury exposure from human milk had any adverse effect on milestone development in these 12 month-old infants, the effect was compensated for by advantages offered through breastfeeding.

Computer-Assisted Neurobehavioral Tests in 7-Year-Olds (Dahl et al., 1996)

In this study, 917 children were evaluated at 7 years of age. The study focused on computer-assisted neurobehavioral tests and whether or not they could serve as meaningful parameters of neurotoxicity; three Neurobehaviroal Evaluation System (NES) tests were administered with slight modifications. The NES tests were selected to assess motor speed (Finger Tapping [FT]), sustained attention (Continuous Performance Test [CPT]), and motor coordination (Hand-Eye Coordination [HEC] Test). The CPT was modified to use animal silhouettes as a stimuli instead of letters to accommodate those children who had not yet started school and were unfamiliar with the alphabet.

Finger Tapping was relatively easy for most children, but the HEC test was considered too difficult. Of the 914 children who completed the full HEC, 755 had fewer than 25% nonresponses. Decreased visual acuity, strabismus, use of eyeglasses, and contrast sensitivity were markedly associated with decreased performance, especially on the CPT. Boys and older children performed better than girls and younger children, but this was due to increased familiarity with computers and use of a joystick. The authors concluded that maternal hair mercury and cord blood mercury were clearly associated with NES results, especially in the FT and CPT tests.

Main Prospective Longitudinal Study of 7-Year-Olds (Grandjean et al., 1997)

The cohort consisted of 917 children at 7 years of age who survived from the original cohort established in the pilot study. Indices of prenatal exposure included cord blood and maternal hair, and the index for postnatal exposure was children's hair mercury. The geometric mean cord blood mercury concentration was 22.8 μg/L, and the concentration found in children's hair averaged 11.68 ppm. Detailed neurobehavioral and physical examinations and neuropsychological and neurophysiological testings were performed. The neuropsychological tests (Table 3-5) included NES FT Test, NES HEC Test, Tactual Performance Test, NES CPT, Wechsler Intelligence Scale for Children - Revised (WISC-R), WISC-R Similarities, WISC-R Block Designs, Bender Gestalt Test, California Verbal Learning Test-Children [CVLT]), Boston Naming Test (BNT), and Nonverbal Analogue Profile of Mood States. These tests were chosen for their sensitivities in detecting neuropathological abnormalities. The neurophysiological tests were chosen to exclude those with electrical stimulation or long measurement times. These tests include pattern reversal visual-evoked potentials with binocular full-field stimulation, brain stem auditory-evoked potentials (BAEP), and postural sway.

Fewer than 60% of the children completed three of the most difficult tests. The WISC-R Similarities Test, NES HEC Test, and Nonverbal Analoguous Profile of Mood States were found to be too difficult for many of the children to reveal the subtle neurotoxic effects associated with methylmercury. The geometric mean cord blood mercury concentration for the 85 children who failed or refused to take the mood test was 29.5 μg/L, compared with 22.3 μg/L in children who voluntarily completed it. Reciprocal motor coordination and simultaneous finger movement showed no relation to mercury exposure. In the finger opposition test, however, 465 children with geometric mean blood concentrations of 21.8 ug/L mercury performed optimally, whereas those with blood concentrations of 23.9 μg/L had questionable or deficient performances.

Mercury-related abnormalities were not identified in either the neurophysiological or clinical examination. However, in the neuropsychological testing, statistically significant mercury-related dysfunction was observed. This was most pronounced in the areas of language, attention, and memory, and to a lesser extent visuospatial and motor functions. After adjustment of covariates and exclusion of children with maternal hair mercury above 10 ppm, the association remained. This indicates effects of methylmercury at doses lower than that which result in 10 ppm maternal hair mercury. In the neurophysiological test, girls showed significantly shorter latencies of evoked potentials than boys in the electrophysiological tests. For the BAEP latencies, peak I at 40 Hz and 20 Hz was slightly delayed at

Table 3-5. Developmental domains evaluated and tests applied in studies of Faroese children at age 7 years

Developmental Domain	Test
Grandjean et al. (1997) - Main Prospective Study	
General cognitive	WISC-R Similarities
Visuospatial	WISC-R Block Designs Bender Motor Visual Gestalt Test
Attention	NES2 Continuous Performance WISC-R Digit Spans Forward
Speech-language	Boston Naming Test
Memory	California Verbal Learning Test
Motor	NES2 Finger Tapping NES2 Hand-Eye Coordination NES2 Tactual Performance
Personal-social	Nonverbal Analogue Profile of Mood States
Grandjean et al. (1998) - Nested Case Control Study	
General cognitive	WISC-R Similarities
Visuospatial	WISC-R Block Designs Bender Visual Motor Gestalt Test
Attention	NES2 Continuous Performance WISC-R Digit Spans Forward
Speech-language	Boston Naming
Memory	California Verbal Learning Test
Motor	NES2 Finger Tapping NES2 Hand-Eye Coordination
Personal-social	—

Symbols and Abbreviations: — = No test administered; NES2 = Neurobehavioral Evaluation System; WISC-R = Wechsler Intelligence Scale for Children - Revised.

Source: Grandjean et al., 1997, 1998.

increased prenatal mercury exposures and the delays for peaks III and V were statistically significant, but the interpeak latencies showed no associations with mercury. Body sway showed a slight negative association with mercury exposure in all four conditions: eyes open, no foam; eyes closed, no foam; eyes open with foam; and eyes closed with foam.

Four tests were selected for further analysis. Tests were chosen to reflect each of the following brain functions: motor function (Finger Tapping with preferred hand), attention (CPT reaction time), visuospatial performance (error score on the Bender Visual Motor Gestalt Test), language (Boston Naming Test after cues), and memory (long-delay recall on the California Verbal Learning Test). After

adjustment for covariates using the Peters-Belson method, children with scores in the lowest quartile were identified and distributed into quartile groups of mercury exposure (< 15, 15-30, 30-50, and > 50 μg/L). These results indicate that there is a statistically significant trend for the attention, language, and memory test with increasing prenatal mercury exposure (Grandjean et al., 1997).

Pilot whale blubber is also consumed by the Faroese population, and this could result in increased exposure to PCBs, a potential confounding factor. A subset (n = 436) of the cord tissue samples was evaluated for PCBs; inclusion of PCB exposure as a covariate in the regression analysis affected only the regression for the BNT. The authors conclude that results of the expanded data analysis do not suggest that the mercury effect can be explained by concomitant PCB exposure, or that PCB exposure enhances the mercury-associated effects.

Reevaluation of the Evoked Potentials in the Prospective Study (Murata et al., 1999a)

Significant associations with delays in evoked potential latencies and mercury exposure (Murata et al., 1999a) initiated the reanalyses of the data from the prospective longitudinal study. This analysis is limited to only children born during the first half of the cohort generation in 1993. Data from the second year were excluded because of shorter BAEP latencies and delayed latency on the visual-evoked potentials. Three sets of mercury exposure data were utilized in regression analyses: (1) mercury in cord blood (geometric mean of 23.0 μg/L, range of 3.3-351 μg/L), (2) mercury in maternal hair at parturition (geometric mean of 4.49 ppm, range of 0.9-39.1 ppm), and (3) mercury in the child's hair (geometric mean of 3.42 ppm, range of 0.04-26.4 ppm). The mercury concentration in maternal hair was a significant predictor for peak III latency and the I-III interval, where the child's own hair mercury concentration at the time of examination was not associated with these response variables. The cord blood concentration was, however, a significant predictor, supporting the notion that the latency delays are related to increased prenatal methylmercury exposure.

Nested Case-Control Study (Grandjean et al., 1998)

Following the evaluation of 7-year-olds in the prospective longitudinal study, the data were evaluated as a nested case-control study. From the original cohort of 1,022 established in the pilot study, the cases and controls were selected based on maternal hair mercury concentration. The case group of 112 children whose mothers had hair mercury concentrations of 10 to 20 ppm was matched to children with prenatal exposure below 3 ppm (control). Age, sex, time of examination, and maternal Raven score

were matching criteria. The median maternal hair mercury concentrations in the two groups were 1.8ppm for the control group and 12.5 ppm for the cases, a sevenfold difference. The median cord blood mercury concentrations for the control and cases were 11.9 and 59.0 μg/L, respectively. Neuropsychological tests evaluated were these: NES2 FT Test, NES2 HEC Test, NES2 CPT, WISC-R Similarities, WISC Block Designs, Bender Visual Motor Gestalt Test, CVLT, and BNT. The case group performed less satisfactorily than those in the control. On 6 of the 18 test outcomes, the inferior scores achieved by the case group were statistically significant. In particular, the case group showed a deficit on the Finger Tapping condition and the overall hand-eye coordination. Girls and boys scored differently on the Bender Gestalt Test, California Verbal Learning Test, all three Finger Tapping conditions, CPT reaction time, and the average hand-eye coordination score. No differences were reported between girls in the cases versus controls, but boys in the case group scored poorer in the Finger Tapping reaction time than the boys in the control group. The deficit in motor coordination, especially in Finger Tapping with both hands, was highly significant for boys only. The author noted that the findings of this matched case-control study are in accordance with regression analyses performed on all 900 children at the 7-year evaluation; methylmercury effects appear in the several domains of the brain, focusing on motor function, language, and memory.

Benchmark Modeling (Budtz-Jorgesen et al., 2000)

Benchmark modeling of the data from the Faroese children at 7 years of age was reported by Budtz-Jorgesen et al. (2000). The exposure was modeled both as mercury concentration in cord blood and in maternal hair. The number of children that completed neuropsychological tests varied between 837 and 901. One neuropsychological test was selected for evaluation of each of the five domains of brain function:

1. Motor speed (NES FT Test)
2. Attention: NES2 CPT
3. Visuospatial performance: Bender Visual Motor Gestalt Test
4. Language: BNT
5. Short-term memory: CVLT

For tests of motor function, language, and memory, a logarithmic dose-response model tended to show a better fit than a linear dose model using cord blood mercury concentration as the dose parameter. The default p_0 is 5%, which equates to the level (x_0) of abnormal test performance as defined by a probability

of 5% in the unexposed population. The Faroese cohort does not include an unexposed control group; thus the performance level for an unexposed child is obtained by fitting a dose-response curve to all data points, followed by extrapolating to zero exposure. Four different dose-response models were employed: *K* power, linear, square root, and logarithmic.

The results from this analysis indicate that BMDs and BMDLs vary substantially. Of the four models, the logarithmic dose-response model provided the best fit for some of the outcome variables that showed the closest association with the cord blood mercury concentration. The lowest BMDLs averaged approximately 5 μg/L cord blood, which is equivalent to approximately 1 ppm in maternal hair. Most BMDLs for hair mercury concentrations were higher. However, the results for a BMR of 5% are the same order of magnitude as the cord blood results at a BMR of 10%. The authors concluded that the results of the benchmark calculation are highly dependent on the assumed dose-response model. Results of this analysis are discussed further in the Risk Assessment chapter (Chapter 4). (For a description of modeling terms see Section 4.3).

Second Cohort (Steurwald et al., 2000)

During a period from 1994 to 1995, a second cohort of 182 singleton term births was generated from consecutive births at the National Hospital in Thorshavn, Faroe Islands (Steurwald et al., 2000). Maternal hair, serum, breast milk, and umbilical cord blood were analyzed for contaminants, while selenium, thyroid hormones, and fatty acids were measured in cord blood. In addition to methylmercury, PCBs were examined as a possible confounder in test outcome. At 2 weeks of age, infants were administered a neurological examination. Assessment of functional abilities, reflexes and responses, and stability of behavioral status during examination were completed with a score of optimal, questionable, or suboptimal performance. The Neurologic Optimality Score (NOS) was the number of items rated as optimal out of a total of 60. Results from this study indicate that prenatal exposure to methylmercury and PCBs increased from maternal intake of seafood. After adjustment for confounders, a tenfold increase of the cord blood mercury concentration was associated with a decreased NOS of 2.0. This effect corresponds to a decrease in gestational age of about 3 weeks. The authors conclude that prenatal exposure to methylmercury from contaminated seafood was associated with an increased risk of neurodevelopmental deficit. No evidence for a protective or beneficial effect with respect to neurological optimality score (the number of main items rated optimal out of 60) was observed for essential fatty acids or selenium.

3.2.1.8 Germany

Cross-Sectional Study (Altmann et al., 1998)

From a larger comparative environmental screening study, 384 children between the ages of 5 and 8 years were selected to participate in a smaller field experiment to investigate the effects of low-level lead and mercury exposure on the functions of the developing visual system. Blood lead levels and urinary excretion of lead and mercury were used as exposure indices. Neurophysiological and psychophysical measurements were administered to the children. Visual functions were assessed for neurophysiological measurements, while psychophysical measurements were assessed by visual-evoked potentials and contrast sensitivity. Linear regression analyses were used to analyze the possible relationship between exposure to lead and mercury and outcome variables. Adjustments were made for potential confounding factors such as parental education, birth weight, length of lactation, and premature birth.

After adjustment for potential confounding factors, contrast sensitivity values were significantly reduced with increasing urinary mercury levels; four of the ten contrast sensitivity values tested showed a statistically significant decrease with increasing urinary mercury. Very subtle changes in the visual system function were noted at very low levels of urinary mercury. However, no significant associations were found between urinary mercury output and any visually evoked potential outcome variables.

3.2.1.9 Nambija, Ecuador

Cross-Sectional Study on Neurosensory Dysfunction (Counter et al., 2000)

A cross-sectional study was conducted in the remote Andean settlement of Nambija, Ecuador, to investigate whether blood mercury levels are associated with auditory neurosensory dysfunction. Participants in this study included 36 children and 39 adults living in Nambija , an area known to have extensive gold-mining operations where mercury is used in the extraction process. Mercury exposure was measured in whole blood. The mean blood mercury level was 17.5 µg/L. A group of 34 subjects (15 children and 19 adults) from a non-gold-mining area were selected as the control group. Their mean blood mercury level was 3.0 µg/L. A neuro-otological examination was administered; a neurological examination of the cranial nerves was administered using standard procedures and an audiological test was administered to 21 children and 19 adults.

Of those examined, 45% of the group complained of headaches and/or memory loss, three cases involved severe neurological impairment and four cases involved middle ear pathology. A statistically significant relationship was identified between blood mercury level and hearing level in children at 3 kHz in the right ear only. Adults were not affected. BAEP responses showed a significant correlation between blood mercury and the I-III interpeak latency on the left side. The authors conclude that the findings of this study suggest that overall auditory sensory-neural function and neural conduction time at the brain stem level were generally unaffected by elevated blood mercury levels in either children or adults.

3.2.1.10 Amazonian Basin

The conditions in the Amazon—extremely high temperatures and humidity with seasonal fluctuation of water during rainy and dry seasons—are conducive for mercury methylation because of high quantities of suspended organic matter, high temperature, acidity, and redox potential. These elements influence the availability of fish as a food resource. In 1996, Lebel and colleagues published results from a small preliminary study on individuals from the Amazonian basin to determine the relationship between mercury exposure and neurological outcomes and reported the decrease of visual and motor functions with increasing hair mercury levels. In 1998, Lebel and colleagues published another study to determine the neurofunctional and clinical manifestations of nervous system dysfunction in relation to hair mercury levels below 50 ppm. In 1999, Grandjean et al. published results from a study of populations living in four comparable Amazonian riverine communities located upstream of gold-mining fields, while in 2000, Dolbec et al. published results from a cross-sectional study in a village on the Tapajos River.

Lebel et al. (1996)

Lebel et al. (1996) published a study of 29 adult residents living in two villages located on the Tapajos River, a tributary of the Amazon, located approximately 200 kilometers from several gold-mining sites. Total hair mercury concentration ranged from 5.6 to 38.4 ppm; methylmercury constituted between 72.2% and 93.3% of the total mercury measured in hair samples. A quantitative behavioral neurophysiological battery was modified for administration to persons with minimal formal education living in an area without electricity. Women exhibited a decrease in manual dexterity, as measured in the Santa Ana Test (Helsinki version) that was correlated with increased mercury concentration in hair. For both men and women, there was a statistically significant decrease in color discrimination capacity with

increasing hair mercury concentrations. Near visual contrast sensitivity profiles and peripheral visual field profiles were both reduced in the individuals with the highest hair mercury concentrations. The authors note that constriction of the visual field has been observed in other instances of mercury intoxication and that changes in contrast sensitivity have been noted in nonhuman primates exposed to methylmercury (Rice and Gilbert 1982,1990).

Lebel et al. (1998)

A later study was conducted in a Tapajos River village that depends on fish as its main source of protein. A total of 91 adults (45 men and 46 women between the ages of 15 and 81) of the 98 voluntary participants were examined. Four measures of hair mercury concentrations were used: (1) mean total hair mercury, (2) total hair mercury, (3) total hair mercury in the highest value obtained out of all centimeters analyzed, and (4) total hair mercury in the first centimeter and methylmercury in the first centimeter. Several tests were administered to score for neuropsychological dysfunction. Motor strength was determined with a dynameter for grip test; manual dexterity was measured with the Santa Ana Test (Helsinki version); and visual functions, color vision, and contrast sensitivity were assessed with a battery of sensitive neurofunctional tests. Results were analyzed by multiple regression.

There was no difference between genders for all tests except the grip strength test. Women also exhibited decreased grip strength with increasing peak mercury levels. Intermediate and higher frequencies of near visual contrast sensitivity and manual dexterity (measured with the Santa Ana Test) varied with the level of mercury in hair. Gender-nonspecific muscular fatigue was also noted with increasing mercury levels. The authors suggest that there appears to be a dose-effect relationship for certain motor and visual functions. Manual dexterity, alternating hand coordination, and muscular fatigue were associated with hair mercury levels, while near visual contrast sensitivity and restricted visual fields were dose-dependently altered.

Cross-Sectional Study (Grandjean et al., 1999)

A cross-sectional study was conducted in four comparable Amazonian riverine communities located upstream toward gold-mining fields. Fish is consumed as a large part of the population's staple diet. Of the 420 eligible children between the ages of 7 and 12, 351 were examined for neurobehavioral dysfunction. Mercury exposure was measured through children's hair mercury levels because only 37% of the participants had maternal hair mercury samples. Children's hair mercury concentrations had an

overall geometric mean of 11.0 ppm and a median of 12.8 ppm, while mothers had geometric mean hair mercury levels of 11.6 ppm and a median value of 14.0 ppm. Maternal hair mercury concentrations were highly correlated with those of their children. Several neuropsychological tests of motor function, attention, and visuospatial capability were administered. These included Finger Tapping, Santa Ana form board, WISC-III Digit Spans Test, and two subtests of the Stanford-Binet Intelligence Scale (the copying test and memory condition). The relation between mercury exposure and neurobehavioral function was analyzed by multiple regression analyses with adjustment for covariates including, age, sex, health status, maternal education, and maternal marital status.

The Santa Ana form board and Stanford-Binet copying test showed the clearest associations with the hair mercury concentration. The authors note that the effect of mercury was significantly greater in younger children only for the nonpreferred hand condition of the Santa Ana Test. In interpreting these results, the authors caution that there were no data for the level of prenatal exposure experienced in the test children because of the lack of maternal hair samples. Additional sources of uncertainty in this study include nutritional deficiencies that occurred in the past and possible infection of tropical diseases that may have influenced the capabilities of these children at the time of neurological evaluation.

Cross-Sectional Study (Dolbec et al., 2000)

A cross-sectional study was conducted in May of 1996 in a village on the banks of the Tapajos river in the Amazonian Basin, Brazil (Dolbec et al., 2000). This study was conducted on 84 fish-eating adults between the ages of 15 and 79, to evaluate the effect of mercury exposure on motor performance. The mean hair total mercury level was 9 ppm. Pychomotor performance was evaluated using the Santa Ana Test for manual dexterity, the Grooved Pegboard Fine to test fine motor skills and NES Finger Tapping Test for motor speed. Motor strength was measured by dynamometry for grip and pinch strength.

Multivariate analysis of the variance indicated that the hair mercury levels were inversely associated with overall performance on the psychomotor tests, whereas an association was reported with blood mercury. Semipartial regression analyses reported that hair total mercury accounted for 8%-16% of the variance of psychomotor performance. The authors conclude that the findings of this study demonstrated neurobehavioral manifestations of subtle neurotoxic effects on motor functions associated with low-level methylmercury exposure.

3.2.1.11 Madeira

Cross-Sectional Study (Murata et al., 1999b)

A cross-sectional study (Murata et al., 1999) was conducted in the Madeiran community to determine possible—mercury exposure-related effects on evoked potentials in 149 children between the ages of 6.4 and 7.4 years. Children's hair mercury concentrations were used to reflect current exposure levels, while maternal hair levels from mothers who had followed consistent diets since pregnancy represented prenatal mercury exposures 7 years ago. The use of maternal hair concentration as a substitute for exposure during pregnancy is based on the assumption that mercury exposure has changed very little over time. The authors acknowledge, however, that current maternal hair mercury levels provide an imprecise indication of exposure during pregnancy and any recent dietary change would tend to weaken the association with the outcome variables. The 149 children were administered physical and functional neurological examinations, with an emphasis on motor coordination and perceptual motor performance. Tests included these:

- NES2 FT
- NES2 HEC
- NES2 CPT
- WISC-R subtests: Digit Spans forward condition and Block Designs
- Stanford-Binet Bead Memory Test

Evoked potentials were determined with a four-channel electromyograph, while pattern reversal visual-evoked potentials with binocular full-field stimulation were conducted in a darkened room. Associations between these outcomes and exposure to methylmercury were assessed by multiple regression analysis and were adjusted for possible confounding variables: age, sex, maternal and paternal education and employment, maternal alcohol use and smoking during pregnancy, numbers of older and younger siblings, school, and the level of the child's computer acquaintance.

Increased exposure to methylmercury was associated with delays in evoked potential latencies; peak III on the BAEP at 40 Hz, and N145 on the pattern reversal visual-evoked potentials at the 15-minute condition. When the maternal hair mercury concentration exceeded 10 ppm, the increase of the N145 visual-evoked potential latency at 15 minutes was 3.16 milliseconds (ms). The N75-N145 and P100 and N145 interval latencies showed similar regression coefficients for mercury, although

significance was evident only for the 15-minute condition. The authors suggest that this may indicate that there is a mercury-associated delay occurring between P100 and N145. Weak associations were also evidenced between maternal hair mercury levels and deficits on Digit Spans and Bead Memory tests.

3.2.1.12 French Guiana

Case-Control Study (Cordier and Garel, 1999)

High-exposure areas were selected in the Amerind villages in the Upper Maroni, with two other Amerind villages with less mercury contamination to serve as reference groups (Cordier and Garel, 1999. 261 children participated in the study, 69 from the village of Camopi (control), 82 from Awala (control) a total of and 110 in the Upper Maroni (cases). Hair samples were collected from both children and mothers to represent exposure indices. Maternal hair mercury levels ranged from 2.5 to 6.7 ppm. This was used as a surrogate for prenatal exposure. Children had slightly lower hair mercury levels than adults, but this did not vary with age. Neurological examinations were administered to children from 9 months to 6 years of age with special emphasis on neuromotor examination of the upper and lower limbs, axis of the body, deep reflexes, postural reactions, examination of the effects on neuromotor functions, neurosensory examination, and cranial growth. The battery of tests was selected to measure the child's abilities outside of educational or cultural influences; these include the NES FT Test to measure fine motor function, coordination, and speed of execution; and the Stanford-Binet Intelligence Scale, with subtests of immediate memory (bead memory) and ability to assess visuospatial and visuoconstructional function (block-copying). In addition, the McCarthy memory test for digits (backward and forward) and the McCarthy leg coordination test were utilized. Associations were analyzed by linear regression, adjusting for potential confounding factors (alcohol consumption during pregnancy, parity, place of birth of the child, and illnesses during childhood).

Within the case group, there is a significant decrease in the scores with exposure category for the Leg Coordination test and close to significance for the Copying test. When boys and girls were examined separately for the FT test, boys had higher scores than the girls, while a significant decrease is observed in the score on the Block Design test correlated with exposure in girls. Boys also exhibited greater incidence of increased reflexes correlated with maternal hair mercury concentrations. The authors conclude that results of this study suggest a link between exposure to mercury and perturbations of the child's neurological and intellectual development.

3.2.2 Animal Studies

Substantial information on the neurotoxicity of methylmercury has been generated from animal studies that support neurological effects reported in humans. Relatively brief, high-level exposures in rats have been shown to cause characteristic signs of neurotoxicity (flailing and hindlimb crossing when the animal is lifted by the tail), as well as neuronal degeneration in the cerebellum, cerebral cortex, and dorsal root ganglia (Inouye and Murakami, 1975; Leyshon and Morgan, 1991; Magos et al., 1985; Yip and Chang, 1981). As observed in humans, there is a latency period before onset of neurological symptoms. Toxic effects may not be observed or may not show maximal severity until several days after the initiation of dosing. In short-term studies, toxicity may not become evident until after the cessation of dosing. This section summarizes a few selected animal studies on neurotoxicity. For additional detail, please refer to Volume V of the *MSRC* (U.S. EPA, 1997e) and the *Toxicological Effects of Methylmercury* (NRC, 2000).

3.2.2.1 Acute Toxicity

In an acute study, exposure of rats to a single gavage dose of 19.9 mg mercury/kg as methylmercuric chloride resulted in impaired open-field tests such as decreases in standing upright, area traversed, and activity compared with the control group (Post et al., 1973). Animals were lethargic and ataxic initially, but symptoms disappeared within 3 hours.

3.2.2.2 Chronic Toxicity

Longer term, low-level exposures revealed that evidence of neuronal degeneration may be observed before the onset of overt signs of toxicity. Degeneration in the cerebellum was found in rats given 10 mg mercury/kg as methylmercuric chloride once every 3 days for 15 days (Leyshon and Morgan, 1991). Severe degenerative changes in the dorsal root fibers were observed in rats given 1.6 mg mercury/kg-day as methylmercuric chloride for 8 weeks (Yip and Chang, 1981). Munro et al. (1980) observed demyelination of dorsal nerve roots and damage in sciatic nerves with oral exposure to 0.25 mg mercury/kg-day as methylmercuric chloride for up to 26 months. In mice given 1.9 mg mercury/kg-day as methylmercury, cerebellar lesions were observed as early as 8 days after the start of dosing, but changes in motor activity did not develop until after 24 weeks of exposure (MacDonald and Harbison, 1977). Similarly, cats receiving methylmercury in the diet for 11 months displayed degenerative changes

in the cerebellum and cerebral cortex, but uncoordinated movements or weakness were observed only in a small number of animals with histopathological changes (Chang et al., 1974).

A 2-year feeding study of methylmercuric chloride was conducted in B6C3F1 mice (60 mice/sex/group) at doses of 0, 0.4, 2, and 10 ppm (0, 0.03, 0.15, and 0.73 mg mercury/kg-day in males; 0, 0.02, 0.11, and 0.6 mg mercury/kg-day in females) to evaluate chronic toxicity and carcinogenic effects (Mitsumori et al., 1990). Mice were examined clinically during the study, and neurotoxic signs characterized by posterior paralysis were observed in 33 males after 59 weeks and in 3 females after 80 weeks in the 0.6 mg mercury/kg-day group. A marked increase in mortality and a significant decrease in body weight gain were also observed in the high-dose males, beginning at 60 weeks. Postmortem examination revealed toxic encephalopathy consisting of neuronal necrosis of the brain and toxic peripheral sensory neuropathy in both sexes of the high-dose group. An increased incidence of chronic nephropathy was observed in the 0.11- and 0.6-mg mercury/kg-day males.

Groups of Wistar rats (50/sex/group) were administered daily doses of 0.002, 0.02, 0.05, and 0.25 mg mercury/kg-day as methylmercuric chloride for 26 months (Munro et al., 1980). Female rats that received 0.25 mg/kg-day had reduced body weight gains and showed only minimal clinical signs of neurotoxicity. Male rats that received this dose did show overt clinical signs of neurotoxicity, had decreased hemoglobin and hematocrit values and reduced weight gains, and showed increased mortality. Histopathologic examination of rats of both sexes receiving 0.25 mg/kg-day revealed demyelination of dorsal nerve roots and peripheral nerves. Males showed severe kidney damage and females had minimal renal damage. This study identified a NOAEL of 0.05 mg/kg-day and a LOAEL of 0.25 mg/kg-day, based on the observed demyelination effect.

Bornhausen et al. (1980) reported a decrease in operant behavior performance in 4-month-old rats whose dams had received methylmercuric chloride on gestation days 6 to 9. A statistically significant effect was seen in offspring whose dams had received 0.01 and 0.05 mg/kg five times during gestation. The authors postulated that more severe effects of *in utero* exposure would be seen in humans because the biological half-life of mercury in the brain of humans is five times longer than in the rat. In addition, much longer *in utero* exposure to mercury would occur in humans because gestation is much longer.

In a study of prenatal coexposure to metallic mercury vapor and methylmercury and their effects on the developing central nervous system, Fredriksson et al. (1996) reported interactive behavioral effects following exposure of pregnant female Sprague-Dawley rats to methylmercury and metallic mercury

vapor. Between 4 and 5 months, testing of behavioral function, spontaneous motor activity, spatial learning in a circular bath, and instrumental maze learning for food were performed. Exposure to mercury vapor at 1.8 mg/m^3 for 1.5 hours per day on gestation days 14 to 19 was related to hyperactivity and decreased spatial learning. Although exposure to methylmercury at 2 mg/kg per day on gestation days 6 to 9 was not related to adverse behavioral effects, coexposure to methylmercury and mercury vapor potentiated the activity and spatial learning effects observed with mercury vapor alone. The results of this study indicate that mercury vapor causes central nervous system functional disturbances in offspring after both prenatal and postnatal exposure. The authors also suggest that coexposure to methylmercury served to significantly aggravate the changes, whereas methylmercury alone did not cause any significant functional alterations in this study.

Ramussen and Newland (1999) studied the acquisition of Multiple Differential Reinforcement of High-Rate Extinction (MULT DRH-N:T EXT) schedules of reinforcement in female rats exposed to methylmercury during development. Female rats were administered methylmercury (0, 0.5, or 6.4 ppm) in drinking water from 4 weeks premating to postnatal day 16. Postnatal methylmercury concentrations in the brain at birth were 0.49 and 9.8 ppm for two exposure groups. In the MULT DRH-N:T EXT, female offspring were trained to press levers under schedules of reinforcement. Whenever a response occurred within a specific time measured in seconds, a food pellet was given. Two acquisition protocols were examined; one imposed three successive sessions in a 3:1, 5:2, and 9:4 ratio. Values were chosen so that the same rate of response was required by the schedules. The second acquisition protocol required lever repressing as reestablished and the three schedules were continued until the behavior became stable, which required more than 10 sessions. This study was not able to replicate the finding of abnormal response patterns using the DRL paradigm used by Bornhausen (1980).

Cholinergic systems also play an important role in learning and memory. Coccini et al. (2000) investigated the effect of low-level methylmercury exposure on muscarinic cholinergic receptor (mAChR) binding characteristics in adult female Sprague-Dawley rats. The rats (4/dose) were administered methylmercury in the drinking water at nominal concentrations of 0, 2.5, and 10 µg/L for 16 days. Mean daily intake in the methylmercury-exposed groups was 0.45 and 1.8 mg/kg-day, respectively. mAChR binding was assessed using the muscarinic antagonist [^{3}H]quinuclidinyl benzilate (QNB) to label receptors in excised brain tissues (cerebral cortex, hippocampus, and cerebellum). Exposure to methylmercury selectively increased mAChR density in the hippocampus and cerebellum by 20% to 44%. This response was characterized by a 2-week latency period before onset. Receptor affinity was

unaffected, as indicated by values for the dissociation constant. No significant effect on mAChR in cerebral cortex was observed.

Nonhuman Primates—Macaca Fascicularis Monkeys

Monkeys appear to be more sensitive to the neurotoxic effects of methylmercury than are rodents. The primate model is particularly useful for studies of developmental exposures because monkeys, like humans, have relatively prolonged periods of gestation, infancy, and adolescence (Burbacher and Grant, 2000). Long-term studies in primates have shown neurological impairment at doses as low as 0.05 mg mercury/kg-day. Exposure of monkeys to 0.03 mg mercury/kg-day as methylmercury for approximately 4 months caused no detectable changes in motor activity or effects on vision or hearing, but degenerative changes were observed in neurons of the calcarine cortex and sural nerve when these were examined by electron microscopy (Sato and Ikuta, 1975). At higher doses (0.08 mg mercury/kg-day), slight tremor, lack of motor coordination, and blindness were observed in monkeys after 4 months of exposure (Burbacher et al., 1988).

Gunderson et al. (1986) administered daily doses of 0.04–0.06 mg mercury/kg as methylmercuric hydroxide to 11 crab-eating macaques *(Macaca fascicularis)* throughout pregnancy. This dosing protocol resulted in maternal blood levels of 1,080–1,330 µg/L in mothers and 1,410–1,840 µg/L in the offspring. Infants of treated mothers exhibited visual recognition deficits when tested 35 days after birth.

Rice (1989b) dosed five cynomolgus monkeys *(Macaca fascicularis)* with 0.05 mg mercury/kg-day as methylmercuric chloride from birth to 7 years of age. Clinical and neurological examinations were performed during the dosing period and for an additional 6 years. Impairment of spatial visual function was observed after 3 years. In the later stages of the observation period, monkeys dosed with methylmercury were clumsier and slower to react when placed in the exercise cage than were unexposed monkeys. Decreased fine motor performance, touch, and pinprick sensitivity, and impaired high-frequency hearing were observed 6-7 years after cessation of dosing (Rice 1989a; Rice and Gilbert, 1982, 1990).

Rice (1998) did auditory testing of *Macaca fascicularis* monkeys exposed to methylmercury chloride at 10, 25, or 50 ug/kg per day *in utero*, throughout gestation, plus 4 years postnatally at 11 and 19 years of age. Results from this study indicated that at 19 months of age, all five *Macaca fascicularis* monkeys experienced deterioration in auditory function and elevated pure-tone thresholds throughout the

full range of frequencies tested (0.125 to 31.5 kHz) when compared with age-matched controls. The elevation of thresholds was in some cases 50 dB or higher. Because the auditory deficits are experienced approximately 7 to 15 years after cessation of methylmercury exposure, they are considered irreversible and permanent. The author concluded from this study that the high-dose monkeys experience an earlier onset of effect on the auditory function than do low-dose monkeys. The group of monkeys that showed delayed neurotoxicity at 15 years also had visual deficits identified at 3 years, as well as auditory and somatosensory impairment. The high-dose monkeys were also impaired at 11 years, and relatively more impaired than controls at 19 years, thus providing evidence for accelerated aging. These results provide evidence for the accelerated impairment of auditory function during aging as a consequence of developmental methylmercury exposure.

In another study by Rice (1998), monkeys with robust methylmercury-induced deficits in visual, auditory, and somatosensory function were tested on a series of tasks assessing central processing speed. This task is thought to be similar to tests measuring human intelligence. Five *Macaca fascicularis* monkeys were dosed with 50 μg/kg per day methylmercuric chloride from birth until 7 years of age. Blood mercury levels ranged from 0.8 to 1.1 μg/g until cessation of dosing. At 20 years of age, the monkeys and four age-matched and rearing-matched controls were tested on a series of simple and complex reaction-time tasks. In the simple reaction-time test, the monkeys were required to press a button when it changed from off to on (bright red light). The monkeys then performed a sequence of complex reaction-time tasks: two-button pressing, four-button pressing, and several tasks of increasing complexity using four buttons and multiple colors. The results indicated no differences between groups on any aspect of the experiment. The author concluded that the data provide further evidence for the absence of cognitive impairment in monkeys exposed developmentally to methylmercury.

In 1999, Burbacher et al. published a study that assessed visual and auditory functions in adult *Macaca fascicularis* monkeys exposed to methylmercury *in utero*. Maternal doses were 0, 50, 70, or 90 μg/kg per day; this resulted in infant blood mercury levels that ranged from 1.04 to 2.45 ppm. When the monkeys reached 15 years of age, they were tested on spatial visual contrast sensitivity tasks at spatial frequencies of 1, 4, 10, and 20 cycles per degree of visual angle and auditory pure tone detection tasks at frequencies of 125, 500, 1,000, 4,000, 10,000, 25,000, and 31,500 Hz. The results of these tests indicated that *in utero* exposure to methylmercury has long-term effects on visual contrast sensitivity thresholds. Preliminary results from the auditory task suggest that auditory thresholds are not affected by methylmercury exposure. The authors suggest that results from this study point to the postnatal period as a possible critical window for methylmercury induced auditory neurotoxicity.

3.3 CARDIOVASCULAR TOXICITY

3.3.1 Human Studies

3.3.1.1 Cardiovascular Effects From the Faroe Islands (Sorensen et al., 1999)

Sørensen et al. (1999) evaluated the relationship between prenatal exposure to methylmercury and occurrence of cardiovascular effects at 7 years of age in a birth cohort (n = 1,000) of children from the Faroe Islands. Prenatal exposure was assessed by analysis of cord blood and maternal hair collected at parturition. More than 80% of the hair samples exceeded a methylmercury concentration of 2 ppm, which corresponded to a cord blood concentration of approximately 10 μg/L. The cardiovascular endpoints evaluated at 7 years included systolic and diastolic blood pressure, heart rate, and heart rate variability. Weight, height, body mass index, sex, and maternal hypertension were examined as predictors of blood pressure and heart rate in approximately 900 children. Birth weight and placental weight were also examined as predictors of blood pressure. Following adjustment for body weight, diastolic and systolic blood pressure increased by 13.9 mm mercury (95% confidence limits [CL] = 7.4, 20.4) and 14.6 mm mercury (95% CL = 8.3, 20.8), respectively, as cord blood mercury concentrations increased from 1 to 10 μg/L. No further increase was noted at higher concentrations of mercury. Low-birth-weight children were more likely to experience methylmercury-related increase in blood pressure. A gender-specific decrease in heart rate variability was also noted with increasing mercury exposure. This effect was most pronounced in boys, where a 47% reduction in heart rate variability was observed when cord blood mercury concentrations increased from 1 to 10 μg. The authors concluded that the findings suggest that prenatal exposure to methylmercury may influence the development of cardiovascular regulatory mechanisms.

3.3.1.2 Cross-Sectional Study (Salonen et al., 1995)

Salonen et al. (1995) examined the relationship between dietary intake of fish and mercury and risk of acute myocardial infarction (AMI), death from coronary heart disease (CHD), and other cardiovascular diseases (CVD). Participants of this study included 1,833 men in eastern Finland between the ages of 42 and 60 with no clinically diagnosed CHD, claudication, stroke, or cancer. Baseline examinations were administered between March 1984 and December 1989. Fish consumption was assessed at time of blood sampling with an interview-verified 4-day food record. The food recording was repeated approximately 12 months after the baseline examination in a random sample of 50 men in the

cohort. Daily fish intake ranged from 0 to 619.2 g (mean of 46.5 g/day). Mercury in hair and urine was determined by flow injection analysis-cold vapor atomic absorption spectrometry and amalgamation. Hair mercury concentrations ranged from 0 to 15.67 ppm (mean of 1.92 ppm) while dietary mercury intake ranged from 1.1 to 95.3 μg /day (mean of 7.6 μg per day). In 2 to 7 years, 73 of the 1,833 men experienced an AMI; 18 of the 73 patients with AMI died of CHD, while 24 of the 73 died of CVD. Covariates included these: age; examination year; family history of CHD; place of residence (rural vs. urban); diabetes; socioeconomic status; iron intake; number of cigarettes, cigars, and pipefuls of tobacco currently smoked daily; duration of regular smoking in years; alcohol consumption; history of myocardial infarction; angina pectoris and other ischemic heart disease; presence of hypertension; and current antihypertensive medication. The Cox models reported dietary intakes of fish and mercury associated with increased risk of AMI and death from CHD, CVD, and any death. Results from this study indicated that eastern Finnish men with hair mercury levels exceeding 2 ppm had a twofold age- and CHD-adjusted risk of AMI and a 2.9-fold adjusted risk of cardiovascular death compared with those having lower hair mercury content.

3.3.1.3 Nested Case-Control Study (Salonen et al., 1995)

A nested case-control study was also conducted using a subsample of the original study participants. Serum immune complexes containing oxidized LDL were measured in a subsample of 187 control subjects using an ELISA assay with copper-oxidized LDL as the antigen. Pearson correlation coefficients adjusted for age and year of baseline examination were used to determine the association between hair mercury content and dietary intakes of fish and mercury. Partial associations of hair and urinary mercury with titers of immune complexes against oxidized LDL were estimated by SPSS step-up least-squares regression analysis. A multivariate logistic model included the following covariates: cigarette-years, serum ferritin concentration, ischemic exercise ECG, serum apolipoprotein, family history of CHD, maximal oxygen uptake, and serum HDL2 cholesterol. There was a statistically significant association between urinary mercury excretion and the risk of AMI was reported. For each microgram of mercury excreted daily, the risk of AMI increased by 36%. From the immunotoxicity test, both the hair and urinary excretion mercury levels were associated with immune complex titers measured with a rabbit antiserum against oxidized LDL and the γ-globulin fraction of a rabbit antiserum against oxidized LDL. Overall, hair mercury was the strongest predictor of both immune complex titers.

On the basis of these data, the authors concluded that a high intake of mercury from nonfatty freshwater fish, and the consequent excess risk of AMI as well as death from CHD and CVD in eastern Finnish men, may be due to the promotion of lipid peroxidation by mercury.

3.3.2 Animal Studies

Data on cardiovascular effects following oral methylmercury exposure were obtained from two studies in rats. Rats given two daily doses of methylmercuric chloride exhibited decreases in heart rates following two daily doses of methylmercury at 12 mg/kg per day (Arito and Takahashi, 1991). Wistar rats (n = 80) treated by subcutaneous injection with 0.5 mg/kg-day methylmercuric chloride for 1 month had increased systolic blood pressures beginning 42 days after cessation of dosing (Wakita, 1987). This effect persisted for more than a year.

Mitsumori et al. (1983, 1984) fed Sprague-Dawley rats diets containing methylmercuric chloride (males 0, 0.011, 0.05, or 0.28 mg/kg/day; females 0.014, 0.064, or 0.34 mg/kg/day) for up to 130 weeks. Polyarteritis nodosa and calcification of the arterial wall were seen at the highest dose. Histological examination revealed evidence of hemosiderosis and extramedullary hemotopoiesis of the spleen.

In a study on 7-week-old, hypertensive SHR/NCrj rats, Tamashiro et al. (1986) reported an increase in blood pressure resulting from exposure to methylmercury chloride once a day at 2 mg/kg/day for 26 consecutive days. Body weight loss, an early sign of methylmercury intoxication, was more marked in males than females. All male rats died by the 29th day posttreatment. Neurological signs, hindleg crossing, disturbed righting movement and abnormal gait always preceded death. No mortality was reported for the female rats. However, increase in blood pressure was sex-specific, being observed only in females. The authors noted that considerable variation was observed in blood pressure for both the methylmercury-exposed and the control rats; and that these findings suggest strain differences in male-female toxicity of methylmercury chloride.

3.4 IMMUNOTOXICITY

3.4.1 Human Studies

At this time, there are no studies published on the effect of methylmercury on the human immune system. In occupational exposure studies, elemental mercury has been found to affect particular immune

parameters. A study by Queiroz and Dantas (1997) evaluated B-lymphocyte, T-helper, T-suppressor, and T-cell proliferative response to phytohemagglutinin in 33 male workers in a Brazilian mercury production facility. These workers had a mean age of 29 and a mean mercury exposure period of 19 months. All of the workers had urinary mercury concentrations below 50 µg/g of creatinine. Analysis of the T-cell populations found a reverse CD4+ to CD8+ ratio that was characterized by a reduction in the number of CD4 lymphocytes. B-lymphocytes were also significantly reduced. Analysis of serum antibody levels found increased immunoglobulin E levels but did not detect anti-DNA or anti-nucleolar antibodies. No changes were observed in the proliferative response to phytohemagglutinin of lymphocytes from exposed individuals. The authors reported a negative correlation between the length of exposure to mercury and IgE levels, and no correlations between lymphocyte changes and urinary mercury concentrations, time of exposure, or the age of the workers. (Queriroz and Dantas, 1997)

Another occupational exposure study by Moszczynski et al. (1995) examined the lymphocyte subpopulation of T-cells, T-helper cells, T-suppressor cells, and natural killer cells in the peripheral blood of 81 men exposed to metallic mercury vapors and 36 unexposed men. The average workplace exposure to mercury in air was 0.0028 mg/m^3. Urinary mercury concentrations ranged from 0 to 240 µg/L and concentrations in the blood varied from 0 to 30 µg/L. Stimulation of the T-lymphocytes manifested by an increased number of T-cells, T-helper cells, and T-suppressor cells was observed.

3.4.2 Animal Studies

Data on the potential immunotoxic effects of methylmercury are available from several animal studies. Suppression of humoral and cellular immune responses has been observed in animals after oral exposure to methylmercury or methylmercuric chloride. Decreases in the production of antibody-producing cells and/or decreased antibody titer following inoculation with immune-stimulating agents (such as sheep red blood cells) have been observed in mice and rabbits (Blakley et al., 1980; Koller et al., 1977; Ohi et al., 1976). Decreases in natural killer T-cell activity and reduced thymus weight have been observed in female mice after 14 weeks of exposure to methylmercury (Ilback, 1991). Bernaudin et al. (1981) observed IgG deposits along the glomerular capillary wall of Brown Norway rats treated with methylmercury for 2 months and noted that these deposits were suggestive of autoimmune disease. The following sections include summaries of selected studies.

Wild et al. (1997) evaluated immune function in the offspring of Sprague-Dawley rats exposed to methylmercuric chloride (5 or 500 µg/L) or methylmercury sulfide (5 µg/L) via drinking water. There

were three exposed groups and one control group. The control group was fed plain tap water. Rats of both sexes were treated for 8 weeks prior to mating and treatment of female rats continued throughout pregnancy and nursing. The total duration of indirect exposure of the offspring to methylmercury was 42 days. Immunological function was assessed in six offspring per treatment group at 6 and 12 weeks of age (3 and 9 weeks after termination of methylmercury exposure at weaning, respectively). At 6 weeks, total body weights, splenic weights, and thymic weights were increased in the methylmercury chloride-exposed rats, whereas the rats exposed to methylmercury sulfide experienced only an increase in thymic weight at 6 weeks. At 12 weeks, natural killer cell activity was markedly depressed (56%) for rats exposed to methylmercury chloride in comparison with controls. Methylmercury sulfide appeared to have different effects on the immune system than did methylmercury chloride. For example, the sulfide form affected only thymic weight and had no significant effect on NK or splenocyte cell activity or splenocyte LPR. Whether this result reflects differential distribution of the sulfide form or affinity for different targets in the immune system is unknown. The authors concluded that methylmercury chloride seems to have an effect on splenocytes and natural killer cell activity.

Inorganic mercury has been observed to induce a variety of immune effects in mice. However, until recently there has been limited investigation of the ability of methylmercury to induce similar immune responses. Hultman and Hansson-Georgiadis (1999) investigated the ability of subcutaneously injected methylmercury to induce systemic autoimmunity in five genetically susceptible and resistant strains of mice. Female SJN/L, A.SW, B10.S (H-2^s), BALB/C, DBA/2 (H-2^d), A.TL, and B10.TL (H-2^u) mice were administered subcutaneous injections of 1 mg/kg methylmercury every third day for 4 weeks. This treatment protocol resulted in an average daily dose of approximately 350 µg mercury/kg-day. The immune response to methylmercury differed qualitatively and quantitatively from the response to inorganic mercury. Treatment with methylmercury induced at most a small increase in serum Ig concentrations after 4 weeks of treatment. The observed increases during the treatment period were generally marginal when compared with increases induced by mercuric chloride. Treatment with methylmercury induced development of antinucleolar antibodies (ANoA) targeting the nucleolar protein fibrillarin in the susceptible SJL, A.SW, and B10.S strains. Susceptibility to development of ANoA was linked to the mouse major histocompatibility complex H-2. However, background genes determined the strength of the response in susceptible strains. Serum IgE concentration and ANoA titer increased 2 to 3 weeks after cessation of treatment with methylmercury. In H-2^s mice, methylmercury induced a weaker general (polyclonal) and specific (ANoA) response when compared to mercuric chloride. Unlike mercuric chloride-treated mice, animals administered methylmercury did not develop systemic or renal immune system deposits.

3.5 REPRODUCTIVE TOXICITY

3.5.1 Human Studies

There are no studies of reproductive deficits in humans exposed to low-dose methylmercury.

3.5.2 Animal Studies

There are no two-generation reproductive assays for methylmercury.

3.6 GENOTOXICITY

3.6.1 Human Studies

Data from several studies in humans suggest that ingesting methylmercury may cause chromosomal aberrations and sister chromatid exchanges (SCE) (Skerfving et al., 1970; Wulf et al., 1986; Franchi et al., 1994).

A study of nine Swedish subjects who consumed mercury-contaminated fish and four controls showed a statistically significant rank correlation between blood mercury and percentage of lymphocytes with chromosome breaks (Skerfving et al., 1970). An extension of this study (Skerfving et al. 1974) included 23 exposed (5 females and 18 males) and 16 controls (3 females and 13 males). The authors reported significant correlations between blood mercury level and frequency of chromatid changes and "unstable" chromosome aberrations; there was no correlation with "stable" chromosome aberrations.

The Wulf et al. (1986) study was of 92 Greenlander Eskimos. Subjects were divided into three groups based on intake of seal meat (six times per week; two to five times per week, once a week, or no consumption of seal meat). Higher frequency of SCE in lymphocytes was correlated with blood mercury concentration; an increase of 10 μg mercury per liter of blood was associated with an increase of 0.3 SCE/cell. Positive correlations were also found for smoking, diet, living district, and cadmium exposure.

Franchi et al. (1994) evaluated formation of micronuclei in peripheral blood lymphocytes of Mediterranean fishers, a group with presumed high exposure to methylmercury. Fifty-one subjects were

interviewed on age, number of seafood-based meals/week, and habits such as smoking and alcohol consumption. Total blood mercury was measured; the range was 10.08-304.11 ng/g with a mean of 88.97 ± 54.09 ng/g. There was a statistically significant correlation between blood mercury concentration and micronucleus frequency and between age and micronucleus frequency (U.S. EPA, 1997e)

3.6.2 Animal Studies

In a study with cats (Charbonneau et al. 1976), methylmercury did not induce dose-related unscheduled DNA synthesis in lymphocytes or chromosomal aberrations in bone marrow cells after oral exposure for up to 39 months (Miller et al., 1979). Statistically significant decreases in unscheduled DNA synthesis and increases in chromosomal aberrations were observed, but there was no dose-response.

Strain-specific differences exist with respect to the ability of methylmercury to produce dominant lethal effects in mice (Suter, 1975). When (SEC × $C57B_1$)F_1 males were injected with 10 mg/kg methylmercury hydroxide, there was a slight reduction in the total number of implantations and a decrease in the number of viable embryos. This was not observed when (101 × C3H)F_1 males were exposed in a similar fashion. When female (10 × C3H)F_1 mice were treated with methylmercuric hydroxide, no increase in the incidence of dead implants was observed (unlike the case for mercuric chloride). Changes in chromosome number, but no increase in chromosome aberrations, were observed in oocytes of Syrian hamsters treated with one interperitoneal injection of 10 mg/kg methylmercuric chloride (Mailhes, 1983). Methylmercury was administered subcutaneously to golden hamsters at doses of 6.4 mg or 12.8 mg mercury/kg/body weight. Polyploidy and chromosomal aberrations were increased in bone marrow cells, but there was no effect on metaphase II oocytes. There was an inhibitory effect on ovulation, which the authors noted was not as severe as that induced by mercuric chloride in the same study (Watanabe et al., 1982). Nondysjunction and sex-linked recessive lethal mutations were seen in *Drosophila melanogaster* treated with methylmercury in the diet (Ramel, 1972).

As reviewed in WHO (1990), methylmercury is not a point mutagen but is capable of causing chromosome damage in a variety of systems. In vitro studies have generally shown clastogenic activity but only weak mutagenic activity. Methylmercuric chloride and dimethylmercury were both shown to induce chromosome aberrations and aneuploidy in primary cultures in human lymphocytes; methylmercuric chloride was the more potent clastogen at equally toxic doses (Betti et al., 1992). Both methylmercury and mercuric chloride induce a dose-dependent increase in SCE in primary human

lymphocytes and muntjac fibroblasts; methylmercury was about five times more effective in this regard (Verschaeve et al., 1984; Morimoto et al., 1982).

Methylmercury has been shown to inhibit nucleolus organizing activity in human lymphocytes (Verschaeve et al., 1983). Methylmercury can induce histone perturbation and has been reported to interfere with gene expression in cultures of glioma cells (WHO, 1990). Impaired growth and development was noted in cultured mouse embryonic tissue treated in vitro with methylmercuric chloride, but there was no increase in SCE (Matsumoto and Spindle, 1982). Costa et al. (1991) showed that methylmercuric chloride caused DNA strand breaks in both V79 and rat glioblastoma cells treated in vitro. Methylmercuric chloride produced more strand breaks than did mercuric chloride.

Evidence of DNA damage has been observed in the *Bacillus subtilis* rec-assay (Kanematsu et al., 1980). These authors reported negative results for methylmercury in spot tests for mutagenicity in the following bacterial strains: *E. coli* B/r WP2 and WP2; and *Salmonella typhimurium* strains TA1535, TA1537, TA1538, TA98, and TA100. Jenssen and Ramel (1980) indicated in a review article that methylmercury acetate was negative in both micronucleus assays and mutagenicity tests in Salmonella; the article referred to Heddle and Bruce (1977) and provided no experimental details. Weak mutagenic responses for methylmercuric chloride and methoxyethyl mercury chloride were observed in Chinese hamster V79 cells at doses near the cytotoxic threshold (Fiskesjo, 1979), and methylmercury produced a slight increase in the frequency of chromosomal nondysjunction in *Saccharomyces cerevisiae* (Nakai and Machida, 1973). Methylmercury, however, caused neither gene mutations nor recombination in *S. cerevisiae* (Nakai and Machida, 1973). Methylmercury retarded DNA synthesis and produced single-strand breaks in DNA in L5178Y cells (Nakazawa et al., 1975).

3.7 CARCINOGENICITY

3.7.1 Human Studies

At this time, no human studies have reported an association between methylmercury exposure and overall cancer rates. Three studies were identified that examined the relationship between methylmercury exposure and cancer. No persuasive evidence of increased carcinogenicity attributable to methylmercury exposure was observed in any of the studies. Interpretation of these studies, however, was limited by poor study design and incomplete descriptions of methodology and/or results.

3.7.2 Animal Studies

The results from three dietary studies in two strains of mice indicate that methylmercury is carcinogenic. Interpretation of two of the positive studies was complicated by observation of tumors only at doses that exceeded the Maximum Tolerated Dose (MTD). Therefore, only one positive animal study is appropriate for consideration. A fourth dietary study in mice, three dietary studies in rats, and a dietary study in cats failed to show carcinogenicity of methylmercury. Interpretation of four nonpositive studies was limited because of deficiencies in study design or failure to achieve an MTD.

Methylmercuric chloride was administered in the diet at levels of 0, 0.4, 2, or 10 ppm (0, 0.03, 0.14, and 0.69 mg Hg/kg-day in males and 0, 0.03, 0.13, and 0.60 mg Hg/kg-day in females) to B6C3F1 mice (60/sex/group) for 104 weeks (Mitsumori et al., 1990). In high-dose males, a marked increase in mortality was observed after 60 weeks (data were presented graphically; statistical analyses not performed). Survival at study termination was approximately 50%, 60%, 60%, and 20% in control, low-, mid-, and high-dose males, respectively, and 58%, 68%, 60%, and 60% in control, low-, mid-, and high-dose females, respectively. The cause of the high mortality was not reported. At study termination, the mean body weight in high-dose males was approximately 67% of controls and in high-dose females was approximately 90% of controls (data presented graphically; statistical analyses not performed). Focal hyperplasia of the renal tubules was significantly ($p<0.01$) increased in high-dose males (14/60; the incidence was 0/60 in all other groups). The incidence of renal epithelial carcinomas (classified as solid or cystic papillary type) was significantly ($p<0.01$) increased in high-dose males (13/60; the incidence was 0/60 in all other groups). The incidence of renal adenomas (classified as solid or tubular type) was also significantly ($p<0.05$) increased in high-dose males; the incidence was 0/60, 0/60, 1/60, and 5/60 in control, low-, mid-, and high-dose males, respectively, and 0/60, 0/60, 0/60, and 1/60 in control, low-, mid-, and high-dose females, respectively. No metastases were seen in the animals. The incidences of a variety of nonneoplastic lesions were increased in the high-dose rats including these: sensory neuropathy, neuronal necrosis in the cerebrum, neuronal degeneration in the cerebellum, and chronic nephropathy of the kidney. Males exhibited tubular atrophy of the testis (1/60, 5/60, 2/60, and 54/60 in control, low-, mid-, and high-dose, respectively) and ulceration of the glandular stomach (1/60, 1/60, 0/60, and 7/60 in control, low-, mid-, and high-dose males, respectively). An MTD was achieved in middose males and high-dose females. High mortality in high-dose males indicated that the MTD was exceeded in this group.

Mitsumori et al. (1981) administered 0, 15, or 30 ppm of methylmercuric chloride (99.3% pure) in the diet (0, 1.6 and 3.1 mg Hg/kg-day) to ICR mice (60/sex/group) for 78 weeks. Interim sacrifices of up to 6/sex/group were conducted at weeks 26 and 52. Kidneys were microscopically examined from all animals that died or became moribund after week 53 or were killed at study termination. Lungs from mice with renal masses and renal lymph nodes showing gross abnormalities were also examined. Survival was decreased in a dose-related manner; at week 78 survival was 24/60, 6/60, and 0/60 in control, low-, and high-dose males, respectively, and 33/60, 18/60, and 0/60, in control, low-, and high-dose females, respectively (statistical analyses not performed). The majority of high-dose mice (51/60 males and 59/60 females) died by week 26 of the study. Examination of the kidneys of mice that died or were sacrificed after 53 weeks showed a significant ($p<0.001$) increase in renal tumors in low-dose males (13/16 versus 1/37 in controls). The incidence of renal epithelial adenocarcinomas in control and low-dose males was 0/37 and 11/16, respectively ($p<0.001$). The incidence of renal epithelial adenomas in control and low-dose males was 1/37 and 5/16, respectively ($p<0.01$). No renal tumors were observed in females in any group. No metastases to the lung or renal lymph nodes were observed. Evidence of neurotoxicity and renal pathology was observed in the treated mice at both dose levels. The high mortality in both groups of treated males and in high-dose females indicated that the MTD was exceeded in these groups.

A followup study to the Mitsumori et al. (1981) study was reported by Hirano et al. (1986). Methylmercuric chloride was administered in the diet to ICR mice (60/sex/group) at levels of 0, 0.4, 2, or 10 ppm (0, 0.03, 0.15, and 0.73 mg Hg/kg-day in males and 0, 0.02, 0.11, and 0.6 mg Hg/kg-day in females) for 104 weeks. Interim sacrifices (6/sex/group) were conducted at 26, 52, and 78 weeks. Complete histopathological examinations were performed on all animals found dead, killed *in extremis*, or killed by design. Mortality, group mean body weights and food consumption were comparable to controls. The first renal tumor was observed at 58 weeks in a high-dose male, and the incidence of renal epithelial tumors (adenomas or adenocarcinomas) was significantly increased in high-dose males (1/32, 0/25, 0/29, and 13/26 in the control, low-, mid-, and high-dose groups, respectively). Ten of the 13 tumors in high-dose males were adenocarcinomas. These tumors were described as solid type or cystic papillary types of adenocarcinomas. No invading proliferation into the surrounding tissues was seen. The incidence of renal epithelial adenomas was not significantly increased in males, and no renal adenomas or adenocarcinomas were observed in any females. Focal hyperplasia of the tubular epithelium was reported to be increased in high-dose males (13/59; other incidences not reported). Increases in nonneoplastic lesions in high-dose animals provided evidence that an MTD was exceeded. Nonneoplastic lesions reported as increased in treated males included the following: epithelial

degeneration of the renal proximal tubules; cystic kidney; urinary cast and pelvic dilatation; and decreased spermatogenesis. Epithelial degeneration of the renal proximal tubules and degeneration or fibrosis of the sciatic nerve were reported in high-dose females.

No increase in tumor incidence was observed in a study using white Swiss mice (Schroeder and Mitchener 1975). Groups of mice (54/sex/group) were exposed from weaning until death to methylmercuric acetate in the drinking water at two doses. The low-dose group received 1 ppm methylmercuric acetate (0.19 mg Hg/kg-day). The high-dose group received 5 ppm methylmercuric acetate (0.95 mg Hg/kg-day) for the first 70 days and then 1 ppm, thereafter, due to high mortality (21/54 males and 23/54 females died prior to the dose reduction). Survival among the remaining mice was not significantly different from controls. Significant ($p<0.001$) reductions in body weight were reported in high-dose males (9–15% lower than controls) and high-dose females (15–22% lower than controls) between 2 and 6 months of age. Mice were weighed, dissected, gross tumors were detected, and some sections were made of heart, lung, liver, kidney, and spleen for microscopic examination. No increase in tumor incidence was observed. This study is limited because complete histological examinations were not performed, and pathology data other than tumor incidence were not reported.

Mitsumori et al. (1983, 1984) conducted a study in Sprague-Dawley rats. They administered diets containing 0, 0.4, 2, or 10 ppm of methylmercuric chloride (0, 0.011, 0.05, and 0.28 mg Hg/kg-day in males; 0, 0.014, 0.064, and 0.34 mg Hg/kg-day in females) to Sprague-Dawley rats (56 animals/sex/group) for up to 130 weeks. Interim sacrifices of 10/group (either sex) were conducted at weeks 13 and 26 and of 6/group (either sex) at weeks 52 and 78. Mortality was increased in high-dose males and females. At week 104, survival was approximately 55%, 45%, 75%, and 10% in control, low-, mid-, and high-dose males, respectively, and 70%, 75%, 75%, and 30% in control, low-, mid-, and high-dose females, respectively (data presented graphically). Body weight gain was decreased in high-dose animals (approximately 20–30%; data presented graphically). No increase in tumor incidence was observed in either males or females. Noncarcinogenic lesions that were significantly increased ($p< 0.05$) in high-dose rats included the following: degeneration in peripheral nerves and the spinal cord (both sexes); degeneration of the proximal tubular epithelium of the kidney (both sexes); severe chronic nephropathy (females); parathyroid hyperplasia (both sexes); polyarteritis nodosa and calcification of the abdominal arterial wall (females); bone fibrosis (females); bile duct hyperplasia (males); and hemosiderosis and extramedullary hematopoiesis in the spleen (males). In addition, mid-dose males exhibited significantly increased degeneration of the kidney proximal tubular epithelium and hyperplasia

of the parathyroid. An MTD was achieved in mid-dose males and in high-dose females; the MTD was exceeded in high-dose males.

No increase in tumor incidence or decrease in tumor latency was observed in another study using rats (strain not specified) (Verschuuren et al., 1976). Groups of 25 female and 25 male rats were administered methylmercuric chloride at dietary levels of 0, 0.1, 0.5, and 2.5 ppm (0, 0.004, 0.02, and 0.1 mg Hg/kg-day) for 2 years. No significant effects were observed on growth or food intake except for a 6% decrease (statistically significant) in body weight gain at 60 weeks in high-dose females. Survival was 72%, 68%, 48%, and 48% in control, low-, mid- and high-dose males, respectively; and 76%, 60%, 64%, and 56% in control, low-, mid- and high-dose females, respectively (statistical significance not reported). Increases in relative kidney weights were observed in both males and females at the highest dose. No effects on the nature or incidence of pathological lesions were observed, and tumors were reported to have been observed with comparable incidence and latency among all of the groups. This study was limited by the small sample size and failure to achieve an MTD.

No tumor data were reported in a study using Wistar rats (Munro, 1980). Groups of 50 Wistar rats/sex/dose were fed diets containing methylmercury; doses of 2, 10, 50, and 250 micrograms Hg/kg-day were fed for 26 months. High-dose female rats exhibited reduced body weight gains and showed minimal clinical signs of neurotoxicity; however, high-dose male rats showed overt clinical signs of neurotoxicity, decreased hemoglobin and hematocrit values, reduced weight gains and significantly increased mortality. Histopathologic examination of the high-dose rats of both sexes revealed demyelination of dorsal nerve roots and peripheral nerves. Males showed severe dose-related kidney damage, and females had minimal renal damage.

No increase in tumor incidence was observed in a multiple generation reproduction study using Sprague-Dawley rats (Newberne et al., 1972). Groups of rats (30/sex) were given semisynthetic diets supplemented with either casein or a fish protein concentrate to yield dietary levels of 0.2 ppm methylmercury (0.008 mg Hg/kg-day). Another group of controls received untreated rat chow. Rats that received diets containing methylmercury during the 2-year study had body weights and hematology comparable to controls. Detailed histopathologic analyses revealed no lesions of the brain, liver, or kidney that were attributable to the methylmercury exposure. Mortality data were not presented. Interpretation of these data is limited by the somewhat small group sizes and failure to achieve an MTD.

No increase in tumor incidence was observed in a study using random-bred domestic cats (Charbonneau et al., 1976). Groups of cats (4–5/sex/group) were given doses of 0.0084, 0.020, 0.046, 0.074 or 0.176 mg Hg/kg-day either as methylmercury-contaminated seafood or as methylmercuric chloride in the diet for up to 2 years. Controls were estimated to have received 0.003 mg Hg/kg-day. Food consumption and body weight were not affected by treatment with methylmercury. Due to advanced signs of neurotoxicity (loss of balance, ataxia, impaired gait, impaired reflexes, weakness, impaired sensory function, mood change and tremor), cats at the highest dose tested were sacrificed after approximately 16 weeks, and cats at the next highest dose were sacrificed after approximately 54–57 weeks. Cats at the next highest dose generally exhibited mild neurological impairment (altered hopping reaction and hypalgesia). One cat at this dose was sacrificed after 38 weeks because of neurotoxicity, and one cat died of acute renal failure after 68 weeks. Cats at the two highest doses had pathological changes in the brain and spinal cord, but no histopathological changes were noted in other tissues examined. Interpretation of the results of this study is limited because of the small group sizes, early sacrifice of cats at the two highest dose levels and no available data regarding pathological changes in cats at the three lowest dose levels. This study was also limited by its short duration when compared to the lifespan of a cat.

Blakley (1984) administered methylmercuric chloride to female Swiss mice (number/group not specified) in drinking water at concentrations of 0, 0.2, 0.5 or 2.0 mg/L for 15 weeks. This corresponded to approximately 0, 0.03, 0.07 and 0.27 mg Hg/kg-day. At the end of week 3, a single dose of 1.5 mg/kg of urethane was administered intraperitoneally to 16–20 mice/group. No effects on weight gain or food consumption were observed. Lung tumor incidence in mice not administered urethane (number/group not specified) was less than 1 tumor/mouse in all groups. Statistically significant trends for increases in the number and size of lung adenomas/mouse with increasing methylmercury dose were observed; the tumor number/mouse was 21.5, 19.4, 19.4, and 33.1 in control, low-, mid- and high-dose mice, respectively, and the tumor size/mouse was 0.70, 0.73, 0.76 and 0.76 mm in control, low-, mid- and high-dose mice, respectively. The study authors suggest that the increase in tumor number and size may have been related to immunosuppressive activity of methylmercury. It should be noted that this is considered a short-term assay and that only pulmonary adenomas were evaluated.

4.0 RISK ASSESSMENT FOR METHYLMERCURY

4.1 BACKGROUND

Methylmercury is highly toxic to mammalian species and causes a variety of adverse effects. It is a developmental toxicant in humans and animals. It causes chromosomal effects but does not induce point mutations. The *Mercury Study Report to Congress* (MSRC) (U.S. EPA, 1997) concluded that because there are data for mammalian germ-cell chromosome aberration and limited data from a heritable mutation study, methylmercury is placed in a group of high concern for potential human germ-cell mutagenicity. There is no two-generation study of reproductive effects, but shorter term studies in rodents, guinea pigs, and monkeys have reported observations consistent with reproductive deficits. There are no data to indicate that methylmercury is carcinogenic in humans, and it induces tumors in animals only at highly toxic doses. Application of the revised Guidelines for Cancer Risk Assessment leads to a judgment that methylmercury is not likely to be carcinogenic for humans under conditions of exposure generally encountered in the environment.

The quantitative health risk assessment for a noncarcinogen is the reference dose (RfD). This is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious health effects during a lifetime.

EPA has published two RfDs for methylmercury that represented the Agency consensus at that time. The original RfD of 0.3 μg/kg/day was determined in 1985. The current RfD of 0.1 μg/kg/day was established as the Agency consensus estimate in 1995. While EPA was developing the MSRC (U.S. EPA, 1997), it became apparent that considerable new data on the health effects of methylmercury in humans were emerging. Among these data sources were large studies of seafood-consuming populations in the Seychelles and Faroe Islands. Smaller scale studies were being reported on effects in populations around the U.S. Great Lakes and in the Amazon basin. Publications also included novel statistical approaches and applications of physiologically based pharmacokinetic (PBPK) models.

In 1997 the MSRC was undergoing final review; at that time many of the new data had either not been published in the peer-reviewed press or not been subjected to rigorous review. EPA decided that it was premature to make a change in the 1995 methylmercury RfD for the MSRC. This decision was in accordance with the advice of the Science Advisory Board (SAB). Since 1997 the field of

methylmercury toxicology and assessment has expanded dramatically. This criteria document presents a revised RfD that considers data from the human studies published in the 1990s, recent evaluations of health and pharmacokinetic data, and recent statistical and modeling approaches to assessing those data.

The following sections include brief descriptions of the previously published EPA RfDs as well as descriptions of some of the evaluation processes that took place at the end of the 1990s.

For this document the following definitions apply. These reflect usage in the National Research Council publication *Toxicological Effects of Methylmercury* (NRC, 2000) (see Section 1.5).

NOAEL No-observed-adverse-effect level. An exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects in a comparison between an exposed population and a control group. Effects may be seen at this level of exposure, but they are not considered to be adverse. For risk assessment the NOAEL is generally the highest level at which no adverse effects are seen.

LOAEL Lowest-observed-adverse-effect level. The lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects in a comparison between an exposed population and a control group.

BMD Benchmark dose. In common parlance this term refers to a quantitative assessment for noncancer health effects that uses a curve-fitting procedure to determine a level functionally equivalent to a NOAEL. In this chapter, BMD will be used to mean an estimated dose that corresponds to a specified risk above the background risk.

BMDL Benchmark dose lower limit, a statistical lower limit on a calculated BMD. In this document that will be the 95% lower confidence limit. The BMDL will be used as the starting point for the calculation of the methylmercury RfD.

4.1.1 Other RfDs Published by EPA

Two RfDs based on human studies have been published as consensus values for EPA. In addition, the MSRC (EPA, 1997) describes an RfD that could be estimated from animal data.

4.1.1.1 1985 RfD

A hazard identification and dose-response assessment was proposed for methylmercury in 1980 (U.S. EPA, 1980). This assessment was reviewed and consensus was achieved by the EPA RfD/RfC (reference concentration) Work Group on December 2, 1985. This RfD was published on EPA's Integrated Risk Information System (IRIS) in 1986. The critical effects were multiple central nervous system (CNS) effects, including ataxia and paresthesia in populations of humans exposed to methylmercury through consumption of contaminated grain (summarized by Clarkson et al., 1976; Nordberg and Strangert, 1976; and WHO, 1976).

The RfD for methylmercury was determined to be 3×10^{-4} mg/kg-day (0.3 µg/kg/day), based on a LOAEL of 0.003 mg/kg-day (corresponding to 200 µg/L blood concentration) and an uncertainty factor of 10 to adjust the LOAEL to what is expected to be a NOAEL. An additional uncertainty factor (UF) of 10 for sensitive individuals for chronic exposure was not deemed necessary, as the adverse effects were seen in what was regarded as a sensitive group of individuals: adults who consumed methylmercury-contaminated grain.

The RfD/RfC Work Group ascribed medium confidence to the choice of study, the database, and the RfD. The blood levels associated with the LOAEL were well supported by more recent data, but neither the chosen studies nor supporting database described a NOAEL. Medium confidence generally indicates that new data may change the assessment of the RfD.

4.1.1.2 1995 RfD

After publication of the RfD of 0.3 µg/kg/day, questions were raised as to its validity; some of these questions were in formal submissions requesting a change on the IRIS entry. In particular it was asked whether the RfD based on effects in exposed adults was protective against developmental effects. Subsequent to the RfD publication, the effects in Iraqi children of *in utero* exposure to methylmercury were reported by Marsh et al. (1987). The RfD/RfC Work Group discussed the methylmercury RfD in 1992 and again in 1994. Consensus on a revised RfD was reached in January 1995. Detailed description of the RfD derivation can be found in Volume V of the MSRC (U.S. EPA, 1997e).

Marsh et al. (1987) was chosen as the most appropriate study for determination of an RfD protective of a putative sensitive subpopulation, namely infants born to mothers exposed to

methylmercury during gestation. The data collected by Marsh et al. (1987) summarize clinical neurologic signs of 81 mother-and-child pairs. Maternal hair mercury concentrations were collected as the exposure metric. Concentrations ranging from 1 to 674 ppm mercury were determined from X-ray fluorescent spectrometric analysis of selected regions of maternal scalp. These were correlated with clinical signs observed in the affected members of the mother-child pairs. The hair concentration at a hypothetical NOAEL for developmental effects was determined by application of a BMD approach (see subsequent section for discussion of methods and data used). The analysis used the combined incidence of all neurological effects in children exposed *in utero* as reported in the Marsh et al. (1987) study. A Weibull model for extra risk was used to determine the BMD; in current terminology, this was a BMDL (95% lower confidence limit) on the dose corresponding to a 10% risk level. This level was calculated to be 11 ppm mercury in maternal hair (11 mg/kg hair). A description of BMD determination, choice of model, and issues on grouping of data is on pages 6-25 to 6-31 of Volume V of the MSRC.

The BMD of 11 ppm maternal hair mercury was converted to an exposure level of 44 μg mercury/L blood using a 250:1 ratio as described in the MSRC (U.S. EPA, 1997e, pp. 6-22 to 6-23):

$$11 \text{ mg/kg hair} / 250 = 44 \text{ μg/L blood}$$

To obtain a daily dietary intake value of methylmercury corresponding to a specific blood concentration, factors of absorption rate, elimination rate constant, total blood volume, and percentage of total mercury present in circulating blood were taken into account. Calculation was by the following equation, based on the assumptions that steady-state conditions exist and that first-order kinetics for mercury are being followed:

$$d\ \mu g/day = \frac{C \times b \times V}{A \times f}$$

where:

d = daily dietary intake (expressed as μg of methylmercury)
c = concentration in blood (expressed as 44 μg/L)
b = elimination constant (expressed as 0.014 $days^{-1}$)
V = volume of blood in the body (expressed as 5 L)

A = absorption factor (expressed as a unitless decimal fraction of 0.95)

f = fraction of daily intake taken up by blood (unitless, 0.05)

Solving for d gives the daily dietary intake of mercury that results in a blood mercury concentration of 44 µg/L. To convert this to daily ingested dose (µg/kg-day), a body weight of 60 kg was assumed and included in the equation denominator:

$$d = \frac{c \times b \times V}{A \times f \times bw}$$

$$d = \frac{44\ \mu g/L \times 0.014\ days^{-1} \times 5\ L}{0.95 \times 0.05 \times 60\ kg}$$

$$d = 1.1\ \mu g/kg\text{-}day$$

The dose d (1.1 µg/kg-day) is the total daily quantity of methylmercury that is ingested by a 60-kg individual to maintain a blood concentration of 44 µg/L or a hair concentration of 11 ppm. The rationales for use of the hair:blood ratio and specific values for equation parameters can be found on pages 6-21 to 6-25 of Volume V of the MSRC.

A composite uncertainty factor of 10 was used. This uncertainty factor was applied for variability in the human population, in particular the wide variation in biological half-life of methylmercury and the variation that occurs in the hair-to-blood ratio for mercury. In addition, the factor accounts for lack of a two-generation reproductive study and lack of data for possible chronic manifestations of adult effects (e.g., paresthesia observed during gestation). The default value of 1 was used for the modifying factor.

The RfD was calculated using the following equation:

$$RfD = \frac{BMD}{UF \times MF}$$

$$= \frac{1.1\ \mu g/kg\text{-}day}{10}$$

$$= 1 \times 10^{-4}\ mg/kg\text{-}day$$

or 0.1 µg/kg/day.

Confidence in the supporting database and in the RfD were considered medium by the RfD/RfC Work Group. The MSRC (U.S. EPA, 1997e) says the following:

> The principal study (Marsh et al. 1987) is a detailed report of human exposures with quantitation of methylmercury by analysis of specimens from affected mother-child pairs. A strength of this study is that the quantitative data are from the affected population and quantitation is based upon biological specimens obtained from affected individuals. A threshold was not easily defined; extended application of modeling techniques was needed to define the lower end of the dose-response curve. This may indicate high variability of response to methylmercury in the human mother-child pairs or misclassification in assigning pairs to the cohort.

Further discussion of areas of uncertainty and variability are on pages 6-31 to 6-51 of Volume V of the MSRC (U.S. EPA, 1997e). A quantitative analysis of uncertainty in an RfD based on the Iraqi data is found in Appendix D of Volume V, and additional discussions of areas of uncertainty are in Volume VII, Risk Characterization, of the MSRC (U.S. EPA, 1997g).

4.1.1.3 Reference Values Derived From Animal Data

There are issues inherent to epidemiological studies, including the possibility of coexposure to other potential toxicants, that are not of concern in controlled experimental animal studies. It is therefore informative to compare RfDs that may be derived from animal studies to those derived from the epidemiological literature. RfDs derived from monkey studies are particularly relevant, as the neurotoxic effects produced by developmental methylmercury exposure in monkeys are similar to those identified in humans (Burbacher et al., 1990a; Gilbert and Grant-Webster, 1995). The studies at the University of Washington were of a relatively large cohort of macaque monkeys whose mothers were exposed throughout pregnancy to 50 µg/kg/day of methylmercury. The studies revealed deficits on cognitive tests during infancy, which may represent retarded development (Burbacher et al., 1986; Gunderson et al., 1986, 1988). These methylmercury-exposed monkeys also displayed aberrant play and social behavior (Burbacher et al., 1990b). Studies at the Canadian Health Protection Branch in the same species of monkey, dosed with 50 µg/kg/day from birth to 7 years of age, revealed visual, auditory, and somatosensory deficits, including evidence of delayed neurotoxicity identified in middle age (Rice and Gilbert, 1995, 1992, 1982; Rice, 1989a). Research in a cohort of monkeys dosed beginning *in utero* and continuing until 4 years of age revealed similar sensory system impairment (Rice, 1998; Rice and Gilbert, 1995, 1990). Three individuals dosed at 10 or 25 µg/kg/day all exhibited impaired function in at least

one sensory system in addition to evidence of delayed neurotoxicity (Rice, 1998). In none of these studies was a NOAEL identified.

Calculation of an RfD from these data according to the method typically used by the EPA would include application of a number of UFs, including dividing the LOAEL by a factor of 10 (because no NOAEL was identified), division by 10 again for extrapolation from animal to human data, and division by another factor of 10 in consideration of individual variation in sensitivity. Monkeys and humans have approximately the same brain:blood mercury ratio following chronic exposure (Burbacher et al., 1990a), although the ratio in humans may be slightly higher than in monkeys (Rice, 1989b). However, the half-life of mercury in the blood of monkeys is about 15 days (Rice, 1989c), whereas clearance times for humans averaged 45-70 days in several studies, with some individuals having even longer clearance times (see Section 4.2.3). The shorter clearance time in monkeys would result in an UF of at least 5 based on pharmacokinetic considerations alone; therefore an overall factor of 10 appears appropriate for interspecies extrapolation. This calculation would yield an RfD of 0.05 µg/kg/day from the *in utero* and postnatal exposure studies, and an RfD as low as 0.01 µg/kg/day based on combined *in utero* and postnatal exposure (Rice, 1996). Gilbert and Grant-Webster (1995) suggested an RfD of 0.025 µg/kg/day based on the same data.

4.1.2 Risk Assessments Done by Other Groups

Quantitative estimates of hazards of oral exposure to methylmercury have been considered by the Food and Drug Administration (FDA), Agency for Toxic Substances and Disease Registry (ATSDR), and other countries (WHO/IPCS), among others.

4.1.2.1 Food and Drug Administration

In 1969, in response to the poisonings in Minamata Bay and Niigata, Japan, the U.S. FDA proposed an administrative guideline of 0.5 ppm for mercury in fish and shellfish moving in interstate commerce. This limit was converted to an action level in 1974 (Federal Register *39*, 42738, December 6, 1974) and increased to 1.0 ppm in 1979 (Federal Register *44*, 3990, January 19, 1979) in recognition that exposure to mercury was less than originally considered. In 1984, the 1.0 ppm action level was converted from a mercury standard to one based on methylmercury (Federal Register *49*; November 19, 1984).

The action level takes into consideration the tolerable daily intake (TDI) for methylmercury as well as information on seafood consumption and associated exposure to methylmercury. The TDI is the amount of methylmercury that can be consumed daily over a long period of time with a reasonable certainty of no harm. FDA established a TDI based on a weekly tolerance of 0.3 mg of total mercury per person, of which no more than 0.2 mg should be present as methylmercury. These amounts are equivalent to 5 and 3.3 μg, respectively, per kilogram of body weight. Using the values of methylmercury, this tolerable level would correspond to approximately 230 μg/week for a 70-kg person, or 33 μg/person/day (0.47 μg/kg bw/day). The TDI was calculated from data developed in part by Swedish studies of Japanese individuals poisoned in the Niigata episode, which resulted from the consumption of contaminated fish and shellfish and the consideration of other studies of fish-eating populations.

Based on observations from the later poisoning event in Iraq, FDA has acknowledged that the fetus may be more sensitive than adults to the effects of mercury (Federal Register *44*, 3990, January 19, 1979; U.S. FDA Consumer, September 1994). In recognition of these concerns, FDA has provided advice to pregnant women and women of childbearing age to limit their consumption of fish known to have high levels of mercury (U.S. FDA Consumer, 1994). FDA believes, however, that given existing patterns of fish consumption, few women (less than 1%) eating such high-mercury fish will experience slight reductions in the margin of safety. However, because of the uncertainties associated with the Iraqi study, FDA has chosen not to use the Iraqi study as a basis for revising its action level. Instead, FDA has chosen to wait for findings of prospective studies of fish-eating populations in the Seychelles Islands.

4.1.2.2 World Health Organization

The International Programme on Chemical Safety (IPCS) of the World Health Organization published a criteria document on mercury (WHO, 1990). In that document, it was stated that "a daily intake of 3 to 7 μg Hg/kg body weight would cause adverse effects of the nervous system, manifested as an approximately 5% increase in the incidence of paraesthesias." The IPCS expert group also concluded that developmental effects in offspring (motor retardation or signs of CNS toxicity) could be detected as increases over background incidence at maternal hair levels of 10-20 ppm mercury. These levels of concern were based on evaluation of data including the human poisoning incident in Iraq.

4.1.2.3 ATSDR

In 1993, ATSDR first published a Minimal Risk Level (MRL) for methylmercury. An MRL is derived in a manner similar to the RfD; it is defined as an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. In 1999 ATSDR published a revised methylmercury MRL using the Seychelles Islands study (SCDS) (Davidson et al., 1998) as the starting point (ATSDR, 1999). In this study (described in detail in Section 3.2.2.5 and summarized in Section 4.2.13), the investigators examined the correlation between subtle neurological effects and low-dose chronic exposure to methylmercury. No correlation between maternal hair mercury concentrations and neurological effects was seen in the SCDS 66-month-old children. ATSDR determined a minimal risk level of 0.3 μg/kg per day, based on a dose of 1.3 μg/kg per day, which reflects the average concentration of the upper quintile of the exposed population but does not necessarily correspond to a NOAEL. ATSDR used a UF of 1.5 to account for pharmacokinetic variability within the human population; they made their choice based on the analyses of Clewell et al. (1998). An additional factor of 1.5 was applied to account for any other individual variability (e.g., pharmacodynamics) as well as a modifying factor of 1.5 to account for the possibility that domain-specific tests used in the Faroe Islands study might have allowed detection of subtle neurological effects that were not evaluated in the Seychelles cohort. Although the conventional risk assessment approach is to multiply UFs, ATSDR summed these factors to develop an overall safety factor of 4.5.

4.1.3 SAB Review of the Mercury Study Report to Congress

The Science Advisory Board (SAB) is a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the EPA. The SAB is structured to provide balanced, expert assessment of scientific matters relating to problems facing the Agency. The SAB reviewed a draft of the eight-volume MSRC (U.S. EPA, 1997a-h) in the context of a public meeting held February 13 and 14, 1997. A panel of 33 scientists reviewed the entire MSRC. A subgroup focused on the health effects data, and in particular EPA's use of those data to derive the methylmercury RfD of 0.1 μg/kg/day, based on effects observed in Iraqi children exposed *in utero*.

The SAB report was published in October 1997 (EPA-SAB-EC-98-001). It made the following statement:

> In general, from the standpoint of looking at human health effects and the uncertainties, the draft report [MSRC] is a very good document and an important step forward in terms of bringing the relevant information together into one place for the first time. The current RfD, based on the Iraqi and New Zealand data, should be retained at least until the on-going Faeroe and Seychelles Islands studies have progressed much further and been subjected to the same scrutiny as has the Iraqi data.

The SAB report continued:

> Investigators conducting two new major prospective longitudinal studies—one in the Seychelles Islands, the other in the Faeroe Islands—have recently begun to publish findings in the literature and are expected to continue releasing their findings during the next 2-3 years. These studies have advantages over those cited in the previous paragraph in that they have much larger sample sizes, a larger number of developmental endpoints, potentially more sensitive developmental endpoints, and control a more extensive set of potential confounding influences. On the other hand, the studies have some limitations in terms of low exposures (to PCBs in the Faeroes) and ethnically homogenous societies. Since only a small portion of these new data sets have been published to date and because questions have been raised about the sensitivity and appropriateness of the several statistical procedures used in the analyses, the Subcommittee concluded that it would be premature to include any data from these studies in this report until they are subjected to appropriate peer review. **Because these data are so much more comprehensive and relevant to contemporary regulatory issues than the data heretofore available, once there has been adequate opportunity for peer review and debate within the scientific community, the RfD may need to be reassessed in terms of the most sensitive endpoints from these new studies.** [Emphasis theirs]

4.1.4 Interagency Consensus Process

Among the many reviews of the MSRC was one by scientists and policy-makers from interested Federal agencies, sponsored by the Committee on Environment and Natural Resources (CENR), Office of Science and Technology (OSTP). This review highlighted many divergent points of view as to the appropriate basis for quantitative assessment of the low-dose effects of methylmercury exposure. It was decided that an interagency process with external involvement would be undertaken to review new methylmercury data and evaluate new and existing data. EPA committed to participate in this process and, at its conclusion, to assess its 1995 RfD for methylmercury to determine if a change was warranted. Subsequently a workshop was organized by an interagency committee at the request of OSTP. The organizing committee was chaired by the National Institute of Environmental Health Sciences (NIEHS) and included representatives from several agencies:

Department of Health and Human Services (DHHS)
Office of the Assistant Secretary for Planning and Evaluation
Centers for Disease Control and Prevention (CDC)
Agency for Toxic Substances Disease Registry (ATSDR)
Food and Drug Administration (FDA)
Environmental Protection Agency (EPA)

National Oceanic and Atmospheric Administration (NOAA)

Office of Science and Technology Policy (OSTP)

Office of Management and Budget (OMB)

The Methylmercury Workshop was a response to the suggestion that the emerging Seychellois and Faroese data undergo a level of scrutiny beyond journal peer review if they were to be used in policy setting.

The Workshop on the Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury was held in Raleigh, North Carolina, November 18–20, 1998. The purpose of the workshop was to discuss and evaluate the major epidemiologic studies associating methylmercury exposure with an array of developmental measures in children. The workshop did not attempt to derive a risk assessment, but it was assumed by participants that the workshop evaluation would facilitate agreement on risk assessment issues. The major studies considered were those that have examined populations in Iraq, the Seychelles, the Faroe Islands, and the Amazon, along with the most relevant animal studies. Study authors made detailed presentations to respond to a series of questions on study exposures, potential confounders, measurements of effect, and other related topics. Five expert panels discussed the presentations and published data; panels covered the following areas: exposure, neurobehavioral endpoints, confounders and variables, design and statistics, and experimental (animal and *in vitro*) data. The results of their deliberations were published in the Spring of 1999 (NIEHS, 1999). Conclusions of the report were reviewed by workshop panelists and by Federal scientists who had attended the workshop. The conclusions are quoted below.

1. Methylmercury is a developmental neurotoxin, but effects at low doses encountered by eating fish are difficult to evaluate.

2. All the studies reviewed were considered of high scientific quality, and the panel recognized that each of the investigations had overcome significant obstacles to produce important scientific information. The panel also stated that continued funding of the studies in the Seychelles, Faroes, and Amazon is necessary for the full potential of those studies to be realized. This is particularly the case for the Faroes and Seychelles studies, which have assessed and are currently assessing the potential developmental neurotoxic effects of methylmercury in fish-eating populations. The developmental studies would benefit by evaluation of common endpoints using similar analytical methods. It is important to note that the Amazon study did not assess developmental endpoints but assessed effects in adults.

3. Results from the Faroes and Seychelles studies are credible and provide valuable insights into the potential health effects of methylmercury.

4. Some differences are clearly present in results from the Faroes, Seychelles, and Amazon, but the panel was not able to clearly identify the sources of these differences. Among possible sources are the different effects of episodic versus continuous exposure, ethnic differences in methylmercury responses, lack of common

endpoints in the Faroes and Seychelles studies, and several other confounders or modifying factors such as those found in diet and lifestyle, as well as in chemicals present in seafood, which is the source of methylmercury to these populations. The other chemical constituents of seafood that may be explanatory include those that may be beneficial to fetal neurodevelopment (i.e., omega-3 fatty acids) and those that may be harmful to fetal neurodevelopment (e.g., PCBs).

5. These studies have provided valuable new information on the potential health effects of methylmercury, but significant uncertainties remain because of issues related to exposure, neurobehavioral endpoints, confounders and statistics, and design.

The interagency organizing committee agreed unanimously that the deliberations of the panels and the workshop report will be a key factor in subsequent public health policy actions taken by each of the participating agencies.

4.1.5 National Academy of Sciences Review

Congress directed EPA, through the House Appropriations Report for FY99, to contract with the National Research Council (NRC, a body of the National Academy of Sciences) to evaluate the body of data on the health effects of methylmercury, with particular emphasis on new data since the publication of the MSRC. NRC was asked to provide recommendations regarding issues relevant to the derivation of an appropriate RfD for methylmercury.

The NRC empaneled a group of scientific experts who held public meetings at which there were presentations from methylmercury researchers, government agencies, trade organizations, public interest groups, and concerned citizens. The panel evaluated the scientific basis for risk assessments done by EPA and other groups as well as new data and findings available since publication of the MSRC. The committee was not charged with developing an RfD as an alternative to the EPA assessment, but rather provided scientific guidance that would inform such an assessment. The NRC report, *Toxicological Effects of Methylmercury*, was released to the public on July 11, 2000 (NRC, 2000). Conclusions of that report are summarized below.

The report concludes that methylmercury is a highly toxic substance; a number of adverse health effects associated with methylmercury exposure have been identified in humans and in animal studies. Most extensive are the data for neurotoxicity, particularly in developing organisms. The nervous system is considered by the NRC committee to be the most sensitive target organ for which there are data suitable for derivation of an RfD. The committee also concludes on the basis of data from humans and from animal studies that exposure to methylmercury can have adverse effects on the developing and adult cardiovascular system. They note that some research demonstrated adverse cardiovascular effects at or

below levels associated with effects on the developing nervous system. The NRC also cites evidence of low-dose methylmercury effects on the immune and reproductive systems.

The NRC report presents some conclusions on the public health implications of methylmercury exposure; one conclusion is quoted below:

> The committee's margin-of-exposure analysis based on estimates of MeHg exposure in the U.S. population indicates that the risk of adverse effects from current MeHg exposure in the majority of the population is low. However, individuals with high MeHg exposure from frequent fish consumption might have little or no margin of safety (i.e., exposures of high-end consumers are close to those with observable adverse effects). The population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school and who might require remedial classes or special education. (NRC, 2000 p. 9)

The NRC report gives an evaluation of the 1995 EPA RfD. Their conclusion is as follows:

> On the basis of its evaluation, the committee's consensus is that the value of EPA's current RfD for MeHg, 0.1 μg/kg/day, is a scientifically justifiable level for the protection of public health. However, the committee recommends that the Iraqi study no longer be used as the scientific basis of the RfD (NRC, 2000 p. 11).

The NRC report made several recommendations on the appropriate basis for a revised RfD. The Committee thoroughly reviewed three epidemiological longitudinal developmental studies: the Seychelles Islands, the Faroe Islands, and New Zealand. The Seychelles study yielded scant evidence of impairment related to *in utero* methylmercury exposure through 5.5 years of age, whereas the other two studies found dose-related effects on a number of neuropsychological endpoints. The Faroe Islands study is the larger of the latter two studies and has been extensively peer-reviewed. NRC recommended use of data from the Faroe Islands study for derivation of the RfD (NRC, 2000 p. 11).

NRC recommended BMD analysis as the most appropriate method of quantifying the dose-effect relationship. They recommend the lower limit on a 5% effect level obtained by applying a K-power model ($K \geq 1$) to dose-response data based on Hg in cord blood. NRC noted that for the Faroe Islands data the results of the K-power model under this constraint are equivalent to a linear model (NRC, 2000, pp. 11-12).

NRC recommended use of the Boston Naming Test (BNT) as the critical endpoint. This endpoint yields the second-lowest BMDL but was judged by the Committee to be more reliable than the endpoint

that yields the lowest BMDL. The BMDL for the BNT from the Faroe Islands study is 58 ppb Hg in cord blood.

NRC described alternative dose conversion processes using a one-compartment model similar to that used in the MSRC.

In their discussion of uncertainty factors, NRC reviewed several sources of variability and uncertainty and recommended that an uncertainty factor of at least 10 be used. NRC recommended a factor of 2 to 3 for biological variability in dose estimation. They also recommended an additional factor to account for data gaps relating to possible long-term neurological effects not evident in childhood, as well as possible effects on the immune and cardiovascular systems (NRC, 2000, p. 327).

4.1.6 External Peer Review of Draft RfD

A draft EPA RfD document was submitted for external scientific peer review in late October 2000; the reviewers are listed at the front of this document. At the same time the draft RfD document was circulated for comment to other Federal Agencies through CENR and OSTP. A public scientific review meeting was held November 15, 2000; the final peer review report was delivered to EPA on December 7, 2000, and is available in the docket. The external peer reviewers supported the use of the Faroes data, derivation of a BMD as described by NRC, and application of a tenfold uncertainty factor to the BMDL. They agreed with EPA's use of a one-compartment model for dose conversion as well as with most of the parameter estimates; they commented correlation among some of the parameters. The peer reviewers disagreed with NRC's recommendation to set the RfD on the BNT results from the full Faroese cohort. They felt that the BNT scores showed an effect of concomitant PCB exposure in some analyses. They preferred a PCB-adjusted BMDL of 71 ppb mercury in cord blood for the BNT. They also offered suggested alternatives to use of the BNT test reslts. The peer reviewers validated a final RfD of 0.1 µg/kg bw /day.

4.1.7 Revised RfD

The development of this RfD considered the NRC recommendations and followed them for the most part. Most recommendations of the peer-review panel were incorporated as well. The following sections provide rationales for choices made by EPA in determining the basis for the RfD.

4.2 CHOICE OF CRITICAL STUDY AND ENDPOINT

NRC concluded, and EPA agrees, that the data from human studies showing developmental neurotoxicity are the most appropriate basis for the RfD. NRC concluded that human studies on methylmercury carcinogenicity are inconclusive and that the renal tumors observed in mice were found only when animals were exposed at or above the maximally tolerated dose (MTD). In the MSRC, EPA noted that if one applied the principles of the revisions to the Risk Assessment Guidelines for Carcinogenicity, the following conclusions would be reached:

> Methylmercury is not likely to be a human carcinogen under conditions of exposure generally encountered in the environment. Data in humans were inadequate; interpretation is limited by inappropriate study design and incomplete descriptions of methodology. Dietary exposure in two strains of mice resulted in increased renal adenomas and adenocarcinomas. Tumors were observed only in dose groups experiencing profound nephrotoxicity. Studies in rats exposed to an MTD showed no increased tumor incidence. Several studies show that methylmercury can cause chromosomal damage in somatic cells. While evidence is good for chromosomal effects, it does not appear that methylmercury is a point mutagen. The mode of action in renal tumor induction is likely to be related to reparative changes in the tissues. Human exposure is likely to be from consumption of contaminated foods, especially fish. It is expected that exposure, even in groups consuming large amounts of fish from contaminated sources, will be to levels far below those likely to cause the tissue damage associated with tumor formation in animals (U.S. EPA, 1997).

NRC concluded that human data, as well as results of animal tests, indicate the cardiovascular system is a sensitive target for methylmercury effects. This is particularly true for developing organisms. Their report also cites animal and *in vitro* data linking methylmercury exposure to immunotoxic and reproductive effects (summarized in NRC, 2000, pp. 190-191). It is clear, however, that at the current time the human data set on developmental neurotoxicity is the most extensive, best reviewed, and most thoroughly evaluated. The RfD will thus rely on those data. It is expected that an RfD based on developmental neurotoxicity will be protective against adverse effects likely to occur at higher levels of mercury exposure. Following NRC's recommendation, EPA's choice of critical study was limited to those developmental studies of populations experiencing long-term, low-dose exposure. Only those studies are summarized in subsequent sections of this document.

4.2.1 Summary of Available Data

This section gives brief summaries of studies on the developing central nervous system that were described by NRC. This section follows the format used by the NRC report; studies are grouped into subsections by endpoint and chronologically within subsection. Section 4.2.1.1 describes the evidence for effects of methylmercury on neurological status; Section 4.2.1.2 describes the effects on attainment of

developmental milestones during infancy; Section 4.2.1.3 describes other effects during infancy and early childhood; Section 4.2.1.4 presents evidence for cognitive deficits during childhood (school age); and Section 4.2.1.5 describes sensory and other effects of methylmercury.

For more detailed study descriptions refer to Section 3 of this document or to the MSRC.

4.2.1.1 Status on Neurological Examination

Cree Population—McKeown-Eyssen et al. (1983)

McKeown-Eyssen et al. (1983) studied a population of 234 12- to 30-month-old Cree Indian children for whom prenatal methylmercury exposure was estimated on the basis of maternal hair samples. The subjects lived in four communities in northern Quebec. Hair samples were collected on 28% of the mothers during pregnancy; prenatal exposure for the rest of the cohort was estimated from hair segments assumed to date from the time the study child was *in utero*. No child was judged to have any abnormal physical findings. Overall, 3.5% (4) of the boys and 4.1% (5) of the girls were considered to have abnormal neurological findings. The most frequent abnormality (observed in 11.4% [13] of the boys and 12.2% [14] of the girls) involved tendon reflexes. Abnormalities of muscle tone or reflexes in boys were the only neurological finding for which there was a statistically significant association with prenatal methylmercury exposure, either before or after adjustment for confounding. The risk of an abnormality of tone or reflexes increased seven times with each 10 ppm increase in maternal hair mercury. When exposure was categorized, the prevalence of tone or reflex abnormality did not increase in a clear dose-response manner across categories. In girls, incoordination was negatively associated with prenatal methylmercury exposure. The authors noted that these mild, isolated neurological findings were different from those described in previous reports of neurological abnormalities after prenatal exposure to higher levels of methylmercury.

Mancora, Peru—Marsh et al. (1995)

Neurological examination was done on 194 children in Mancora, Peru. Although the study was conducted in the early 1980s, it was not published until 1995 (Marsh et al., 1995). Fish consumption was the primary route of methylmercury exposure and maternal hair was used as the index of exposure (geometric mean 7.05 ppm; range 0.9 to 28.5 ppm). Comparison of peak and mean hair-mercury concentration suggested that the women's exposure was at steady state because of stability in their fish-

consumption patterns. Maternal hair samples and data on child neurological status were available for 131 children. Several elements of the study design are not described: the size of the eligible population from which the 131 children were sampled, the specific elements of the neurological assessment conducted, and the ages at which the children were examined. Frequencies were reported for the following endpoints: tone decreased, tone increased, limb weakness, reflexes decreased, reflexes increased, Babinski's sign, primitive reflexes, and ataxia. No endpoint was significantly associated with either mean or peak maternal hair mercury.

SCDS Pilot Study—Myers et al. (1995b)

In the cross-sectional or pilot study of the SCDS (Myers et al., 1995), 789 infants and children between the ages of 5 and 109 weeks were evaluated by a pediatric neurologist. Mean maternal hair mercury in the cohort was 6.1 ppm (range 0.6 to 36.4 ppm). The endpoints assessed were mental status, attention, social interactions, vocalizations, behavior, coordination, postures and movements, cranial nerves, muscle strength and tone, primitive and deep tendon reflexes, plantar responses, and age-appropriate abilities such as rolling, sitting, pulling to stand, walking, and running. The statistical analyses focused on three endpoints chosen on the basis of their apparent sensitivity to prenatal methylmercury exposure in the Iraq and Cree studies: overall neurological examination, increased muscle tone, and deep tendon reflexes in the extremities. There was no association between maternal hair mercury and questionable and abnormal results. The frequency of those results ranged from 16.5% in the group with hair mercury at 0 to 3 ppm to 11.7% in the group with Hair mercury at more than 12 ppm. The frequencies of abnormalities of limb tone or deep tendon reflexes were about 8%; there was no dose-dependent variation in frequency of either endpoint.

SCDS Main Study—Myers et al. (1995c)

The main cohort of the SCDS consisted of 779 mother-infant pairs, representing approximately 50% of all live births during the period of recruitment. The final sample size was 740. When the infants were 6.5 months old, a pediatric neurologist administered essentially the same neurological examination that had been used in the pilot phase; testing was blinded as to child's exposure. A total of 3.4% (25) of the children had overall neurological scores considered abnormal or questionable; this frequency was too low to permit statistical analysis of the overall neurological examination. The frequency of abnormalities was 2% for both limb tone and abnormal deep tendon reflexes. Questionable limb tone was identified in approximately 20% of the children, and questionable deep tendon reflexes in approximately 15%.

Although such findings were not considered pathological, they were combined with abnormal findings for statistical analyses. The frequency of abnormal and questionable findings for limb tone or deep tendon reflexes was not significantly associated with maternal hair mercury concentrations.

Faroes Population—Dahl et al. (1996)

A functional neurological exam was part of a general physical examination administered to a cohort of 7-year-old children from the Faroe Islands. Of 1,386 infants eligible at recruitment, cord-blood and maternal hair samples were obtained from 1,022 singleton births (75%), and 917 children were examined (66%) (Grandjean et al., 1992). The mean cord-blood concentration was 22.9 μg/L; the mean maternal hair mercury concentration was 4.3 ppm. The examination focused on motor coordination and perceptual-motor performance (Dahl et al., 1996). Results were scored as automatic, questionable, or poor. There was no association between cord-blood mercury and the number of tests on which a child's performance was considered automatic or performed optimally. On the tests of reciprocal motor coordination, simultaneous finger movement, and finger opposition, fewer than 60% of the children achieved a score of automatic for optimal performance. On the finger opposition test, children with questionable and poor performance (425 children) had a significantly higher mean cord-blood mercury concentration than children with automatic performance (465 children) (23.9 versus 21.8 μg/L, $p = 0.04$) (Grandjean et al., 1997).

Faroes Population—Steurwald et al. (2000)

A cohort of 182 singleton, full-term infants born in the Faroe Islands between 1994 and 1995 was recruited. The cohort represented 64% of all births in the study area. Data were collected on maternal hair mercury, cord whole-blood mercury, and cord serum mercury. A total of 15 maternal hair measurements exceeded 10 ppm. Measurements were also taken of 18 pesticides or metabolites and 28 polychlorinated biphenyl (PCB) congeners in maternal serum. At 2 weeks of age infants were given a neurological examination designed to assess functional abilities, reflexes and responses, and stability of behavioral status during examination. Responses were categorized as optimal, questionable, or suboptimal. The neurological optimality score (NOS) was the number of items rated as optimal out of a total of 60. Two subscores were generated (muscle tone and reflexes) and a variety of thyroid-function indices were also assessed. Maternal hair mercury concentrations were not significantly associated with NOS score, but there was a significant inverse relationship between NOS scores and cord whole-blood mercury. The mean mercury concentration was 20.4 μg/L (range 1.9 to 102 μg/L). Based on NOS score,

a tenfold increase in cord-blood mercury was associated with the equivalent of a 3-week reduction in gestational age. Adjustments for total PCBs and fatty acid concentrations had no effect on results, and selenium was not an effect modifier. Muscle-tone and reflexes subscores were not significantly associated with any exposure biomarker.

Cordier and Garel (1999)

Cordier and Garel (1999) studied a cohort of Amerind children from a gold-mining area in French Guiana. Median maternal hair concentration was 6.6 ppm with a range of 2.9 to 17.8 ppm; 35% of maternal hair mercury levels were greater than 10 ppm. Neurological examination included the following: neuromotor examination of the upper an lower limbs, body axis, deep reflexes, and postural reactions; neuromotor functions; neurosensory examination; and cranial growth. The authors report that for children greater than 2 years of age, increased reflexes were found with greater incidence as a function of maternal hair mercury; the effect was greater in boys than in girls. When 10 children were retested 9 months later by a different examiner, only 3 were found to have the increased reflex response. The authors commented that this poor reproducibility makes the reflex response difficult to interpret.

Conclusions

There is some evidence that neurological status in children is associated with low-dose *in utero* exposure: (1) an increased incidence (not dose dependent) of tone or reflex anomalies in boys associated with increased maternal hair mercury (McKeown-Eyssen et al., 1983); (2) an inverse association between newborn neurological optimality score and cord-blood mercury in Faroese children (Steurwald et al., 2000); (3) a statistically significant increase in the mean cord-blood mercury of 7-year-old Faroese children who performed less than optimally on a finger opposition test, compared with Faroese children with normal performance (Grandjean et al., 1997); (4) the association of increased reflexes with increasing maternal hair mercury in a group of children aged 9 months to 6 years in French Guiana (Cordier and Garel, 1999). NRC notes that a particular limitation of the use of neurological status is the categorical nature of the response; in other words, the subject has either an abnormal response or a normal response. This may have been a factor in the evaluation of results from the SCDS. The number of abnormal responses in this population was very low; thus there was reduced statistical power for hypothesis testing.

4.2.1.2 Age at Achievement of Developmental Milestones

SCDS—Myers et al. (1997) and Axtell et al. (1998)

The association between achievement of developmental milestones and prenatal methylmercury exposure was evaluated in the main cohort of the SCDS (Myers et al., 1997). Data were available for 738 of the 779 children enrolled. The mean average age for walking was 10.7 months for girls and 10.6 months for boys; for talking it was 10.5 months for girls and 11.0 months for boys. The mean age at which a child was considered to talk was not significantly associated with maternal hair mercury in any of the regression models used. In regressions stratified by child sex, a positive association was found between age at walking and maternal hair mercury in boys only. The interaction between mercury and sex was not statistically significant in the analyses of the complete cohort. The authors considered the magnitude of the delay in boys' walking to be clinically insignificant; a 10-ppm increase in maternal hair mercury was associated with approximately a 2-week delay. This association in boys was not significant when four statistical outliers were excluded from the analysis. Authors concluded that hockey-stick models provided no evidence of a threshold for developmental delay, as the fitted curves were essentially flat.

Axtell et al. (1998) reanalyzed the milestone data, applying semiparametric generalized additive models that are less restrictive than the approaches used by Myers et al. (1997). Their major finding was that the association between age at walking and maternal hair mercury in boys was nonlinear. In their modeled estimates, walking was delayed as maternal hair concentrations increased from 0 to 7 ppm but was observed at a slightly earlier age as mercury concentration increased beyond 7 ppm. The size of the effect associated with the increase from 0 to 7 ppm was very small, corresponding to a delay of less than 1 day in the achievement of walking. Because of the contradictory nature of the dose-response relationships above and below 7 ppm, the authors expressed a doubt that the association found below 7 ppm reflected a causal effect of mercury exposure on age at walking.

Mancora, Peru—Marsh et al. (1995)

Data on developmental milestones were collected in the Peruvian study conducted by Marsh et al. (1995). The study was conducted prospectively, and data were apparently collected in an ongoing manner over the course of a mother's visits to a postnatal clinic. Regression analyses, including analyses stratified by child sex, did not reveal any significant associations between maternal hair mercury

concentrations and the ages at which children sat, stood, walked, or talked. The rates of developmental retardation, especially in speech (13 of 131), were substantial. Children's birthweight, height, and head circumference were unrelated to maternal hair mercury concentrations.

Faroes Population—Grandjean et al. (1995)

Ages at achievement of motor development milestones were investigated in a 21-month birth cohort (1,022 infants born in 1986-1987) of children in the Faroe Islands. Complete data were available for 583 children. Three motor-development milestones commonly achieved between 5 and 12 months of age were selected for analysis: "sits without support," "creeps," and "gets up into standing position with support." There was no significant association between age at achievement and either cord-blood or maternal hair mercury for any of the three milestones. For all three, however, the authors reported a significant inverse association between age at achievement and the child's hair mercury concentration at 12 months. Children's hair mercury was interpreted as an index of postnatal exposure to methylmercury. Breastfeeding was associated with both increased hair mercury concentrations and more rapid achievement of milestones. Therefore, the authors concluded that the inverse association reflected residual confounding by duration of breastfeeding.

Conclusions

The recent human studies provide little evidence of an association between maternal hair mercury below 30 ppm and delayed developmental milestones. The NRC report noted that in the SCDS, mean age of walking was higher in the part of the population born to mothers with higher hair mercury. The association was for male children only and it was not dose related. In the Faroese population, there was a negative association for maternal hair mercury and three developmental milestones. The study authors attributed this to higher mercury exposure in the breastfed population and the salutary effect of breast milk on development. The NRC report commented on the reported developmental delays in the Iraqi population, which has been the subject of much discussion as to the degree of uncertainty in the estimates (see also MSRC Volumes V and VII). NRC cites analyses by Cox et al. (1995) and Crump et al. (1995), which indicate that the earlier estimates of the Iraqi threshold for late walking were too low. The threshold for late walking appears highly dependent on assumptions on background incidence, the definition of delayed walking, and the effect of a small number of influential data points.

4.2.1.3 Infant and Preschool Development

Cree population—McKeown-Eyssen et al. (1983)

In the study of a Cree population, the Denver Developmental Screening Test (DDST) was administered to the 12- to 30-month-old children in the cohort (n = 234). Scores were reported as the percentage of items passed on each subscale as well as on the entire test. The authors did not provide estimates of significance of association between test scores and maternal hair mercury concentrations; they concluded that there was no significant association indicative of an adverse effect of methylmercury before or after adjustment for confounding variables.

New Zealand population—Kjellstrom et al. (1986)

Kjellstrom et al. (1986) studied a cohort of New Zealand children for whom prenatal methylmercury exposure was estimated on the basis of maternal hair samples as well as dietary questionnaires collected during the period when the study child was *in utero*. Exposure information was collected on nearly 11,000 women; the study focused on 935 women who reported eating fish more than three times per week during pregnancy. Seventy-three women had hair mercury concentrations greater than 6 ppm. The 74 children of those women were designated as the high-mercury group. Efforts were made to match each child in the high-mercury group with a reference child on the basis of maternal ethnicity, hospital of birth, maternal age, and child age. In the followup evaluations at 4 years of age, a total of 38 exposed and 36 reference children were tested; this data set included 30 completely matched pairs. Fifty-two percent of the children in the high-mercury group had an abnormal or questionable DDST score compared with 17% of the children in the control group ($p < 0.05$). That result corresponds to an odds ratio of 5.3. Results were similar when pairs that were poorly matched on ethnicity were excluded.

SCDS pilot study—Myers et al. (1995b)

In the SCDS cross-sectional study, a revised version (DDST-R) of the DDST was administered to 789 children between the ages of 1 and 25 months. No association was found between maternal hair mercury concentration during pregnancy (mean 6.6 ppm) and DDST-R results when normal and questionable examinations were combined. The prevalence of abnormal findings was so low (three children <1%) that the statistical analysis was not meaningful. When abnormal and questionable results

were grouped (in 65 children, 8%), high maternal hair mercury concentrations were significantly associated with poor outcomes ($p = 0.04$, one-tailed test). That result was largely attributable to the higher frequency of abnormal and questionable results among children in the highest maternal hair mercury category (greater than 12 ppm), by contrast to the frequency of approximately 7% among children in each of the other four groups (0-3, 3-6, 6-9, and 9-12 ppm).

SCDS main study—Myers et al. (1995c)

In the main SCDS study, the DDST-R was administered to a cohort of 740 children at age 6.5 months. The frequency of examinations considered to be abnormal or questionable was very low, precluding meaningful statistical analysis of the DDST-R data. The researchers also administered the Fagan Test of Infant Intelligence, an assessment of visual-recognition memory or novelty preference. Results were not related to maternal hair mercury concentrations.

SCDS main cohort at 19 and 29 months—Davidson et al. (1995)

The Bayley Scales of Infant Development (BSID) were administered to children in the SCDS cohort at ages 19 and 29 months. In addition, at 29 months, six items of the Infant Behavior Record, a rating scale, were completed by the examiner. There are two primary scores on the BSID: the mental development index (MDI) and psychomotor development index (PDI). At both ages, MDI scores were similar to the expected mean for U.S. children. At both ages, however, the Seychellois children performed markedly better on PDI than the expected mean for U.S. children. There was no association between MDI scores at 19 or 29 months with maternal hair mercury concentration during pregnancy. Similar results were obtained in a secondary analysis that included only children with the lowest or highest maternal hair mercury concentrations. Assessments of perceptual skills at 19 months were not associated with mercury exposure. Scores on that test at 29 months could not be evaluated because of a pronounced ceiling effect; that is, there were so many high scores on the test that no difference would be detectable. Likelihood of a PDI score below the median was not significantly associated with maternal hair mercury concentration in the full logistic regression model, but was associated with this exposure index in a model that included limited covariates.

Conclusions

There is some indication of low-dose mercury effects in very young children, but there are difficulties in the measurement of such effects. The DDST was administered to four study populations. When abnormal and questionable results were combined, there was a significant association with increasing maternal hair mercury in the New Zealand cohort and in the SCDS cross-sectional study (but not the main study). The NRC report comments on the bases for the different findings: age at examination, different rates of abnormal and questionable scores, and the possibility that test items or criteria for judging scores differed among studies. NRC offered the general conclusion that screening tests such as the DDST are not useful in neurobehavioral toxicology studies; such tests are insufficiently sensitive to variations in the range of normal performance (NRC 2000, p. 200).

The NRC panel noted that the BSID is currently considered to be the best available instrument for infant assessment and is useful for measurement of prenatal exposures to neurotoxicants (NRC 2000, p. 200). In the SCDS main study there was no significant association between young children's scores on the BSID and maternal hair mercury. At 19 and 29 months, the Seychellois children scored higher than the means for U.S. children on the PDI portion of the scales.

4.2.1.4 Childhood Development

New Zealand population—Kjellstrom et al. (1989)

Children in the New Zealand cohort were followed up at 6 years of age. Children were given a battery of 26 psychological tests, tests of scholastic aptitude, and behavioral tests. The following domains were assessed: general intelligence, language development, fine and gross motor coordination, academic attainment, and social adjustment. Maternal hair mercury concentration was associated with poorer scores on full-scale IQ tests (Wechsler Intelligence Scale for Children, Revised [WISC-R]), language development (Test of Language Development, spoken language quotient), and visual-spatial and gross-motor skills (McCarthy Scales of Children's Abilities). Multiple regression analyses were done on these endpoints: Test of Language Development, spoken language quotient (TOLD-SL); WISC-R, performance IQ; WISC-R full-scale IQ; McCarthy Scales, perceptual performance; and McCarthy Scales, motor scales. Covariates in the regressions were these: maternal ethnic group, maternal age, maternal smoking and alcohol use during pregnancy, length of maternal residence in New Zealand, social class, primary language, siblings, sex, birthweight, fetal maturity, Apgar score, and duration of

breastfeeding. Observations were weighted in the regression to deal with outliers. In the analyses there were statistically significant associations between maternal hair mercury and poorer scores on the following measures: full-scale IQ; language development (spoken language quotient), visual-spatial skills (perceptual-performance scale), and gross motor skills (motor scale). The poorer mean scores of the children in the high-mercury group were largely attributable to children of mothers with mercury concentrations above 10 ppm. In this group, mean average hair mercury was 13 to 15 ppm and mean peak was 25 ppm. Maternal hair mercury concentrations accounted for relatively small amounts of variance in the outcome measures and generally accounted for less than covariates such as social class and ethnic group.

In the original analyses of five test scores (Kjellstrom et al., 1986), hair mercury was used in regression analyses as a binary variable; that is, either >6 ppm or between 3 and 6 ppm. Analyses found an association between high prenatal mercury exposure and decreased test performance. Later regression analyses by Crump et al. (1998), which used maternal hair mercury level as a continuous variable, did not find significant associations between mercury and children's test scores. However, this finding was highly influenced by a single child whose mother's mercury hair level (86 ppm) was more than four times that of any other. When this child was excluded, there were significant associations between hair mercury and TOLD-SL and MC-PP scores. When regression analyses were done on scores from all 26 scholastic and psychological tests, and the data on the influential point were omitted, scores on six tests were significantly associated with mothers' hair mercury: Clay Reading Test-concepts, Clay Reading Test-letter test, McCarthy Scales-general cognitive index, McCarthy Scales-perceptual-performance scale, Test of Language Development-grammar completion, and Test of Language Development-grammar understanding.

SCDS pilot study— Myers et al. (1995a), Davidson et al. (2000), Davidson et al. (1998), Myers et al. (2000).

A portion of the pilot cohort of 789 children were given developmental assessments; these were children who were 66 months old within a 1-year testing window (Myers et al., 1995a). Of the 247 eligible children, 217 were administered a test battery consisting of the McCarthy Scales of Children's Abilities, the Preschool Language Scale, and two subtests of the Woodcock-Johnson Tests of Achievement (letter-word identification and applied problems). The median maternal hair mercury concentration in that subsample of the pilot cohort was 7.1 ppm. Maternal hair mercury was associated with significantly lower general cognitive index (GCI) scores on the McCarthy scales. Scores declined

approximately five points between the lowest and highest exposure categories. Similar associations were found on the perceptual-performance scale of the McCarthy scales and on the auditory comprehension scale of the Preschool Language Scale. Scores declined approximately 2.5 points across the range of maternal hair mercury concentrations. When outliers and influential points were removed from the regressions the statistical significance of the associations was lost for all except auditory comprehension (Preschool Language Scale Auditory Comprehension subscale). In the pilot phase of the SCDS, information was not collected on several key variables that frequently confound the association between neurotoxicant exposures and child development. Those variables are socioeconomic status, caregiver intelligence, and quality of the home environment.

Further evaluation was performed on a portion of the Seychelles pilot cohort at 108 months of age (Davidson et al., 2000). Eighty-seven children were tested on five subtests of the WISC-III (Information, Block Design, Vocabulary, Digit Span, and Coding), CVLT, BNT, Beery-Buktenica Development Test of Visual Motor Integration (VMI) (copying geometric figures), finger tapping, grooved pegboard, Trailmaking (tracing the correct route through a form with a pencil), and the design memory subtest of the Wide Range Assessment of Memory and Learning (WRAML) (drawing each of four geometric designs from memory). Performance on BNT, VMI, and grooved pegboard showed a positive association related to mercury exposure in males, whereas there were trends toward poorer performance related to mercury exposure for grooved pegboard in females ($p = 0.07$). Given the small number of subjects, the power of the study was probably quite low; these largely negative results should be interpreted with caution.

No effect of mercury was identified on the Child Behavior Check List (CBCL) at 66 months of age in the main cohort of Seychelles study as determined by the total T score (Davidson et al., 1998). The CBCL is a report inventory scored by the caregiver that assesses eight domains: withdrawn, somatic complaints, anxious/depressed, social problems, thought problems, attention problems, delinquent behavior, and aggressive behavior. An analysis of these subscales was performed on the 711 children assessed on this test (Myers et al., 2000). No effect of mercury was identified on individual subscales.

SCDS Main Study—Davidson et al. (1998), Axtell et al. (2000), Palumbo et al. (2000)

As part of the main SCDS, 711 children 66 months of age (from the original cohort of 779) were evaluated with a battery of standardized neurodevelopmental tests. At this evaluation, mercury was measured in a 1-cm segment of the child's hair as an indicator of postnatal exposure. The following were assessed: general cognitive ability (McCarthy Scales of Children's Abilities), expressive and receptive

language (Preschool Language Scale, PLS), reading achievement (letter-word recognition subtest of the Woodcock-Johnson Tests of Achievement), arithmetic (applied problems subtest of the Woodcock-Johnson Tests of Achievement), visual-spatial ability (Bender Gestalt Test), and social and adaptive behavior (CBCL). The scores of the six primary endpoints indicated no adverse effect of either prenatal or postnatal mercury exposure. The only significant associations were consistent with enhanced performance among children with increased exposure to methylmercury. Increased pre- and postnatal mercury concentrations were significantly associated with better scores on the total score of the Preschool Language Scale. For the applied problem test, increased postnatal mercury concentrations were associated with better scores. Among boys, increased postnatal mercury concentrations were associated with fewer errors on the Bender Gestalt Test.

The investigators published additional analyses of the 66-month data evaluating the possibility of non-linear relationships associated with mercury exposure (Axtell et al., 2000). Endpoints included the six primary variables analyzed previously: McCarthy GCI, PLS, Woodcock-Johnson (WJ) applied problems, WJ letter/word recognition, Bender copying errors, and CBCL total T score. Generalized additive models, which make no assumptions about the relationship between exposure and test score, were used. Nonlinearities were identified between prenatal exposure and PLS and CBCL, and between postnatal exposure and McCarthy GCI. For the PLS the trend involved a decrement of 0.8 points (poorer performance) from 0 to 10 ppm and an increase of 1.3 points above 10 ppm. For the CBCL there was an increase (representing a poorer score) between 0 and 15 ppm and a decrease above 10 ppm. The GCI increased (improved) by 1.8 points through 10 ppm in the child's hair and declined by 3.1 above 10 ppm. Although these results are difficult to interpret, they provide limited evidence of an adverse effect of mercury exposure below 10 ppm maternal hair on two measures, and are associated with child's hair mercury concentration above 10 ppm on the GCI. As pointed out by the authors, there are fewer data points above 10 ppm (this is especially true for child's hair mercury), and therefore trends above this level are estimated less precisely.

The SCDS investigators used multiple linear regression to assess the results of the McCarthy GCI administered at 66 months (Palumbo et al., 2000). They analyzed the standard MSCA subscales and also constructed specific subscales to approximate the domains of cognitive functioning assessed in the Faroe Islands study: attention, executive function, expressive language, receptive language, nonverbal memory, visuospatial, and gross motor visuomotor development. They found a positive association between the child's hair mercury at 66 months and the standard memory subscale, with no other associations identified. As with all the previous analyses of these variables, the raw scores were converted to "normative" scores. As pointed out by the OSTP panel (NIEHS, 1999, Section 3.5 of the Confounders

and Variables Section), the applicability of U.S. norms to this population is unclear, and the use of standardized scores may decrease sensitivity by collapsing different raw scores to one standard score.

Faroes Population—Grandjean et al. (1997)

Testing was done at approximately 7 years of age on 917 of the surviving members of a 1986-1987 birth cohort of 1,022 singleton births. Maternal hair was sampled at parturition (geometric mean 4.3 ppm); children's hair mercury was measured at 12 months (geometric mean = 1.1 ppm) and 7 years of age (geometric mean = 3.0 ppm). Mercury was also measured in cord blood. The neuropsychological tests were these: computer-administered tests from the Neurobehavioral Evaluation System (NES) (finger tapping, hand-eye coordination, and continuous performance test); Tactual Performance Test; three subtests of the WISC-R (digit span, similarities, and block design); Bender Gestalt Test; CVLT; the BNT; and Nonverbal Analogue Profile of Mood States. Not all children could complete the entire battery; this was associated with increased mercury exposure for some tests such as the finger opposition test and mood test.

In multiple-regression analyses, increased cord-blood mercury concentration was significantly associated with worse scores on finger tapping, continuous performance test (CPT) (in the first year of data collection), WISC-R digit span, BNT, and CVLT. The investigators estimated that a tenfold increase in cord mercury concentration was associated with delays of 4 to 7 months in those neuropsychological domains. The maternal hair mercury concentration showed regression coefficients that were generally lower than those obtained with cord-blood mercury as the exposure indicator. For the finger tapping test, maternal hair mercury was a better predictor of effect, especially for the both-hands condition. The child's hair mercury measured at 12 months was a significant predictor for finger tapping with both hands and CPT reaction time; by contrast, hair mercury at the time of examination was significantly associated with continuous performance test reaction time, block designs, and Bender Visual Motor Gestalt errors.

When the Peters-Belson method for covariate adjustment was used, two additional endpoints (WISC-R block design, Bender Gestalt Test errors) were found to be associated with mercury exposure. Associations remained significant when the part of the cohort with maternal hair mercury concentrations greater than 10 ppm was excluded from the analyses. A term for the interaction between mercury and sex was not statistically significant, indicating that the effects were similar among boys and girls. In general, children's test scores were more strongly associated with cord-blood mercury concentration than

with either maternal hair mercury concentration or mercury concentrations in samples of children's hair collected at 1 and 7 years of age.

Grandjean et al. (1998) also analyzed the Faroese data in a case-control fashion. Two groups were assembled: a case group of 112 children with maternal hair concentrations of 10 to 20 ppm at parturition, and a control group of 272 children with maternal hair mercury concentrations less than 3 ppm. Controls were matched to cases on age, sex, year of examination, and caregiver intelligence. The median maternal hair mercury concentrations in the two groups were 1.8 and 12.5 μg/g, constituting a sevenfold difference. Median cord-blood mercury concentrations also differed substantially (59.0 μg/L in the case group versus 11.9 μg/L in the control group). On 6 of the 18 endpoints, the case group scored significantly lower than did the control group. The results of those analyses differ in certain respects from those of the main analyses. First, the set of endpoints on which the cases and controls differed is similar but not identical to the set of endpoints that was significantly associated with cord blood mercury concentration found in the main analyses. In the case-control analyses, a term for the interaction between mercury and sex was statistically significant for several scores: the Bender Gestalt Test error score, short-term reproduction on the CVLT, all three finger tapping conditions, CPT reaction time, and average hand-eye coordination score. For all scores, adverse mercury effects were noted for boys but not girls.

Amazon Valley—Grandjean et al. (1999)

A study cohort was assembled numbering 351 children ages 7 to 12. The population, which was drawn from four riverine communities in Amazonian Brazil, had increased exposures to methylmercury because of their consumption of fish contaminated by upstream gold-mining activities. When data on all four villages were combined, children's hair mercury concentrations were significantly associated with their scores on finger tapping, Santa Ana dexterity test, WISC-III digit span, Stanford-Binet copying and recall, and Stanford-Binet bead memory. Adjustment for community generally reduced the magnitude of the associations, sometimes dramatically. It was noted that hair mercury concentrations and village residence were so highly confounded, however, that adjustment for village might be inappropriate.

French Guiana population—Cordier and Garel (1999)

Cordier and Garel (1999) studied a cohort from a gold-mining area in French Guiana. Median maternal hair concentration was 6.6 ppm with a range of 2.9 to 17.8 ppm. Children ages 5 to 12 years old (n = 206) were administered a battery of neuropsychological tests: finger tapping, three subtests from the Stanford-Binet (block design, copying designs, bead memory), and two subtests from the McCarthy

scales (numerical memory, leg coordination). After adjustment for potential cofounders, increased maternal hair mercury concentrations were significantly associated with copying-design score; the effect was greater in boys. The data were reanalyzed to include only those observations from the region with highest mercury exposures (Upper Maroni). When observations were separated by gender, there was an association in boys between mercury exposure and poorer leg coordination, and with poorer block-design scores in girls.

Conclusions

There is ample evidence of low-dose *in utero* mercury effects on neuropsychological indices in school-age children. In the New Zealand population, maternal hair mercury was associated with poorer scores on several measures: full-scale IQ, language development (spoken language quotient), visual-spatial skills (perceptual-performance scale), and gross motor skills (motor scale). The poorer mean scores in the high-mercury group were largely attributable to the children of mothers with hair mercury above 10 ppm. One analysis by Crump et al. (1998) used maternal hair mercury as a continuous, rather than binary, variable; in this analysis there was no significant association with hair mercury. These analyses were heavily influenced by a single data point (a child with purported high developmental exposure who showed no abnormal scores). If data for this child are excluded, and parental education and age at testing are included as covariates, there are significant associates between mercury exposure and six scores.

In the SCDS pilot (cross-sectional) study, increasing maternal hair mercury was associated with the GCI and the perceptual performance scale of the McCarthy scales. Exclusion from analyses of several influential points reduced the significance of the mercury effect. As it was intended as a feasibility study, the pilot SCDS did not collect information on socioeconomic status, caregiver intelligence, or quality of home environment. In the SCDS main study there was no observation of any adverse effect of prenatal or postnatal mercury exposure. The NRC report commented on the regression model for the GCI score:

> The R^2 (square of the multiple correlation coefficient) value (0.10) of the reduced regression model for the GCI score in the main SCDS study was identical to that in the pilot study. That also appeared to be true for scores on the Preschool Language Scale.... That finding is puzzling because the pilot-study models...did not include several key covariates...and because the regression coefficients for socioeconomic status and caregiver intelligence were statistically significant for total scores of the GCI and Preschool Language Scale in the main study cohort. Those differences suggest that maternal hair Hg concentration is very highly confounded with

those key covariates in the Seychelles population, or they suggest that the associations between child neurodevelopment and the covariates differ substantially in the pilot and main study cohorts, or both (NRC 2000, pp. 203, 205).

In the Faroes population, mercury exposure measured in cord blood was associated with deficits on several measures: finger tapping, preferred hand; CPT (first year of data collection, two scores); mean reaction time, WISC-R digit span; BNT (with and without cues); and CVLT (short-term and long-term reproduction). The mercury effect was similar in males and females. Most test scores were more strongly associated with cord-blood mercury than with maternal hair mercury. In the case-control analysis, the case group scored significantly lower than the control group on 6 of 18 endpoints.

In two smaller populations there were observed effects of mercury exposure. Combining results from four communities in the Amazon basin showed a significant association of children's hair mercury with deficits on four measures. In a French Guiana cohort (n = 206), it was shown that maternal hair mercury was associated with one measure (a Stanford-Binet subtest), particularly in boys.

4.2.1.5 Sensory, Neurophysiological, and Other Endpoints in Children

Faroes population—Grandjean et al. (1997)

In the Faroe Islands cohort, the evaluation of 7-year-old children included assessments of visual acuity, near-contrast sensitivity, otoscopy and tympanometry, and some neurophysiological tests. Visual acuity, contrast sensitivity, auditory thresholds, and visual-evoked potentials were not significantly associated with prenatal methylmercury exposures. For brainstem auditory-evoked potential, peaks I, III, and V were slightly delayed at increased cord-blood mercury concentrations at both 20 and 40 Hz; interpeak latencies were not associated with mercury at either frequency.

Madeira population—Murata et al. (1999b)

Many of the same neurophysiological tests that had been done in the Faroe Islands study were administered to 6- to 7-year-old children living in Madeira. This was a cross-sectional study of 149 subjects. For brainstem auditory-evoked potential, maternal hair mercury was significantly associated with I-III and I-V interpeak latencies at both 20 and 40 Hz, as well as with total latencies for peaks III and V at both frequencies. Those results are similar to the findings in the children tested in the first year of the Faroes cohort. For visual-evoked potentials on a pattern-reversal task, maternal hair mercury

concentration was significantly associated with one of the three latencies, as well as with the N75-N145 and P100-N145 latencies.

Ecuador—Counter et al. (1998)

Auditory function in children and adults was investigated by Counter et al. (1998). The study sample consisted of 75 individuals (36 children and 39 adults) from a gold-mining region in Ecuador and 34 individuals (15 children and 19 adults) from nonmining areas as a control. Blood mercury concentrations were significantly higher in individuals (both adults and children) from the gold-mining area than in individuals from the control region (mean level of 17.5 μg/L versus 3.0 μg/L). Neurological examinations were carried out on all individuals. In children, blood mercury was significantly associated with hearing threshold at 3 kHz in the right ear only. No association was found for adults. A borderline association was found between blood mercury concentration and I-III interpeak transmission time on the left side in both children and adults. The authors concluded that overall auditory sensory-neural function and neural conduction time at the brainstem level were generally unaffected by elevated blood mercury levels in either children or adults.

Conclusions

There is increasing evidence of adverse endpoints other than cognitive development in mercury-exposed children. In the Faroes cohort, there were delays in some auditory-evoked potential peaks as a function of cord-blood mercury. Similar findings were reported for a smaller population from a fishing village in Madeira. A population of children in a gold-mining region of Ecuador showed an association between blood mercury and hearing threshold in the right ear at 3 kHz.

4.2.2 Choice of Study

Of the three large human developmental studies, two reported associations between low-dose *in utero* exposure to methylmercury and performance on standardized neurobehavioral tests. The Faroes investigators reported effects in the domains of attention, fine-motor function, confrontational naming, visual-spatial abilities, and verbal memory. Although similar results were reported for the New Zealand population (and in the Seychelles pilot study), there were no observations of adverse effects attributable to methylmercury in the main SCDS.

This section discusses issues relevant to the choice of critical study for calculation of a reference dose from among these three studies.

4.2.2.1 Critique of New Zealand Study

The study by Kjellstrom et al. (1986) included 57 fully matched groups of four 6-year-old children each as well as four incomplete sets, for a total of 237. As was the case for the Faroes study, these authors reported deficits in measures associated with methylmercury exposure. NRC noted (NRC, 2000 p. 251) that the New Zealand population's sources of methylmercury exposure and the study endpoints were similar to those examined in the Seychelles. While EPA was developing its RfD for the MSRC, the New Zealand data were available as a report that had not been subjected to standard peer-review procedures. In 1998, Crump and associates published a reanalysis of the New Zealand data that was peer reviewed. This paper reported associations of prenatal methylmercury exposure with several endpoints (when one extreme outlier was excluded), including four endpoints that were not found to be related to methylmercury in the Seychelles study. The New Zealand study has been criticized for errors in matching exposed children to controls and for testing exposed children and controls at different ages (Myers et al., 1998). Those errors occurred in the 4-year followup but were corrected in the 6-year followup. NRC notes (NRC, 2000, p. 209) that there is no reason to expect differential measurement error across the studies. An error of that type is likely to be nondifferential (i.e., unbiased), and it would reduce the likelihood of detecting associations between methylmercury exposure and neurobehavioral test scores.

The Kjellstrom et al. (1986) study collected data on several potential confounding factors and used a broad battery of standardized measures that were administered by trained examiners. It is likely that the exposure was relatively low-dose and not episodic, reflecting well-established food consumption patterns. The section below discussed controls for possible confounders in the SCDS and Faroes studies. An important variable is the concomitant exposure to organochlorine compounds such as PCBs and pesticides that could have neurotoxic effects. There is essentially no information on the extent of such exposures in the New Zealand study population, either in the original report or in follow-up analyses (e.g. Crump, 1998).

4.2.2.2 Control for Possible Confounding

Both the Faroes study and the SCDS evaluated most of the variables that have been linked to childhood cognitive development. Table 6-2 of the NRC report lists these and notes which study

controlled for the particular variable. Although neither study controlled for all potential confounders, it was felt by the authors of the NRC report that the influences of those variables on cognitive outcome are probably too weak to account for any major inconsistencies between the two studies. The Confounders and Variables Panel of expert workshops sponsored by OSTP had earlier concluded that neither the SCDS nor the Faroese study was critically flawed and that these studies were suitable for determination of the upper limit of a methylmercury NOAEL (NIEHS, 1999).

Place of Faroese residence—town versus country

At the 1998 OSTP workshop, the Faroes investigators noted that the maternal Ravens scores and the child verbal-test scores were generally higher among families residing in one of the three towns in the Faroes compared with those living in the countryside (NIEHS, 1999). This was thought to be due to social-class differences. It was suggested that because more fish and, in particular, whale meat was consumed by rural residents, the associations of mercury exposure with child verbal-test scores could in fact reflect those social-class differences. However, analyses presented at the workshop showed that these associations remained significant even after controlling for a dichotomous town-country control variable (Table 6-3 in the NRC report). NRC felt it would not be appropriate to control for town residence in all analyses. They made the following statement:

> Because fish and whale consumption constitute a large proportion of the rural diet, the disappearance of associations after controlling for residence could be due to the fact that residing in a rural area leads to increased Hg exposure which, in turn, causes an adverse outcome. It would not necessarily indicate that the lower social class associated with rural residence is the true cause of the Hg-associated deficit. The disappearance of an association between Hg and neurobehavioral effects under those circumstances would be very difficult to interpret, because the interpretation would depend upon what condition is considered the reason for the association between living in a rural area and poor outcome (i.e., lower social class or greater Hg exposure) (NRC, 2000, p. 261).

Another source of town versus country difference could be the distance traveled to the testing site, with resulting fatigue in the children from the countryside. However, analyses showed that the regression coefficients for prenatal mercury exposure remain significant even after controlling for child's residence.

Test administration

The neuropsychological test examiner was routinely controlled for in the Faroe Islands study (see NIEHS, 1999, Section 3.5), but not the SCDS. It was suggested at the OSTP workshop that if an examiner who is less adept at eliciting optimal performance from the subjects tested a large proportion of less-exposed children, the results could be affected (NIEHS, 1999). NRC noted:

> If those children performed more poorly than they otherwise would have on the test, an association between Hg concentration and test scores might be obscured by failure to control for the examiner. That result could also occur if an adept tester tested a large proportion of the more heavily exposed children, leading them to achieve higher scores than they would have if tested by other examiners (NRC, 2000 p. 263).

Age at testing

The SCDS controlled for age at testing by converting the raw test scores to age-corrected standard scores with conversion tables based on U.S. norms (NIEHS, 1999). The Faroes investigators analyzed the raw scores by adjusting statistically for the child's age (measured in days since birth). NRC found the latter approach to be preferable (NRC, 2000, p. 263). They noted, first, that the applicability of U.S. norms to these study populations is uncertain. In this context it should be noted that the Seychellois scores on the BSID were higher than U.S. averages at both 19 and 29 months. Second, NRC felt that the use of age-corrected standard scores could reduce the sensitivity of the test, because several adjacent raw scores are treated as equivalent in converting to standard scores. Last, they noted that age-corrected standard scores use 3-month intervals, which introduces a degree of arbitrariness in assigning a child to a particular group. The NRC report found the approach of controlling statistically for age by multiple regression to be appropriate, because the effect of age is likely to be linear across the relatively short age period (3 months in both studies); that is, over short time periods, development is most likely to take place at a constant rate.

Some members of the scientific community have noted the possibility that the most important difference in the design of the two studies is the age of the child at assessment; 7-year-olds were tested in the Faroes as opposed to children 5.5 years of age in the SCDS. Developmental assessments are likely to be less sensitive in detecting subtle neurotoxic effects when they are administered during a period of rapid developmental change. Individual differences in the rate of neurocognitive maturation may mask subtle differences in function attributable to toxic exposures. NRC (2000, pp. 257-258) also noted that

infant assessments in the SCDS (namely the 19 and 29 month Bayley Scale examinations) were not given at optimal age points for detecting effects, particularly in this developmentally robust population.

Selection bias from exclusion of individuals with severe impairments

The OSTP workshop Confounders and Variables Panel (NIEHS, 1999) identified what they considered a serious potential issue with the SCDS. They noted that recruitment was limited to children with no severe debilitating conditions. This panel felt that such a restriction could lead to underestimation of effect when the shape of the dose-response curve is not known.

PCB exposure in the Faroese population

PCB exposure through maternal consumption of whale blubber was discussed at length at the OSTP workshop and in the report of the Confounders and Variables Panel (NIEHS, 1999). Using the data from the part of the cohort for which cord PCB was measured, Grandjean et al. (1997) performed a series of analyses to ascertain if the PCB and mercury effects could be separated. Of the eight outcomes for which there was a significant association with cord-blood mercury, four were also associated ($p<0.1$) with log transformed PCB levels in cord tissue before adjustment for mercury. These four endpoints were also significantly related to mercury cord-blood concentrations. These were CPT reaction time, BNT with and without cues, and CVLT long-term reproduction (Table 4-1). When PCBs were included in the regression analysis, only the CPT reaction time remained significantly associated with mercury. CVLT and BNT with no cues were not significantly associated with either agent, whereas BNT with cues was about equally associated with both ($p \leq 0.10$). It is important to recognize that such an analysis removes the shared variance related to both mercury and PCBs, thereby reducing the p value associated with either agent.

The Faroes investigators considered CPT reaction time to be a test of attention, BNT to assess language, and CVLT to assess memory (Grandjean et al., 1997). Deficits in overall cognitive functioning and verbal comprehension have been found to be associated with *in utero* PCB exposure in a study of 4.5-year-old children in the Netherlands (Patandin et al., 1999a), whereas deficits on a vigilance task similar to the CPT were associated with cord PCB levels (commission errors) as well as the child's concurrent PCB exposure (reaction time) (Patandin et al., 1999b). In the Patandin et al. study, PCB and dioxin exposure was through diet unrelated to fish consumption. Another study reported effects of exposure to children through their mothers' consumption of contaminated Lake Michigan fish. Deficits in attention, language processing (reading comprehension), and memory related to prenatal PCB

Table 4-1. Regression coefficients (betas) for effects of logarithmic transformations of mercury before and after adjustment for PCB concentrations on Faroese neuropsychological tests: results from 7-year-old children from the first year of testing.

	Before Adjustment		After Adjustment for PCB			
				p-Values		
Neuropsychological Test	Beta	p-Value	Beta	Mercury	PCB	Both
Continuous Performance Test						
Average reaction time (ms)	39.3	<0.001	37.8	0.002	0.64	0.001
Boston Naming Text						
No cues	-1.58	0.04	-1.04	0.21	0.16	0.05
With cues	-2.03	0.007	-1.36	0.10	0.08	0.008
California Verbal Learning Test (Children)	-0.99	0.03	-0.78	0.11	0.26	0.05
Long-term reproduction						

From Grandjean et al., 1997.

exposure were identified in 11-year-old children (Jacobson and Jacobson, 1996). Other contaminants undoubtedly present in the fish, including methylmercury, were not assessed in this study; the potential contribution of methylmercury exposure to the observed effects could not be evaluated.

It is informative to compare PCB levels in other studies reporting adverse effects associated with PCBs with PCB levels in the Faroese women. No breast milk or blood PCB levels from the mothers or infants in the Faroe Islands cohort have been published. However, a recent study compared levels of PCB congener 153 in human blood in pregnant women from the Faroe Islands consuming 0-1 blubber meals/month ("low") or 2-3 blubber meals/month ("high") with other populations (Fängström et al., 2000). "Low" Faroese exposure was comparable to blood PCB levels in an unspecified number of pregnant women in the Netherlands, whereas "high" Faroese blood PCB levels were comparable to those in an identified highly exposed population in the Quebec Arctic. The Faroese samples in the Fängström et al. (2000) analysis were collected in 1994-1995, and the cohort for the Faroe study of developmental neurotoxicity was recruited in 1986-1987. It is unclear when the Dutch samples in the Fängström et al. (2000) study were collected; the cohort in the Dutch developmental study was recruited in 1990-1992. Blood levels cannot be directly compared between the Dutch study and the Fängström et al. (2000) data because one was on lipid-adjusted serum and the other on non-lipid-adjusted plasma. Similarly, breast

milk levels cannot be directly compared (Grandjean et al., 1995; Steurwald et al., 2000; Lanting et al., 1998). In general, human body burdens of PCBs have decreased by about 50% over the past decade, so it is possible that blood levels in the Dutch study were higher than those reported in the Fängström *et al.* (2000) paper. It is also quite probable that PCB levels in the Faroe Islands were higher in the mid-1980s than the mid-1990s, suggesting that the "low" Faroe exposure is comparable to levels in the Dutch study. It is important to reiterate that whereas there may have been effects of PCBs in addition to those of methylmercury, statistical analyses indicated that the effects were independent in this population (Budtz-Jørgensen et al., 1999).

The Confounders and Variables Panel at the OSTP meeting (NIEHS, 1998) concluded that both PCB and mercury had adverse effects on the CVLT score and on the BNT scores with and without cues. They felt that it was not possible to determine the relative contribution of each. NRC concluded that there was no empirical evidence or theoretical mechanism to support the opinion that *in utero* Faroese exposure to PCBs exacerbated the reported methylmercury effect. They note that statistical tests for interaction between PCB and mercury show no interaction. NRC reached a similar conclusion to the Confounders and Variables Panel; a likely explanation is that both PCB and mercury adversely affect some test outcomes, but their relative contributions cannot be determined given their co-occurrence in the Faroes population. NRC states it is unlikely that a difference in PCB exposure between the two populations explains the lack of developmental neurotoxic effects in the Seychelles (NRC, 2000, pp. 220 and 223).

In a second set of analyses, Budtz-Jørgensen et al. (1999) found that the effect of prenatal PCB exposure was reduced when the data were sorted into tertiles by cord PCB concentrations. Regressions assessing mercury exposure and the five principal test outcomes were then run separately for each of the three groups. The regression coefficients for a mercury effect in the lowest PCB tertile were no weaker than those for the higher two PCB groups. This lends additional credence to a conclusion that the associations between mercury and test outcomes are not attributable to confounding by prenatal PCB exposure. Calculations of benchmark doses and lower limits (BMDLs) were done using the whole cohort, after a PCB correction and for the portion of the cohort with the lowest PCBs (NRC 2000 , Table 7-4, reproduced here as Table 4-2). In this table results are reported separately for methylmercury measured in hair and cord blood and are calculated using the K-power model described in Section 4.3.4. NRC commented on the results for the low-PCB-exposed subset for the two endpoints that were related to PCB exposure, the BNT and the CVLT. They noted that the BMDs for these outcomes did not differ from the BMDs for the total sample by any more than the BMDs for the two endpoints that were not related to PCB exposure. NRC opined that the variability seen in Table 4-2 is no more than that expected

by chance; the BMDs and BMDLs for both the PCB-adjusted and the low-PCB subset analyses are within the intervals defined by the BMDs and corresponding BMDLs derived for the full cohort. The difference between the BMDs based on the full cohort and the low PCB subset is less than one standard error of the low PCB subset (NRC, 2000, p. 288). These analyses support a conclusion that there are measurable effects of methylmercury exposure in the Faroese children that are not attributable to PCB toxicity.

PCB body burdens in the Seychellois are very low by comparison to North American and European populations. In 28 serum samples obtained from Seychelles study children, there were no detectable concentrations of any PCB congeners. In the Faroes study, prenatal PCB exposure was measured in 436 stored umbilical cord tissue samples. It was noted at the OSTP workshop that cord tissue PCB concentration has never been validated in relation to blood or milk concentration; because cord tissue is lean and PCBs are lipophilic, the panel felt that it may not be the most reliable indication of total PCB body burden (NIEHS, 1999). The cord samples were analyzed for a small subset of PCB congeners that were used to represent the biologically significant PCB exposure. In an earlier publication (Grandjean, et al., 1995) it was shown that these congeners predominate in samples from the Faroes cohort; comprise these three congeners comprise approximately 50% of the PCBs in breast milk lipid. These same three congeners, along with one other, were used to quantify PCB body burdens in milk and plasma in a study of children in the Netherlands (Lanting et al., 1998). The approach taken in the Faroes for quantifying PCB exposure (adding three key congeners together and multiplying by 2) appears to be a reasonable approach for estimating total PCB exposure and is not expected to introduce a bias into the analysis.

4.2.2.3 Population Differences in Susceptibility

Populations may be more or less susceptible to effects of a toxicant as a consequence of predisposing factors, such as nutritional status, exposure to other agents (see Section 4.2.2.1), or genetic susceptibility.

The SCDS cohort is predominantly African in descent; the Faroes cohort is Caucasian. The latter population has been somewhat isolated and thought to be descended from a small number of "founders." This homogeneity in the Faroes could increase or decrease genetic susceptibility to effects of toxic insult. NRC noted that methylmercury neurodevelopmental effects were observed in a genetically heterogeneous and racially diverse sample studied in New Zealand, a population that was predominantly non-Caucasian.

Table 4-2. BMD (BMDL) Estimates from the Faroe Islands Study with and without adjustment for PCBs and in the subset of Low PCB-exposed children (reproduced from NRC 2000)

		Full Cohort	Adjusted for PCBs	Low PCB subset
Exposure	**Endpoint**	**BMD (BMDL)[a]**	**BMD (BMDL)**	**BMD (BMDL)**
Hair	Finger tapping	20 (12)	17 (9)	7 (4)
	CPT Reaction Time	18 (10)	27 (11)	13 (5)
	Boston Naming Test	15 (10)	24 (10)	21 (6)
	CVLT: Delayed Recall	27 (14)	39 (12)	32 (7)
Cord Blood	Finger tapping	140 (79)	149 (66)	41 (24)
	CPT Reaction Time	72 (46)	83 (49)	53 (28)
	Boston Naming Test	85 (58)	184 (71)	127 (40)
	CVLT: Delayed Recall	246 (103)	224 (78)	393 (52)

[a]BMDs are calculated under the assumption that 5% of the responses will be abnormal in unexposed subjects ($P_0 = 0.05$), assuming a 5% excess risk (BMR = 0.05).

Source: E. Budtz-Jørgensen, Copenhagen University, N. Keiding, Copenhagen University, and P. Grandjean, University of Southern Denmark, unpublished material, April 28, 2000.

Data on birthweight and gestation length in the Faroes and Seychelles show no indication of energy or macronutrient (protein and carbohydrate) deficiency. It is possible that members of either population could be deficient in micronutrients. It has been suggested that certain nutrients found in fish eaten by the Seychelles residents (e.g., omega-3 fatty acids and selenium) could attenuate adverse effects of methylmercury exposure. It should be noted that both the Faroese and New Zealand populations would be considered "high fish consumers" by comparison to U.S. norms, and both populations were observed to have measurable effects of mercury exposure. It is unlikely that general health status of the Faroese and Seychellois was a factor in enhancement or attenuation of mercury effects. Both populations receive excellent health care.

The point was made in Section 4.2.2.2 that recruitment in the SCDS was limited to children with no severe debilitating conditions. In the opinion of some scientists this may contribute to making the Faroes sample more representative of the population at risk in the United States in that it includes infants with some degree of initial perinatal risk.

It has been noted in several scientific forums that the cohort in the main Seychelles study appears to have been robust for psychomotor development at early ages. The SCDS authors report a number of abnormal scores on the Denver Developmental Screening Test that are considered to be exceptionally low by U.S. norms. The population also was observed to have an unusually high mean PDI score and a very low rate of referral for mental retardation. The means and standard deviations of the cognitive measures administered at later ages were similar to U.S. norms. It is not clear what, if any, effect this

developmental robustness has on susceptibility to adverse effects of prenatal Hg exposure. Statistical power to find an adverse effect is discussed in Section 4.2.2.8.

4.2.2.4 Assessment of Prenatal Mercury Exposure

In the Faroes study, mercury in cord blood and maternal hair was measured; in the Seychelles, maternal hair mercury was the biomarker of exposure. The maternal hair samples obtained in the Faroes and Seychelles studies did not necessarily reflect the same period of pregnancy. The Seychelles samples were 9-cm lengths of hair reflecting average mercury exposure during pregnancy. The Faroes study analyzed mercury from hair samples of variable length, some 3 cm (reflecting late second and third trimester) and some 9 cm (presumably reflecting the entire pregnancy).

In the analyses of the Faroese data, cord-blood mercury concentration was significantly associated with a slightly larger number of endpoints than was maternal hair mercury. Given the estimated half-life of methylmercury and what is known of PBPK, it could be assumed that cord-blood mercury reflects the latter part of gestation. Hair mercury could reflect the entire pregnancy or could be segmentally analyzed to provide snapshots of various times in gestation. Some of the effects reported in the Faroese cohort could be related to toxic responses in the latter stages of prenatal development. However, hair mercury concentrations in the Faroe Islands study were only a slightly weaker predictor of methylmercury effects than was cord blood. NRC concluded that it would be reasonable to expect that, if children were affected in the main Seychelles study, some indication of an association between child development and maternal hair mercury concentration would have been observed (NRC, 2000, p. 252). It noted that the findings of developmental effects reported in New Zealand were based solely on maternal hair sample data averaged across the entire period of pregnancy. The difference in the observation of effects between the Faroes study and the SCDS is thus not an artifact of biomarkers of exposure.

4.2.2.5 Level of Exposure

In their analyses the SCDS authors used maternal hair mercury as the biomarker of exposure; the Faroes investigators used both cord blood and maternal hair mercury. A comparison of maternal hair mercury levels indicates that exposure in the two studies was in the same range. For the main SCDS, the median hair mercury was 5.9 ppm with a range of 0.5 ppm to 26.7 for the whole cohort. In the Faroes birth cohort (n = 1,020), the median hair mercury was 4.5 ppm with a range of 2.7 to 42.6 ppm (Grandjean et al., 1992) . That the Seychelles Islands study may entail a lower exposure level than the Faroe Islands study could be concluded from two lines of evidence: the hair:blood ratio from the

Seychelles Islands and laboratory studies suggesting that dietary factors can influence tissue levels of methylmercury.

The ratio of hair mercury to blood mercury in the Seychelles study was estimated to be 416, a value that is higher than ratios reported elsewhere, which span 190 to 367 (Stern, 1997). The hair: cord blood ratio for the Faroes cohort was 191 (Grandjean et al., 1992). The value commonly used in dose conversion models is 250 (Stern, 1997; U.S. EPA, 1997e). If the value of 416 is used in estimating maternal or fetal blood mercury then estimates of the dose experienced by the Seychellois fetuses would be lower, by almost twofold, than assumed.

The hair: blood ratio of 416 is plausible for the Seychellois population considering their high fish diet and suggestions in the literature that diet can influence tissue levels of mercury. Average fish consumption in that population is 12 fish meals/week, which is likely to result in comparatively high levels of n-3 fatty acids and selenium. Such a diet may alter the kinetics of mercury by lowering blood or organ levels of mercury associated with a certain level of intake.

4.2.2.6 Episodic Versus Continuous Exposure

Exposure to methylmercury in the Seychelles is through daily consumption of fish. Although the Faroese eat fish more frequently than does the average consumer in the United States (about three meals a week), a significant source of methylmercury exposure in this population is from eating pilot whale meat. Pilot whale meals are relatively infrequent (less than once per month on the average) (Grandjean et al., 1992) with additional intermittent snacks of dried whale (Grandjean et al., 1998). The whale meat mercury concentration varies with the pod. An analysis of 466 whales showed an average concentration of 1.9 ppm, with a range of 0.59 to 3.30 ppm (Faroese Food Agency data quoted in NIEHS, 1999). There is no evidence to indicate that methylmercury bioavailability from the muscle of pilot whale is any different from that of fish tissue.

In the New Zealand study, there was the assumption of regular consumption of a relatively high-mercury fish (shark) in fish and chips, the major fast food of the area; the actual frequency and pattern of exposure are unavailable.

The degree to which differences in exposure pattern among studies account for differences in outcome is uncertain. It has been suggested that the mercury body burden in the Faroe Islands study was the consequence of a "spike" exposure pattern, in contrast to a more continuous exposure pattern in the

Seychelles study, which nonetheless resulted in a similar body burden. The Faroese investigators did segmental analyses of a small number of long hair strands from cohort mothers. Their results indicated a few instances of hair mercury peaks that implied temporal variation or spiking. They noted, however, that the peak level was only about twice the lowest hair mercury concentration (Budtz-Jørgensen et al., 1999).

The pattern of exposure can be a critical determinant of *in utero* toxicity. For example, the NRC report cites data in animals that showed that maternal ingestion of a given dose of alcohol over a short time caused greater neuronal impairment (Bonthius and West, 1990) and behavioral impairment (Goodlett et al., 1987) than that caused by gradual ingestion of the same total dose over several days. The frequency of exposure has a significant influence on the variation in blood levels, even under steady-state conditions, and is dependent on blood half-life (Rice et al., 1989).

It is probable that both episodic and continuous patterns of exposure are present in the population of the United States. Individuals in some ethnic groups engage in a subsistence-type fishing pattern, consuming fish as their major protein source. Most sport fishers, however, consume fish on an intermittent basis. It is not uncommon for piscivorous fish in inland waters to have mercury levels exceeding 1 to 2 ppm (U.S. EPA, 1997), so that the body burden of mercury in this group of fish consumers would presumably be the result of episodic exposure to food sources with levels of mercury similar to those in the Faroe Islands (see also Section 5.4.4 of this document). It may be that the consumption pattern of the Faroe Islands population better represents the pattern of exposure in the majority of the U.S. population exposed to elevated levels of methylmercury than does the consumption pattern of the population of the Seychelles Islands.

4.2.2.7 Endpoints Assessed

As described in Section 4.2.1, there have been inconsistent indications of adverse effect in newborns or preschool children of mothers experiencing low-dose, long-term exposure to methylmercury. The lack of consistent positive findings using standard newborn neurological tests has been considered unsurprising. Neurological examination of the newborn and young infant presents testing challenges that are difficult to meet in large-scale studies. The state of the newborn determines to a significant degree the quality and intensity of response to stimulation during an examination. "The state of an infant is usually dependent upon factors that are often outside the examiner's control, such as hunger, hydration, illness, and the temporal location of an infant in its sleep-wake cycle. The recognition that state is a key variable in newborn behavior can be found in the fact that neonatal behavioral and

neurologic assessments usually indicate what state the newborn should be in before a given item series is administered..." (K. Deitrich, in U.S. EPA, 2000f).

It has been observed that most of the deficits associated with low-level prenatal exposure to developmental toxicants would not be revealed in a pediatric neurological examination and that gross neurological findings are unlikely in such studies. It has also been shown in studies not related to methylmercury that minor neonatal neurological deviations from the norm are not predictive of later neurobehavioral morbidity (U.S. EPA, 2000f).

Screening tests such as the Denver Developmental Screening Test have been used with highly variable results in methylmercury studies. Section 4.2.1 reports the differences in results among the New Zealand, SCDS pilot, and SCDS main cohorts. Recent research suggests that screening tests are not as sensitive as once believed and are no longer recommended for use in studies of low-level environmental chemical exposures to the fetus or infant (U.S. EPA, 2000f).

In the opinion of most developmental scientists, the Faroes and Seychelles studies used very different neurobehavioral test batteries. The tests selected for use in the SCDS are considered apical or omnibus tests (e.g., the McCarthy Scales of Children's Abilities); these provide global scores that integrate performance over many separate neuropsychological domains. The investigators studying the Faroes population were working from a hypothesis that mercury would have multifocal domain-specific neuropsychological effects. The OSTP Neurobehavioral Endpoints Panel was similarly disposed. They noted that it is plausible that prenatal exposure to methylmercury may not affect IQ, but rather domain-specific areas such as memory deficits, motor delays, or effects on so called "executive functions" – the complex domains that involve planning and cognitive flexibility (NIEHS, 1999). The Faroese test battery consisted of highly focused tests selected from those commonly used in clinical neuropsychology (e.g., CVLT and BNT) and did not include an apical test of global function. They observed effects in areas of language, memory, motor skills, visual-spatial abilities, and attention.

Many of the subscales of the McCarthy Scales might be expected to provide measures comparable to some tests administered to the Faroese children. However, there was no evidence from the McCarthy subtests of domain-specific effects in the Seychelles. These included verbal, perceptual-performance, quantitative memory, and motor scores. One conclusion is that if there were actually domain-specific effects occurring in the 5-year-old Seychellois, they should have been observed in the analyses of the McCarthy Scales results. The NRC panel came to a different conclusion: "Although the Faroe Islands and SCDS test batteries include tests of language and memory, it is not appropriate to view the endpoints

used in the studies to assess each domain to be equivalent either in terms of the specific skills assessed or the test sensitivity." (NRC, 2000, pp. 256-257).

One test was administered to both populations: the Bender-Gestalt Test. The investigators used different scoring systems; the SCDS used the Koppitz system whereas the Faroes used the Gottingen system. The NRC report noted that in a paper by Trillingsgaard et al. (1985) scores derived using the more detailed Gottingen system were significantly associated with low-dose lead exposure, whereas scores on the Koppitz system were not. Thus the Gottingen system used in the Faroe Islands might be more sensitive.

A second important difference in the assessment batteries used in the Faroes study and SCDS is the age of the child at assessment; 7-year-olds were tested in the Faroe Islands in contrast to children 5.5 years of age in the SCDS. Assessments in the New Zealand cohort were done at 4 and 6 years of age. It is generally thought that developmental assessments are likely to be less able to detect subtle neurotoxic effects when they are administered during a period of rapid developmental change. The period covering ages 60 to 72 months (when the SCDS and New Zealand cohorts were evaluated) is such a time; individual differences in the rate of cognitive maturation are likely to eclipse subtle differences in function attributable to a teratogenic exposure (Jacobson and Jacobson, 1991). The NRC panel also felt that in the SCDS, assessments of infants (particularly the 19- and 29-month BSID) were not given at optimal age points. Their report makes the following statement:

> Studies of prenatal exposure to alcohol and other substances that have administered the Bayley scales at multiple ages have repeatedly failed to detect effects at 18 months, probably because it too is a period of rapid cognitive maturation, involving the emergence of spoken language. Twenty-nine months is likely to be an insensitive testing point for the Bayley scales because it is at the end of the age range for which the version of this test used in the Seychelles was standardized, leading to a substantial risk of a "ceiling effect" (i.e., too many children receiving the highest possible scores on numerous items) (NRC, 2000 pp. 257-258).

The overall conclusion of NRC, however, was that discrepancies between the Faroe Islands and the main Seychelles studies are probably not due to differences in the assessments. They point out that the New Zealand study observed associations between methylmercury exposure and scores on the McCarthy Scales of Children's Abilities (the primary outcome measure used in the SCDS) at about the same age of assessment as in the Seychelles study (NRC, 2000, p. 258).

4.2.2.8 Power of Studies

NRC commented on the power to detect subtle effects in the admittedly large human studies (NRC, 2000, pp. 266-267). They noted that it is possible that the differences in response between the Faroes study and the SCDS could be due to between-sample variability in the expression of neurotoxicity at low doses. NRC remarked that even large samples can have insufficient power to detect adverse effects if a relatively small number of subjects are exposed in the upper ranges of the exposure distributions, where those effects will presumably be found.

NRC said that the magnitude of the associations found in the methylmercury studies resembles that reported for other environmental contaminants, such as low-dose lead and PCBs. If the magnitude of an association is not large, it is not likely that it would be detected in every cohort studied. NRC noted by comparison that it is well established in the scientific community that a blood lead concentration in excess of 10 μg/dL places a child at increased risk of poor developmental outcomes. However, not all lead studies have found an association between exposure at this level and decreased performance, and substantial variability exists in the magnitudes of the reported effects (Bellinger, 1995). NRC noted for the SCDS, "the evidence consistent with such effects found in the pilot phase, coupled with the suggestion of unusual developmental robustness in the main study, suggest that the failure to detect apparent adverse effects in the main study could be due to the substantial sample-to-sample variation expected when trying to identify weak associations in an inherently 'noisy' system of complex, multi-determined neurobehavioral endpoints" (NRC, 2000, p. 267).

In another comment on power, NRC says that power analyses based on total sample size can be misleading if adverse effects occur primarily among the most heavily exposed individuals, who typically constitute a small proportion of the sample. They note that of 700 children in the SCDS, only about 35 were exposed at levels concordant with maternal hair mercury of 15 ppm or higher. Because multiple-regression analysis examines associations that are averaged across the entire distribution of exposure, associations that hold only for the most highly exposed children can be difficult to detect. "Thus, if adverse effects of prenatal MeHg exposure occur primarily in the upper range, the power to detect them will be limited, and it would not be surprising if associations found in one Seychelles cohort (the pilot study) were not detected in the next cohort (the main study)" (NRC, 2000, p. 267).

In this context it should be noted that Grandjean et al. (1997) published an analysis of their neuropsychological test data on 7-year-old children, wherein they excluded all scores from children born to mothers with 10 ppm or higher hair mercury. This decreased the number of observations by 15%. In

the multiple-regression analyses, regression coefficients and p values were very similar to those obtained when data on the full cohort were used. This indicates that in this study population, adverse effects of mercury were detectable at exposures below 10 ppm maternal hair mercury.

4.2.2.9 Selection of Study

There is a large database on potential neurodevelopmental effects of methylmercury. In particular, three large, well-designed, prospective longitudinal studies have been peer reviewed and intensively analyzed. Some results from these studies of large populations are in apparent conflict. The previous sections reviewed some of the factors that have been suggested to account for the finding of adverse outcomes associated with *in utero* mercury exposure in the Faroes and New Zealand and the lack of this association in the SCDS. None of these factors represents a critical flaw in study design or execution. None of the factors adequately explains the differences in the study outcomes.

The NRC (NRC, 2000, p. 221) suggests that the finding of a low-dose methylmercury effect in a culturally and genetically heterogenous population in New Zealand study decreases the importance of population sensitivity issues in comparing the Seychelles and Faroes studies. The New Zealand study had a higher baseline rate of abnormal and questionable DDST scores in the test (8%-17% in controls) than did the Seychelles study (8% in the complete pilot cohort, 1.9% of the complete main cohort). This observation is consistent with the suggestion that the lack of effects in the Seychelles population is related to its relatively higher level of neurological performance at critical early life stages. Another possibility is that the manner in which the tests were given in the Seychelles led to better test performance, resulting in a less sensitive measure (i.e., an easier test for children to pass). The SCDS may also have had reduced power because of the small number of maternal-child pairs with methylmercury over 15 ppm. A comparison of the numbers in the relatively high-exposure range is instructive. If one uses 10 ppm maternal hair mercury as the high-exposure cutoff, there are about 150 Faroes subjects, at least 100 Seychelles subjects, and only 16 New Zealand subjects in this category (see Fig. 5-6, p. 166, NRC report).

One strength of the New Zealand study is that an effect was shown in an ethnically heterogeneous sample; another advantage was that the study used developmental endpoints with predictive validity. However, EPA acknowledges and shares the NRC reservations about using the New Zealand study as the basis for the methylmercury RfD. The New Zealand study is relatively small, with 237 subjects, by comparison with the population of up to 900 for the Faroes tests. Moreover, the New Zealand data have

not had the exhaustive scientific scrutiny that have been applied to the SCDS and Faroes study. The advantages of the Faroes study include these:

- large sample size;
- good statistical power as calculated by conventional means;
- the use of two different biomarkers of exposure;
- comprehensive and focused neuropsychological assessment;
- assessment at an age and state of development when effects on complex neuropsychological functions are most likely to be detectable;
- statistically significant observations that remain after adjusting for potential PCB effects; and
- extensive scrutiny in the epidemiological literature.

The Faroes data have also undergone extensive reanalyses in response to questions raised by panelists in the NIEHS (1999) workshop and by NRC (2000). The SCDS shares many strengths of the Faroes study. However, EPA agrees with NRC that a positive study, one that shows statistically significant associations between prenatal mercury exposure and adverse outcomes, is the strongest public health basis for an RfD (NRC, 2000, p. 6). Moreover, although one can model the nonpositive results of the SCDS, the resulting estimates of no effect level are difficult to interpret.

The study selected by EPA as the basis of the methylmercury RfD is the report of developmental neurotoxicity in 7-year-old children in the Faroes. The next section discusses issues in choice of endpoint for the RfD calculation. Many of the arguments in study selection pertain to choice of endpoint as well.

4.2.3 Choice of Critical Effect (endpoint)

EPA considered recommendations of NRC and the external peer reviewers in making the choice of a critical effect or endpoint from the Faroese data on neuropsychological effects in children. Rather than choosing a single measure for the RfD critical endpoint, EPA considers that this RfD is based on several Faroese test scores. These test scores are all indications of neuropsychological processes that are involved with the ability of a child to learn and process information. The issues and decision points in coming to this choice are described in the following sections.

4.2.3.1 Endpoints Suitable for RfD Derivation

Several studies have reported significant associations between increased numbers of combined abnormal and questionable scores on standardized neurological examinations. NRC opined that the functional importance of these effects is uncertain. There is little evidence that relatively low-dose, long-term exposure has any significant effect on language or motor-skill developmental milestones. There is some evidence of an association between *in utero* mercury exposure and deficits on the DDST. The NRC put forth the opinion that this screening test is not as useful as others in developmental neurotoxicological testing.

As is shown in Table 4-3, the tests used in the Seychelles and New Zealand studies in general were apical tests, assessing broad functional categories. These tests are widely used clinically and have been validated and normed for the U.S. population (but not the populations in which they were used). In contrast, the tests used in the Faroe Islands study were chosen to assess specific behavioral domains. The global clinical instruments such as the McCarthy, WISC-R, and CBCL have manuals that describe the tests and domains assessed, as well as the predictive validity of scores on these instruments to "real-world" behavior such as school performance. For the tasks used in Faroe Islands, finger tapping is a commonly used assessment of motor speed (Letz, 1990), and the Bender is a standardized test of childhood development. The other three endpoints also have demonstrated clinical relevance and predictive value As outlined in the table, most of these endpoints are predictive of ability in various academic skills, and therefore school performance. These tests, whether designed to be relatively global or domain-specific, were adversely affected by methylmercury exposure in the Faroe Islands and New Zealand, but not the Seychelles Islands, studies. In addition, motor performance was adversely affected in both New Zealand and the Faroe Islands. The only study that assessed social and adaptive behavior was the SCDS. BMD analysis performed by the NRC committee identified adverse effects on the CBCL at maternal hair levels comparable to those at which effects were observed in the Faroe Islands study (NRC, 2000, Table 7-5, p. 291). As concluded by the NRC (NRC, 2000, p. 325), the deficits observed in the New Zealand and Faroe Islands study can be considered predictive of problems in cognitive and academic performance associated with methylmercury exposure.

NRC presented BMDs and BMDLs for several endpoints in the positive Faroes and New Zealand studies as well as for the nonpositive Seychelles study (the next section discusses choices of model and choices made in BMDL calculation). Reproduced below is Table 7-2 from the NRC report (here as Table 4-4), which compares BMDs from the three studies in terms of maternal hair mercury. Included in this table are the New Zealand BMDs calculated after exclusion of the data from the highest exposed

individual. NRC suggested that this hair mercury concentration of 86 ppm is not plausible. The text reads:

> a hair Hg concentration of 86 ppm is more than 4 times the next highest hair Hg concentration in the study. If the one-compartment pharmacokinetic model and EPA's standard default input assumption are used, it can be estimated that a 60-kg woman would have to eat an average of 0.5 pounds (227 g) of fish containing 2.2 ppm of Hg to reach a hair Hg concentration of 86 ppm. Consistent exposure at such a dose seems unlikely when the mean Hg concentration in fish from fish-and-chips shops, a principal source of exposure in New Zealand (Kjellström et al., 1986), is 0.72 ppm (Mitchell et al., 1982). On the basis of those considerations, the committee concluded that analyzing the New Zealand data without the data from that individual is appropriate. (NRC, 2000, p. 282).

The range of BMDL values is relatively small (4 to 25 ppm maternal hair mercury). Inspection of this table shows that all the BMDs (and corresponding BMDLs) from the New Zealand study are lower than those from the other positive study in the Faroes. Often the most sensitive adverse endpoint is selected as the critical effect for calculation of a RfD. The most common surrogate for "most sensitive" is the lowest BMDL or bounded NOAEL (that is, NOAEL from a study wherein an effect was observed). The lowest BMDL is 4 ppm maternal hair mercury for the McCarthy Perceptual Performance Test calculated by Crump et al. (1998, 2000) on the New Zealand data (Kjellstrom et al., 1986). NRC had reservations about using the Kjellstrom (1986) data as the basis for the methylmercury RfD, with which EPA agreed (see Section 4.2.2.9). In this instance the choice is not of the lowest BMDL, but will be made from among the measures in the Faroese data.

Grandjean and colleagues reported significant associations between either maternal hair mercury or cord-blood mercury and decrements in several neuropsychological measures in 7-year-old Faroese children:

- Finger tapping—preferred hand ($p = 0.05$)
- Continuous Performance Test—first year of data collection
  - – false negatives—($p = 0.02$)
  - – mean reaction time—($p = 0.001$)
- WISC-R Digit Span ($p = 0.05$)
- Boston Naming Test
  - – no cues ($p = 0.0003$)
  - – with cues ($p = 0.0001$)

Table 4-3. Tests modeled by NRC, functions assessed, and potential societal relevance

Study	Test	Domain/Function Assessed	Societal Relevance
Seychelles	Bender Copying Errors	Visuospatial	Math performance
	McCarthy GCI	Full-scale IQ	School performance, intelligence
	WJ Applied Problems	Ability to solve problems	Academic skills
	CBCL	Social and adaptive behavior	Antisocial behavior, need for therapeutic services
	Preschool Language Scale	Broad-based language	Learning, intelligence, school performance
	WJ letter/word recognition	Word recognition	Reading ability, school performance
Faroes	Finger tapping	Motor performance	Motor speed/neuropathy
	CPT Reaction Time	Vigilance, attention, information processing speed	Intelligence, school behavior and performance
	Bender Copying Errors	Visuospatial	Math performance
	Boston Naming Test	Expressive vocabulary	Reading, school performance
	CVLT: Delayed Recall	Memory	Learning ability, school performance
New Zealand	TOLD Language Development	Broad-based language	Literacy skills, learning, school performance
	WISC-R: PIQ	Performance IQ, e.g. visuospatial, sustained attention, sequential memory	Learning, school performance
	WISC-R: FSIQ	Full-scale IQ, e.g. PIQ + verbal processing, expressive vocabulary	Learning, school performance
	McCarthy Perceptual Performance	Performance IQ, e.g. visuospatial, audition, memory	Learning, school performance
	McCarthy Motor Test	Gross and fine motor skills	Motor system integration

Abbreviations: WJ, Woodcock-Johnson Tests of Achievement; CBCL, Child Behavior Check List; CPT, Continuous Performance Test; CVLT, California Verbal Learning Test; TOLD, Test of Language Development; WISC-R:PIQ, Wechsler Intelligence Scale for Children-Revised Performance IQ; WISC-R:FSIQ, Wechsler Intelligence Scale for Children-Revised Full-Scale IQ.

Table 4-4. Benchmark dose calculations (ppm MeHg in maternal hair) from various studies and for various endpoints (NRC, 2000)

Study	Endpoint	BMD[a]	BMDL
Seychelles[b]	Bender Copying Errors	***[c]	25
	Child Behavior Checklist	21	17
	McCarthy General Cognitive	***	23
	Preschool Language Scale	***	23
	WJ Applied Problems	***	22
	WJ Letter/Word Recognition	***	22
Faroe Islands[d]	Finger Tapping	20	12
	CPT Reaction Time	17	10
	Bender Copying Errors	28	15
	Boston Naming Test	15	10
	CVLT: Delayed Recall	27	14
New Zealand[e]	TOLD Language Development	12	6
	WISC-R:PIQ	12	6
	WISC-R:FSIQ	13	6
	McCarthy Perceptual Performance	8	4
	McCarthy Motor Test	13	6

[a]BMDs are calculated from the K-power model under the assumption that 5% of the responses will be abnormal in unexposed subjects ($P_0 = 0.05$), assuming a 5% excess risk (BMR = 0.05).
[b]Data from Crump et al. (1998, 2000). "Extended" covariates.
[c] *** indicates value exceeds 100.
[d]Data from Budtz-Jørgensen et al. (1999).
[e]Data from Crump et al. (1998, 2000).

Abbreviations: WJ, Woodcock-Johnson Tests of Achievement; CPT, Continuous Performance Test; CVLT, California Verbal Learning Test; TOLD, Test of Language Development; WISC-R:PIQ, Wechsler Intelligence Scale for Children-Revised Performance IQ; WISC-R:FSIQ, Wechsler Intelligence Scale for Children-Revised Full-Scale IQ.

- California Verbal Learning Test
  - – short-term reproduction ($p = 0.02$)
  - – long-term reproduction ($p = 0.05$)

When an alternative approach to adjusting for covariates was used (Peters-Belson method) was used, two more measures showed significant associations:

- WISC-R Block Design ($p = 0.05$)
- Bender Gestalt Test errors ($p = 0.05$)

More endpoints were significantly associated with cord-blood mercury than with maternal hair mercury. Table 7-3 from the NRC report is reproduced below as Table 4-5; this presents calculations, in terms of cord-blood mercury concentrations, of BMDs and BMDLs for five Faroese endpoints.

4.2.3.2 Comparison of Endpoints

Boston Naming Test (BNT)

The BNT was the endpoint of choice of the NRC panel (NRC, 2000, p. 327). This test assesses word retrieval and formulation abilities in children, adults, and brain-injured patients. In the test, 60 line drawings are shown to the subject one at a time, and the subject is asked to name each of them. Familiarity (frequency of occurrence of the target names) decreases as the test progresses. Responses of the patient are scored for latency and correctness. When the subject misses an item, two kinds of cues may be given. A "stimulus cue" is a short phrase that gives additional information about the target item (e.g., something to eat). A "phonetic cue" is the first sound of the target word. Scores are summarized according to the number of spontaneously given correct responses, the number of correct responses following stimulus cues, and the number of correct responses following phonetic cues. The number of stimulus cues and the number of phonetic cues given by the examiner also is recorded. The peer-review panel noted that there is not much normative data on the BNT but that it is often used by child clinical neuropsychologists because of its documented validity in various child studies (EPA, 2000e). The BNT

Table 4-5. Benchmark dose calculations (ppb methylmercury in cord blood) from the Faroe Islands Study for various endpoints

Endpoint	BMD[a]	BMDL
Finger Tapping	140	79
CPT Reaction Time	72	46
Bender Copying Errors	242	104
Boston Naming Test	85	58
CVLT: Delayed Recall	246	103

[a]BMDs are calculated from the K-power model under the assumption that 5% of the responses will be abnormal in unexposed subjects ($P_0 = 0.05$), assuming a 5% excess risk (BMR = 0.05).
CPT, Continuous Performance Test; CVLT, California Verbal Learning Test.
Source: NRC (2000); data from Budtz-Jørgensen et al. (1999).

has been useful as a measure of confrontation naming and word retrieval skills and can be used to differentiate between children with and without language-based learning disabilities; moreover, it is a predictor of related cognitive and academic skills, especially reading achievement (Yeates, 1994, as quoted in U.S. EPA 2000e).

Continuous Performance Test (CPT)

The endpoint from the Faroe Islands study that yielded the lowest BMDL in the NRC analysis was the CPT reaction time. This test was modified from the Neurobehavioral Evaluation System (NES) version, which is a standardized battery used mainly in occupational settings in adults. In the Faroe Islands study, the child was required to respond as quickly as possible when a silhouette of a cat appeared on a computer screen, but not when the silhouettes of other animals (number not specified) appeared (Grandjean et al., 1997). Dependent variables included number of missed responses (omission errors) and average reaction time for the last 3 minutes of a 4-minute task. False positives (errors of commission) apparently were not analyzed. Reaction time in a task that includes decision making (respond to cat, don't respond to others) is a measure of the speed of information processing. The investigators found an increase in reaction time correlated with cord blood using all data; this correlation was still seen when only data were used from children whose mothers had hair concentrations below 10 ppm (low-level exposure). In addition, there was an association between cord blood mercury levels and an increase in omission errors in the full group and low-level exposure group. This finding indicates poorer attention to the task as a function of methylmercury exposure.

Speed of information processing as measured by reaction time is highly correlated with IQ in humans (Jensen and Munro, 1979; Matthews and Dorn, 1989; Vernon, 1983; Vernon et al., 1985; Western and Long, 1996). It has been argued that speed of information processing is a measure of *g*, the highest order common factor in all tests of cognitive ability (Jensen, 1993b). Reaction time in complex reaction time tasks is consistently observed to be correlated with psychometric *g* in studies in several cultural groups (Buckhalt and Jensen, 1989; Ja-Song and Lynn, 1992; Lynn et al., 1991; Lynn and Wilson, 1990; Shigehisa and Lynn, 1991). Generally, the association between *g* and decision reaction time increases with increasing task complexity (Beh et al., 1994; Jensen, 1987). It is estimated that the correlation between reaction time and *g*-loaded psychometric tasks is 0.3-0.5, whereas the correlation based on several reaction time and psychometric tasks approaches 0.7 (Jensen, 1993a; Vernon, 1989), which is similar to the correlation among different IQ tests (Jensen, 1993). Reaction time tasks also discriminate between brain-injured and other individuals (Western and Long, 1996) and identify children with attention deficits (Zahn et al., 1991).

The NRC chose not to rely on CPT reaction time as the critical endpoint because results were from only half the cohort. The Faroe investigators reported that effects on CPT reaction time were significant for the first year of testing but not the second, with combined effects for the 2 years significant at p = 0.01. The authors stated that "[b]ecause supervision was stringent only during the first year, these data were chosen for development of the final regression model" (Grandjean et al., 1997, pp. 422-423). The NRC felt that measures from the full cohort would be more reliable than those based on half the cohort; their report did not state any concerns regarding elimination of the second year data per se (NRC, 2000, p.286).

Advantages of the choice of the CPT reaction time as the critical endpoint would be that there was no evidence of an effect of PCBs on this measure, and the correlation of complex reaction time with measures of intelligence such as IQ. The disadvantage is that the analysis is based on half the cohort. However, this limitation also holds true for the BNT corrected for PCB exposure. Therefore, there is little or no reason to choose one over the other in this regard.

California Verbal Learning Test for Children (CVLT)

The California Verbal Learning Test for Children is a word-list-learning task that measures acquisition of information following repeated exposure to verbal stimuli. Of principal interest are the variables of learning, delayed recall, and perseveration. The test has good test-retest reliability as well as internal consistency. The theoretical foundations of the CVLT are based upon several decades of cognitive science research in brain/behavior relationships. The test discriminates clinical groups such as those with hyperactivity/attention deficit disorders, children with learning disabilities, and children suffering prenatal insults such as fetal alcohol syndrome.

4.2.3.3 Consideration of Potential PCB effect

EPA agrees with NRC that analyses of the Faroese test results show that there are real mercury-related adverse effects that cannot be attributed to concomitant PCB exposure. This was noted in Section 4.2.2.2. The external peer review panel for the methylmercury RfD agreed with that conclusion. However, they disagreed with the NRC choice of the BNT results from the full cohort because of the potential effect of PCB exposure. They thought that the BNT results were the most sensitive to PCB influence of any evaluated in the Faroe Islands. The peer review panel pointed to the analyses presented by NRC (reproduced in this document as Table 4-6) as presenting an opportunity to consider the use of benchmark estimates corrected for any potential PCB influence. The Faroes investigators calculated a

PCB-adjusted BMD and BMDL for the BNT using cord blood as the exposure biomarker; these were considerably greater than the BMD/BMDL for either the full cohort without PCB adjustment or that from the low-PCB tertile. Similar increases after adjusting for PCBs were not seen for finger tapping, CPT reaction time, or CVLT delayed recall tests, when cord blood was the exposure metric. NRC noted that the PCB measurements were done on cords from only about one-half of the Faroese cohort (about 450 children) and that the use of data from only the low-PCB tertile further reduces *n* to about 150 children. NRC reported that the reduced sample sizes in these analyses increased the variability in the results. They saw no clear pattern as to how the PCB-adjusted analyses differed from the original results. The NRC concentrated its focus on the low-PCB subset BMDs and BMDLs. They compared results from two tests with no PCB effect (CPT and finger tapping) with those with potential for PCB influence (BNT and CVLT). They reported that the BMDs for the low-PCB subset for the BNT and CVLT did not differ from the BMDs for the whole cohort any more than did the BMDs for the two tests with no influence of PCBs. The NRC authors felt that the variability seen in Table 4-6 is no more than that which would be expected by chance alone (NRC, 2000, p. 288).

Table 4-6. BMD (BMDL) Estimates from the Faroe Islands Study With and Without Adjustment for PCBs and in the Subset of Low PCB-Exposed Children (calculated using the K-power model)

		Full Cohort	Adjusted for PCBs	Low-PCB subset
Exposure	Endpoint	BMD (BMDL)[a]	BMD (BMDL)	BMD (BMDL)
Hair	Finger tapping	20 (12)	17 (9)	7 (4)
	CPT Reaction Time	18 (10)	27 (11)	13 (5)
	Boston Naming Test	15 (10)	24 (10)	21 (6)
	CVLT: Delayed Recall	27 (14)	39 (12)	32 (7)
Cord				
Blood	Finger tapping	140 (79)	149 (66)	41 (24)
	CPT Reaction Time	72 (46)	83 (49)	53 (28)
	Boston Naming Test	85 (58)	184 (71)	127 (40)
	CVLT: Delayed Recall	246 (103)	224 (78)	393 (52)

[a]BMDs are calculated under the assumption that 5% of the responses will be abnormal in unexposed subjects (P_0 = 0.05), assuming a 5% excess risk (BMR = 0.05).

Source: E. Budtz-Jørgensen, Copenhagen University, N. Keiding, Copenhagen University, and P. Grandjean, University of Southern Denmark, unpublished material, April 28, 2000, in Table 7-4, p. 289, NRC 2000.

4.2.3.4 Supporting Studies

A second Faroese cohort was recruited from children born between 1994 and 1995. In the study reported by Steurwald et al. (2000), decreases in neurologic optimality score (NOS) were associated with increasing cord blood mercury. This association remained statistically significant after adjustment for confounders (including cord and maternal serum PCB levels). Inspection of data plotted in the paper indicate that a decrease in NOS was observed in the two highest quartiles; that is, at cord blood mercury levels greater than 20 ppb. This indicates a dose-dependent effect at levels as low as (or lower than) those for which neuropsychological deficits were reported in the main study of 7-year-old children (Grandjean et al, 1997). The size of this study is rather small (N = 182) and involves subtle changes at a very early developmental period, the clinical implications of which are less clear than the changes found in the main study of 7-year-olds.

NRC conducted an analysis that combined results from the SCDS, New Zealand, and Faroes studies (NRC, 2000, pp. 290-294). Their approach was to use a hierarchical random-effects model that followed a method proposed by Dominici et al. (in press). To inform their analyses, NRC plotted BMDs and BMDLs (as ppm mercury in maternal hair) for measures from all three studies. For outcomes in the SCDS for which there were no BMDs, the analysis used an arbitrary value of 150. They concluded from the plot (Figure 7-3, NRC, 2000, p. 285) that study-to-study variability was large relative to outcome-to-outcome variability. NRC felt that use of a hierarchical model would allow one to borrow strength from the different studies to achieve greater precision in BMD and BMDL estimates. The NRC results are seen in their Table 7-5 (NRC, 2000, p. 291). They present what they refer to as smoothed results, which reflect reduced random variability. For the Faroes data, the BMDL estimates are not much changed from the original values; the unsmoothed range of BMDLs is 10 to 15 ppm mercury in maternal hair, while the smoothed results range from 12 to 15 ppm. The NRC notes that all smoothed BMDLs are closer to their BMDs; they also concluded that the hierarchical modeling reduced much variability among outcomes but not among studies.

NRC estimated a central tendency measure, equivalent to a BMD, across all three studies and all endpoints. They also determined a lower limit based on a theoretical distribution of BMDs, which is the logical equivalent of a BMDL. These values as well as other estimates derived from the Faroes and New Zealand studies are in Table 4-7.

Table 4-7. Central tendency estimates, ppm mercury in maternal hair[a]

Approach	Original values		Smoothed values	
	BMD	(BMDL)	BMD	(BMDL)
Most sensitive endpoint from New Zealand	8	(4)	12	(7)
Median endpoint from New Zealand	12	(6)	13	(8)
Mean of endpoints from New Zealand	12	(6)	13	(8)
Most sensitive endpoint from Faroes	15	(10)	17	(12)
Median endpoint from Faroes	20	(12)	20	(13)
Mean of endpoints from Faroes	22	(12)	21	(13)
Mean of all endpoints		(14)		(15)
Integrative analysis			21[b]	(8[c])

[a] Source: Table 7-6, NRC 2000, p. 294.

[b] Logically equivalent to a BMD.

[c] Logically equivalent to a BMDL.

The external review panel for the methylmercury RfD suggested that a reasonable alternative to using a single test result as the basis for the RfD would be to develop a composite index from several test outcomes. Their recommendation was to evaluate mercury-associated endpoints for any potential PCB effect. The next step would be to use either PCB-adjusted results or only those results with no PCB effect in some compositing approach to provide a multiendpoint BMDL. The most appropriate compositing approach would be one with a weighting scheme to account for different sample sizes for the individual tests.

A second way to proceed would be to use factor analysis to create a composite factor that accounts for the majority of the variance among the individual test results. The resulting estimate would serve as the basis for RfD calculation. The peer review panel that suggested this approach noted that it is novel and would require substantial effort to reanalyze the data (U.S. EPA, 2000f).

EPA has decided that the two suggestions have a great deal of merit. We will pursue some of these analyses for the extant Faroes and New Zealand data and for the SCDS data on 7-year-old children as they become available. We felt, however, that the integrative analysis reported by NRC serves as substantial support for the choice of an endpoint from the Faroese test data. We felt that at this time the use of NRC's integrated BMD /BMDL or one derived form the suggested alternatives as the sole basis for an RfD would introduce an unacceptable degree of model uncertainty into the RfD.

4.2.3.5 Choice of Endpoint

The lowest of the BMDLs from the Faroese tests is 46 μg/L mercury in cord blood for the CPT reaction time scores. NRC recommended a different choice. They remarked that in a neuropsychological test battery, the reliability of the individual endpoints can be highly variable, so the most sensitive endpoint may not be the most appropriate choice. The Faroes investigators reported difficulties in administering the CPT. The data from the second half of the cohort were discarded for the analysis of this endpoint; thus the *n* was about half that for the other tests. The NRC panel suggested that a more appropriate choice would be to select the second most sensitive endpoint, the BNT BMDL of 58 ppb mercury in cord blood (NRC, 2000, p. 300). Interestingly, the BNT had the lowest BMDL in the analyses based on maternal hair mercury.

The external peer reviewers of the methylmercury RfD disagreed with the NRC choice. The felt that the use of a single neuropsychological endpoint to form the basis for making a risk assessment is problematic. They felt that the use of the BNT data from the whole Faroese cohort was not warranted, as the BMDL thus derived could reflect an effect of PCB exposure. The peer reviewers preferred the BNT BMDL adjusted for PCB exposure of 71 ppb mercury in cord blood. In their report they noted that the adverse effect of methylmercury reflected in the BNT scores is not isolated, but rather occurs at levels not far removed from effects on other neuropsychological tests, providing some assurance of its credibility. A difficulty with the use of the PCB-adjusted BMDL is that this BMDL is based on scores from only about one-half of the total cohort. As noted in Section 4.2.3.3, NRC felt it was more appropriate to use the BMDL from analyses with the larger *n*.

The peer review panel described three other options for RfD derivation. One option would be to use the BMDL from the CVLT. The panel noted the clinical relevance and predictive value of this test as the well as likelihood that there is no influence of PCB exposure on this measure. The major drawback to this choice is that the BMDL from this test for the full cohort is the highest (103 ppb mercury in cord blood or 14 ppm mercury in maternal hair) of those listed in Table 4-6. One could easily argue that the RfD based on this measure is not public health protective. In the light of analyses that indicate that mercury correlations with test measures remain when the highest exposure subset is eliminated (10 ppm or more mercury in maternal hair), this would seem a poor choice.

A third option would be to develop a composite index across several measures in the Faroes study. The peer reviewers suggested that the BMDLs from the statistically significant tests could be developed, evaluated for effects of PCBs, and composited in some way, such as a geometric mean. The compositing

method should consider a weighting scheme to deal with varying sample sizes for the different tests. NRC essentially did a composite measure with the integrative analysis; for all endpoints in all three large studies, the BMDL is 8 ppm mercury maternal hair, or 32 ppb cord blood mercury (Table 4-7). Geometric means for the Faroese measures are in Table 4-8 below. These were calculated separately for the whole cohort, PCB-adjusted BMDLs, and lowest PCB subset. EPA will pursue the suggestion of a weighted composite index at a future time.

A final longer term option of the peer review panel was to devise a within-study integrative multivariate approach using factor analysis for analytical derivation of a composite factor that combines results across tests with overlapping functional domains. The panel acknowledged that this would require some statistical methodology development.

EPA prepared a comparison of the NRC and peer-reviewer-recommended approaches, which also includes the BMDLs from the NRC integrative analysis and geometric means of four scores from the Faroes. Table 4-8 presents BMDLs in terms of cord blood mercury. These are converted (using a one-compartment model as in Section 4.4.2) to an ingested dose of methylmercury that would result in the cord blood level. The last column of Table 4-8 shows the corresponding RfD from application of a UF of 10 (see Section 4.5.6). The calculated RfD values converge at the same point: 0.1 μg/kg/day. Among all the endpoints listed, there are few deviations from 0.1 μg/kg/day: 0.2 μg/kg/day for the CVLT entire cohort and 0.05 μg/kg/day for CPT and Finger Tapping, lowest PCB subset. For comparative purposes several measures from the New Zealand data analyses were also included in Table 4-8; the median BMDL from the New Zealand study would give an RfD of 0.05 μg/kg/day. If one were to use the NRC integrative analysis BMDL equivalent value, the resulting RfD would be 0.05 μg/kg/day.

Rather than choosing a single measure for the RfD critical endpoint, EPA considers that this RfD is based on several scores from the Faroes measures. These test scores are all indications of neuropsychological processes involved with a child's ability of a child to learn and process information. The BMDLs for these scores are all within a relatively close range. In subsequent sections, one endpoint is carried through the dose conversion and application of the UF to calculation of the RfD; namely, the NRC-recommended BMDL of 58 ppb mercury in cord blood from the BNT.

Table 4-8. Comparison of BMDLs–endpoint from Faroes, New Zealand and NRC Integrative Analysis[a]

Test[b]	BMDL ppb mercury cord blood	Ingested dose µg/kg bw /day[c]	RfD µg/kg bw /day[d]
BNT Faroes			
Whole cohort	58	1.081	0.1
PCB adjusted	71	1.323	0.1
Lowest PCB	40	0.745	0.1
CPT Faroes			
Whole cohort	46	0.857	0.1
PCB adjusted	49	0.913	0.1
Lowest PCB	28	0.522	0.05
CVLT Faroes			
Whole cohort	103	1.920	0.2
PCB adjusted	78	1.454	0.1
Lowest PCB	52	0.969	0.1
Finger Tap Faroes			
Whole cohort	79	1.472	0.1
PCB adjusted	66	1.230	0.1
Lowest PCB	24	0.447	0.05
Geometric mean			
Whole cohort	68	1.268	0.1
PCB adjusted	65	1.212	0.1
Lowest PCB	34	0.634	0.1
Median values			
Faroes	48	0.895	0.1
New Zealand	24	0.447	0.05
Smoothed values			
BNT Faroes	48	0.895	0.1
CPT Faroes	48	0.895	0.1
CVLT Faroes	60	1.118	0.1
Finger Tap Faroes	52	0.969	0.1
MCCPP New	28	0.522	0.05
MCMT New	32	0.596	0.1
Integrative			
All endpoints	32	0.596	0.1

[a]BMDLs from NRC (2000), Tables 7-4, 7-5, 7-6. Hair mercury was converted to blood mercury using a 250:1 ratio and an assumption of equivalent maternal and cord levels.
[b]Abbreviations: BNT, Boston Naming Test; CPT, Continuous Performance Test; CVLT, California Verbal Learning Test; MCCPP, McCarthy Perceived Performance; MCMT, McCarthy Motor Test.
[c]Calculated using a one-compartment model as in Section 4.4.2.4.
[d]Calculated using an UF of 10 as in Section 4.5.6.

4.3 CHOICE OF DOSE-RESPONSE APPROACH

4.3.1 Benchmark Versus NOAEL

In recent years, EPA has been moving to use of BMDs versus experimental NOAELs as the departure point for calculation of RfDs. The Agency is preparing guidance for application of this methodology. Guidance has been published in the Technical Support Document on Risk Assessment, Human Health Methodology for Ambient Water Quality Criteria (U.S. EPA, 2000g).

NRC also made comments on the applicability or preference for BMDs over NOAELs (NRC, 2000, pp. 272-273). They cite comments by several risk assessment scientists on statistical drawbacks to NOAELs. The NOAEL, for example, must correspond to one of the experimental doses; it can vary considerably across different experiments. In calculating an RfD, there is no statistical or other treatment of the data to adjust for the choice of dose groups by different experimenters. NRC notes that the identification of a no-effect dose group is based on statistical comparisons between exposed and controls; thus, larger studies have higher power to detect small changes and tend to produce lower NOAELs. Furthermore, because NOAELs are identified as a consequence of pairwise comparisons, there is no widely accepted procedure for calculating a NOAEL in settings where exposure is measured on a relatively continuous scale.

In its guidance documents EPA lists some other advantages of BMD over the LOAEL/NOAEL approach. The traditional method does not incorporate information on the shape of the dose-response curve, but rather uses only a single point (NOAEL or LOAEL). This point depends on the number of doses and spacing of those doses in the experiment. The possible LOAEL/NOAELs are limited to the discrete values of the experimental doses, whereas the "real" value of the NOAEL could be any value between the experimental NOAEL and the LOAEL.

The determination of a NOAEL is dependent on the background incidence of the effect in controls. Statistically significant differences between treatment groups and controls are more difficult to detect if background incidence is relatively high, even if biologically significant effects are noted.

The peer reviewers of the methylmercury RfD provided comment on the appropriateness of the BMD methodology for the methylmercury human data:

> Derivation of LOAELs and NOAELs from the data would require disaggregation of the data based upon artificial cutpoints (e.g., quartiles) to determine which range of exposure appears to be different from the baseline group. While this approach provides a useful profile of effect with dose (e.g. Fig. 1 of the 1997 Faroes paper), it uses a grouping of the data that makes specifying the threshold less exact than with the more statistically robust and inclusive benchmark dose approach. The LOAEL/NOAEL approach also does not factor variability into the estimation of the threshold dose in the health protective way that the BMDL concept accomplishes. In the LOAEL/NOAEL approach, the more variable the data the higher the LOAELs and NOAELs tend to become because it is more difficult to define a statistical difference from the control group. In contrast, greater variability will tend to drive down the estimate of the BMDL since it is the lower 95% confidence limit estimate on the BMD. (G. Ginzberg in U.S. EPA, 2000f)

NRC recommended and EPA concurred with the use of a BMD approach to calculate the methylmercury RfD.

4.3.2 Choice of Exposure Metric

NRC discussed at length in its Chapter 4 the suitability of both hair and blood mercury as biomarkers of exposure. The measurement of mercury exposure in the study population serves two purposes when applied to risk assessment. The biomarker serves as the surrogate for the methylmercury dose to the target tissue, in this case fetal brain. As such, the biomarker is one of the coordinates of inputs to the dose-response models. From this perspective, the ideal biomarker is one that is closest pharmacokinetically to the target. Of the measurements available, cord blood represents a compartment closer to fetal brain than does hair, which is an excretion compartment.

The other use of biomarker in this risk assessment is as a surrogate for ingested dose, the unit in which an RfD is expressed. The ideal biomarker for this stage is closest pharmacokinetically or has the best correlation with ingested dose. Maternal hair or blood may be more suitable from this point of view.

Another point to consider in biomarker choice is temporality: is the biomarker an adequate indicator of exposure during critical developmental windows? NRC noted that cord-blood mercury tends to reflect exposure in the later stages of pregnancy, whereas hair mercury can be used to determine exposure at any point in pregnancy, given the appropriate sample. The NRC panel noted that for most assessment of hair mercury there will be significant uncertainty when attempting to relate a particular

hair level to a time-specific dose to the fetal brain. In addition, there is no information on differential effects of methylmercury at different periods of gestation; it is in no way certain when critical developmental windows occur. Considering the information (or lack thereof) on time of exposure offered by each biomarker, there is no compelling reason to consider one more appropriate than the other.

NRC provided a table (Table 6-1, NRC, 2000, p. 253) that compares test performance associated with mercury concentration as a function of either cord-blood or maternal hair measurement. This comparison suggests that the cord-blood measure explains more of the variability in more of the outcomes than does maternal hair mercury.

In selecting the exposure metric, the above factors were considered. Cord blood is the biomarker most closely linked (at least conceptually) to the target organ. Cord blood is the marker for which there are the most associated adverse effects in the Faroes study. Neither cord-blood nor maternal hair mercury (as generally measured) provides a clear advantage in assessing exposure during putative critical developmental windows. Maternal hair mercury is conceptually closer to maternal ingested dose than is the cord-blood compartment. However, sensitivity analyses indicate that the maternal hair:maternal blood ratio is a key contributor to variability in calculations of ingested dose (Stern,1997; Clewell et al., 1999). On balance, the best choice for exposure metric for RfD calculation is cord-blood mercury.

4.3.3 Choice of BMD

In applying a BMD approach to data that are continuous in effect, there are several interdependent steps as defined by Gaylor and Slikker (1992). The first is to fit a regression model that characterizes the mean of the set of outcome measurements as a function of dose; the assumption of a normal distribution is made. (Choice of model is described in Section 4.3.4). The second step is to define the cutoff for normal versus abnormal response. This cutoff point (x_0) is defined statistically. In the third step, the dose-specific probability of falling into the abnormal category is determined (P_0). One chooses a specific increase in the frequency of abnormal responses by comparison to background probability; this specific risk above background risk is the benchmark response, or BMR. The dose at which the BMR is reached is the BMD. In other words, the BMD is the dose that results in an increased probability of an abnormal test performance by a benchmark response; that is, from P_0 for an unexposed person to P_0 + BMR for a person exposed to the BMD. The last step is to calculate the BMDL or 95% lower limit on the BMD. Choices for P_0 and BMR are described below.

One could set P_0 based on clinical definitions of adverse response or other information. For example, long experience with birth weight in a population could prompt a choice of 2500 g as a cutoff for normal. Alternatively P_0 can be set as a fixed percentile of performance in the unexposed population. For a linear model and random error normally distributed with variance, this has the effect of setting P_0 at a specified number of standard deviations below the mean for the unexposed group. Generally the larger the P_0, the lower the BMD. For the analysis of the behavioral data, including the Faroe study, the NRC panel (NRC, 2000, p. 298) recommended that $P_0 = 0.05$: that is, that the cutoff for abnormal response be set at the lowest 5% (5^{th} percentile) of children. This means that the cutoff point (x_0) is defined by a probability of 5% in an unexposed population. It should be noted that specification of P_0 for the Faroese data (or the other human methylmercury studies) is somewhat problematic because there are no subjects with true zero exposure. The mean response rate at zero is not actually based on observed data but is extrapolated from the fitted model (Budtz-Jørgensen et al., 1999). Support for P_0 of 0.05 is found in Crump et al. (2000); the authors note that this choice is "suggested by the convention of considering 95% of the clinical responses in healthy individuals to define the normal range." EPA agrees that $P_0 = 0.05$ is a reasonable choice.

BMR is the benchmark response, the specific risk above background risk. In other risk assessments (mostly on quantal data) it has been set at 0.1, 0.05, or 0.01. In the MSRC, BMDs and BMDLs were calculated for BMRs of 0.1, 0.05, or 0.01. EPA chose to apply a BMR of 0.1 to the Iraqi data (MSRC volume V, pp. 6-27-6-28; U.S. EPA, 1997e). This was based on publications by Allen et al. (1994) that indicated that a 10% risk level roughly correlated with a NOAEL for developmental toxicity data from controlled animal studies. For a methylmercury RfD based on the Faroese data, NRC recommended that the BMR be set to 0.05, which would result in a doubling of the number of children with a response at the 5^{th} percentile of an unexposed population (NRC, 2000, pp. 283, 298).

The NRC panel felt that their choice of a P_0 of 0.05 and a BMR of 0.05 was justifiable in terms of being sufficiently protective of public health. The committee recognized, however, that the choice of P_0 and BMR is at the interface of science and policy and should be a science-informed policy judgment. EPA at this time has no established policy on an acceptable risk level for the effects reported in the Faroese children. EPA is in the process of publishing guidance on benchmark dose methodology and processes. Most of the experience that supports this guidance comes from assessment of toxicological

(animal) data. The guidance acknowledges that choices of model, and inputs such as P_0 and BMR, should be informed by a consideration of the type of data and the ancillary information on which the assessment is based. Our decision in the specific case of methylmercury is influenced by the public health conclusions that NRC articulated: the measured effects in the human studies are sentinels of adverse outcomes in children, related to their ability to learn and achieve success in educational settings. Thus, EPA accepts the NRC recommendation to set $P_0 = 0.05$ and BMR = 0.05 in this instance.

4.3.4 Choice of Model

A report prepared for EPA and subsequently published by Budtz-Jørgensen (1999) provided calculations of BMD and BMDL using square root and log transformations as well as calculations for K-power models. NRC used these results and similar calculations for the New Zealand and Seychelles studies to make some assessments of model suitability. They noted great variability in calculated BMDs and BMDLs as a function of model. This was so despite the inability of standard statistical assessments of model adequacy to distinguish between models. In response to NRC, Budtz-Jørgensen and colleagues provided some additional analyses. These were sensitivity analyses that repeated the regression models after omitting some of the highest observations (E. Budtz-Jørgensen, Copenhagen University, N. Keiding, Copenhagen University, and P. Grandjean, University of Southern Denmark, unpublished material, April 28, 2000, quoted in NRC, 2000, p. 293). Their results suggested that the influence of the extreme observations did not explain the model-to-model variability (NRC, 2000, p. 293).

NRC concluded that the most reliable and defensible results for the purpose of risk assessment are those based on the K-power model. (NRC, 2000, pp. 293-298). This model takes the following form, as presented in Budtz-Jørgensen et al. (2000):

$$\mu(d) = \beta \cdot d^K$$

where d is the child's mercury dose and K and β are parameters to be estimated. The K-power model was fit under the constraint that $K \geq 1$, so that supralinear models were ruled out. A power of 1 generally provided the best fit to the Faroese data (Budtz-Jørgensen et al., 2000). With K = 1, the above model is linear.

NRC observed that in situations where there are no internal controls (i.e., no unexposed individuals) and where the dose response is relatively flat, the data will often be fit equally well by

linear, square-root, and log models. The models can yield very different results for BMD calculations, however, because these calculations necessitate extrapolating to estimate the mean response at zero exposure level. Both the square-root and the log models take on a supralinear shape at low doses, leading to lower estimates of the BMD than do linear or K-power models. The mechanisms by which methylmercury exerts its neurotoxic effects in developing systems are speculative. However, no likely mode of action for methylmercury leads one to expect a supralinear dose-response at low dose. Thus, from a toxicological perspective, the K-power model has greater biological plausibility, because it allows for the dose-response to take on a sublinear form, if appropriate.

NRC pointed out that the model sensitivity for BMD from the Faroes data appears in conflict with the concept, put forward by Crump and others, that by estimating risks at moderate levels, such as 5% or 10%, the BMD should be relatively robust to model specification. Budtz-Jørgensen et al. (2000) responded that this model dependence is a consequence of the lack of true controls (subjects with zero exposure). The majority of exposures in the Faroes resulted in hair mercury concentrations exceeding 5 ppm (or 24 ppb cord blood). The interquartile range for hair mercury was 3 to 8 ppm (13 to 40 ppb for cord blood) (Grandjean et al., 1992). Models fit to the Faroese data are in effect capturing the shape of the dose-response in this middle range of exposure. The NRC report Figure 7-5, taken from Budtz-Jørgensen et al. (1999), shows dose-response curves fitted to hair mercury data for the linear, square-root, and log transformations. Budtz-Jørgensen et al. (2000) provided some information on model fit. They did not present goodness-of-fit statistics *per se*, but rather tested each model against an expanded model that included both the linear and logarithmic term. The authors observed that for $P_0 = 0.05$, and with cord blood as the exposure metric, the logarithmic transformation tended to show a better fit than the linear model for the following tests: CPT, BNT, and CVLT. There was no difference in fit for the Finger Tapping and Bender Gestalt test or for any of the five tests when maternal hair mercury was the biomarker. The NRC notes that variations in estimated BMDs are not explained by differences in how well the models fit the bulk of the data, but rather by what the models predict for the mean response for unexposed individuals.

In reaching its conclusion on model choice, NRC concluded that biologically based arguments were needed. The argument was as follows:

> One useful way to think of differences between the various models is that the linear model implicitly assumes an additive effect of Hg exposure, the log model assumes a multiplicative effect, and the square root lies somewhere in between. All three models fit essentially equally well to data that for the most part correspond to concentrations between 2 and 20 ppm in hair. However, the models differ fairly dramatically with regard to

how they extrapolate to values below those levels. The linear model would predict that the change in mean outcome as MeHg concentration goes from 0 to 10 ppm in hair should be the same as the change observed in the mean outcome as concentration increases from 10 to 20 ppm. In contrast, the log model would predict that the change in mean outcome associated with any doubling of MeHg concentration should be the same as the change observed in the mean outcome as concentration increases from 10 to 20 ppm. Thus, the log model would predict that the same magnitude change in outcome would be expected as the concentration goes from 1 to 2 ppm or from 4 to 8 ppm as that observed for the concentration going from 10 to 20 ppm—that is, the extrapolation down to zero exposure will predict a very steep slope at low doses. Given the relative absence of exposures at very low levels, a decision should be made on biological grounds regarding which model makes the most sense for risk assessment. The committee believes that an additive (linear) or perhaps sublinear model is the most justifiable from a biological perspective, thus ruling out square-root and log-transformed models. For MeHg, the committee believes that a good argument can be made for the use of a K-power model with K constrained to be greater than or equal to 1 (NRC, 2000 p. 297).

4.3.6 Selection of the Point of Departure for the RfD

Based on all considerations in the preceding sections, the following is selected as the basis for the RfD. Our choice is a benchmark approach using the results of the Faroese tests with significant associations with cord-blood mercury. As an example, the BNT results for the whole cohort are used. The K-power model ($K \geq 1$ to eliminate supralinearity) is the model choice, with $P_0 = 0.05$ and BMR = 0.05. Consistent with other uses of BMD, the 95% lower limit or BMDL is used as the point of departure for the RfD.

The result for the example calculation is a BMD of 85 ppb and a BMDL of 58 ppb; other BMDs and BMDLs are given in Table 4-8.

4.4 DOSE CONVERSION

The biomarker of choice for the Faroes data was cord blood and the BMDLs were presented in units of ppb mercury in cord blood. In order to calculate an RfD, it is necessary to convert this figure to an ingested daily amount that would result in exposure to the developing fetus at the BMDL level in terms of ppb mercury in blood. NRC (2000) offered advice on the use of these dose-conversion procedures.

4.4.1 PBPK Models Versus One-Compartment Model

In estimating the 1995 RfD, EPA used a one-compartment model. Since publication of the MSRC, there have been evaluations of the use of this model and the parameter inputs as well as the discussion of PBPK models for methylmercury. None of the existing models deal specifically with young children, nor are there data on methylmercury pharmacokinetics in children.

NRC briefly discussed the PBPK model published by Clewell et al. (1999). This model includes several fetal compartments that could be considered fetal submodels. NRC noted that this model is conceptually more accurate and flexible than the one-compartment model. The report also notes that the complexity of the model makes evaluation of it more problematic (NRC, 2000, p. 84). Moreover, given the state of the data on methylmercury exposure, it would be necessary to use default values for some model inputs. These factors add to the overall uncertainty in the use of this or any of the other available PBPK models for methylmercury. EPA has chosen to use the one-compartment model for dose conversion for this RfD. This model has shown reasonably good fit to data on mercury blood level changes in human subjects during and after consumption of methylmercury-contaminated fish (Ginsberg and Toal, 2000). It has been used by other public health agencies such as WHO and ATSDR (1999).

4.4.2 One-Compartment Model for Methylmercury

4.4.2.1 Description of Model

The model is described by the formula below:

$$d\ \mu g/day = \frac{c \times b \times V}{A \times f}$$

where

d = daily dietary intake (expressed as μg of methylmercury)
c = concentration in blood (expressed as μg/L)
b = elimination constant (expressed as $days^{-1}$)
V = volume of blood in the body (expressed as liters)
A = absorption factor (expressed as a unitless decimal fraction)
f = fraction of daily intake taken up by blood (unitless).

The following form of the equation expresses d in units of μg/kg body weight/day.

$$d = \frac{c \times b \times V}{A \times f \times bw}$$

where

bw = body weight (expressed in kg).

In this one-compartment model, all maternal compartments are compressed to one: namely, blood. It is assumed that the blood methylmercury concentration is at steady state. This assumption constitutes an area of uncertainty with the use of this model. One could either assume that the methylmercury concentrations of fetal blood and maternal blood are the same or adjust the cord-blood concentration to maternal levels using an empirically derived factor. There are some published indications that mercury in cord blood is higher than in maternal blood (for example, Dennis and Fehr, 1975: Pitkin et al., 1976; Kuhnert et al., 1981). Other publications show that there is no difference in concentration (for example, Fujita and Takabatake, 1977; Sikorski et al., 1989). EPA has chosen to assume that maternal blood mercury is at the same level as fetal or cord blood and acknowledges that this is an additional area of uncertainty in the dose conversion. This is discussed in Section 4.5.4.1.

4.4.2.2 Choice of Parameter Inputs—Distributions Versus Point Estimates

NRC presents an analysis of uncertainty and variability in the values to be used in the equation above (NRC, 2000, pp. 83-95). Although there are data from human studies that form the basis of the parameter estimates, it is clear that there is variability (and uncertainty) in these estimates. NRC notes that each of the model parameters is a random variable best described by a probability distribution. The ingested methylmercury concentration that leads to the benchmark cord-blood concentration is also a probability distribution determined by the combination of the distributions of the individual parameters. NRC cited two analyses of the variability and uncertainty in the ingested dose estimates based on the one-compartment model applied to maternal hair (Stern, 1997; Swartout and Rice, 2000) as well as similar analysis of a PBPK model (Clewell et al., 1999). Table 4-9 reproduces NRC's compilation of those analyses. In this table NRC also presented results of analyses that took maternal blood as the starting point, rather than maternal hair as was done in the published papers.

In 1995, EPA used central tendency estimates (or point estimates intended to reflect central tendency estimates) for all parameter inputs in the RfD dose conversion. Although this is a reasonable approach, it does not encompass the range of likely parameter values or the range of estimated ingestion values. The RfD is not intended to protect only the mid-part of a population, but the whole population including sensitive subgroups. Thus, if one chooses to use central tendency or point estimates in the dose

Table 4-9. Comparison of Results from Three Analyses of the Interindividual Variability in the Ingested Dose of MeHg Corresponding to a Given Maternal-Hair or Blood Hg Concentration

Study	Maternal medium	50th percentile[a] (μg/kg-d)	50th percentile/ 5th[b] percentile	50th percentile/ 1st percentile[c]
Stern (1997)	Hair	0.03-0.05[d]	1.8-2.4	2.3-3.3
		(mean = 0.04)	(mean = 2.1)	(mean = 2.7)
	Blood	0.01	1.5-2.2	1.7-3.0
			(mean = 1.8)	(mean = 2.4)
Swartout and Rice (2000)	Hair	0.08	2.2	Data not reported
	Blood[e]	0.02	2.1	2.8
Clewell et al. (1999)	Hair	0.08	1.5	1.8
	Blood[f]	0.07	1.4	1.7

[a]Predicted 50th percentile of the ingested dose of methylmercury that corresponds to 1 ppm Hg in hair or 1 ppb in blood.
[b]Ratio of 50th percentile of ingested dose of methylmercury that corresponds to 1 ppm Hg in hair or 1 ppb in blood to the 5th percentile.
[c]Ratio of 50th percentile of ingested dose of methylmercury that corresponds to 1 ppm Hg in hair or 1 ppb in blood to the 1st percentile.
[d]Range reflects minimum and maximum values among eight alternative analyses.
[e]Data from J. Swartout, U.S. Environmental Protection Agency, personal commun.; June 9, 2000.
[f]Data from H.J. Clewell, ICF Consulting, personal commun.; April 19, 2000.

conversion, it is necessary to include a UF in the final RfD calculation to ensure that pharmacokinetic variability is appropriately factored into the consideration of sensitive subgroups.

The choice of UF can be informed by the analyses of variability presented by NRC. In general, all three analyses found similar ranges of variability due to pharmacokinetic factors. The ratios of estimated ingested doses at the 50th percentile/99th percentile ranged from 1.7 to 3.3. If one considers only the estimates using maternal blood as the starting point, then the range for all three studies is 1.7 to 3.0. NRC noted that variability was higher when maternal hair, rather than blood mercury was the biomarker used. In 1997, EPA identified the hair-to-blood ratio as a major contributor to the variability (and thus uncertainty) in estimating the ingested dose and in the RfD based on it. This provides an additional rationale for use of the cord-blood-based BMD.

In determining the methylmercury RfD, EPA chooses to use point estimates, rather than distributions, in the dose conversion and to account for uncertainty by application of a numerical UF. This UF considers the probability distribution that relates biomarker concentration and ingested dose (see Section 4.5). This approach was recommended in the NRC report. NRC notes that use of parameter distributions and an ingested dose distribution (the "direct approach") does not eliminate uncertainty. In the direct approach, one would select an ingested dose corresponding to a BMD blood mercury concentration for the percentile of the population variability that is to be accounted for; that is, one would select the 95th or 99th (or some other suitable) percentile. The choice must be made among probability distributions predicted by analyses such as those done by Stern (1997) and Swartout and Rice (2000). NRC said that "the differences in the analyses are due to the use of different data sets for parameter estimates, and there is no clear basis for choosing one data set over another. Even when central-tendency estimates and uncertainty factors are used, the most appropriate value for each model parameter must be selected. Selection of different values for model parameters could underlie differences in the modeling results" (NRC, 2000, pp. 94-95).

EPA chooses to make explicit choices for each dose-conversion parameter and to deal with both the uncertainty and variability implicit in those choices by the application of a UF in the calculation of the RfD.

4.4.2.3 Choice of Parameter Inputs—Values for One-Compartment Model Terms

NRC recommended (NRC, 2000, p. 95), that in choices of point estimates EPA should consider the information and analyses in three publications: Stern (1997), Swartout and Rice (2000), and Clewell et al. (1999). All are recent contributions to the peer-reviewed literature. In addition, Swartout and Rice (2000) largely comprises analyses that received extensive scientific review as part of the MSRC (U.S. EPA, 1997e). EPA found little in Clewell et al. (1999) that could be used directly to make parameter estimates, but rather used data and analyses from the other two papers. The rationales for use of specific values for equation parameters follow.

Concentration in blood (c)

The concentration in blood is that corresponding to the BMDL (58 ppb in the example). As noted above, no numerical change is made to account for any potential differences between maternal blood mercury level and cord-blood concentration.

Fraction of mercury in diet that is absorbed (A)

After administration of radiolabeled methylmercuric nitrate in water to three healthy volunteers, uptake was reported to be >95% (Aberg et al., 1969). This value is supported by experiments in human volunteers conducted by Miettinen et al. (1971). These researchers incubated fish liver homogenate with radiolabeled methylmercury nitrate to produce methylmercury proteinate. The proteinate was then fed to fish for a week; the fish were killed, cooked, and fed to volunteers after confirmation of methylmercury concentration. The authors reported that the fraction of the administered dose not excreted in the feces within 3 to 4 days ranged from 91.2% to 97.0% with a mean of 94%. This fraction was assumed to be the amount absorbed; it probably includes some inorganic mercury formed from the ingested methylmercury and subsequently excreted. Stern (1997) noted that this method is most likely to result in an underestimate. It is generally felt that absorption of ingested methylmercury is high and not likely to vary a great deal. Use of an absorption factor of 0.95 as was done in the MSRC is reasonable.

Fraction of the absorbed dose that is found in the blood (f)

The MSRC notes that in 1995 EPA used data from Kershaw et al. (1980), Miettinen et al. (1971), and Sherlock et al. (1984) as the basis for the choice of a value of 0.05 (U.S. EPA, 1997e).

There are currently four published reports of the fraction of absorbed methylmercury dose distributed to blood volume in humans. Kershaw et al. (1980) reported an average fraction of 5.9% of absorbed dose in total blood volume, based on a study of five adult male subjects who ingested methylmercury-contaminated tuna. In a group of nine male and six female volunteers who had received ^{203}Hg-methylmercury in fish, approximately 10% of the total mercury body burden was present in 1 L of blood in the first few days after exposure; this dropped to approximately 5% over the first 100 days (Miettinen et al., 1971). In another study, an average value of 1.14% for the percentage of absorbed dose per kg of blood was derived from data on subjects who consumed a known amount of methylmercury in fish over a 3-month period (Sherlock et al., 1984). Average daily intake in the study ranged from 43 to 233 µg/day, and there was a dose-related effect on percentage of absorbed dose that ranged from 1.03% to 1.26% in 1 L of blood. Smith et al. (1994) administered radiolabeled methylmercury to seven subjects. The paper presented published modeled data rather than observations; the mean fraction of absorbed dose in blood was 7.7% (SD, 0.88%).

Stern (1997) noted that although the Smith et al. (1994) and Kershaw et al. (1980) data could be fit by a log-normal distribution, the data sets were too small for a reasonable determination of the

underlying distributions. Stern used the mean and standard deviation of those two data sets for average parameter values as inputs to the log-normal distribution; the average of the means is 0.067. Swartout and Rice (2000) used the observations published by Kershaw et al. (1980), Miettinen et al. (1971), and Sherlock et al. (1984) as adjusted for 5 L of blood as inputs with a log-triangular distribution. The median value was 5.9% or 0.059, close to the values of 0.05 used in the MSRC and by other groups (e.g., Berglund et al., 1971, and WHO, 1990).

ATSDR (1999) used a factor of 0.05. They noted that estimates of f for the 6 women from the study by Sherlock et al. (1984) had an average value of 0.048, as compared with the value of 0.059 for the 14 men in the same study. ATSDR offered the opinion that these data suggest f may be lower for women than men. Apparently the study by Miettinen et al. (1971) included six female volunteers (in addition to nine males), though ATSDR did not comment on whether these data similarly provided any indication that the fraction daily intake taken up by blood was lower for females. It is not likely that any of the female subjects were pregnant. Sherlock et al. (1984) published a negative correlation between f and body weight; thus, if this is generalizable, one would expect f to decrease (as V increases) throughout pregnancy.

EPA chooses to use the median value of 0.059 published by Swartout and Rice (2000) for f in the dose conversion.

Elimination constant (b)

Currently, five studies report clearance half-times for methylmercury from blood or hair: Miettinen et al. (1971), Kershaw et al. (1980), Al-Shahristani et al. (1974), Sherlock et al. (1984), and Smith et al. (1994). The clearance half-lives for blood in these reports are quite variable, ranging from 32 to 189 days. In the Al-Shahristani et al. (1974) study, 10% of the sample population had mercury half-lives of 110 to 120 days. Average mercury half-lives from the five publications are 45 to 70 days. The MSRC (U.S. EPA, 1997e) used an average elimination constant from four of the studies (data from Smith et al. [1994] were not used). The corresponding elimination constant of 0.014 was also noted to be the average of individual values reported for 20 volunteers ingesting from 42 to 233 µg mercury/day in fish for 3 months (Sherlock et al., 1982).

Swartout and Rice (2000) applied a log-triangular distribution to the data from the five extant studies. They note that the distribution is highly skewed and that the median is 53 days; the corresponding elimination constant is 0.013.

Stern (1997) discussed the variability in the data sets. His analysis of variance indicated significant differences among the sets, which were eliminated when the Al-Shahristani data were removed. The author observed that the half-lives reported by Al-Shahristani are larger than those observed in the other studies. Stern offers the opinion that this may be due to the relatively large size of the Al-Shahristani data set by comparison to the others. Stern says that an alternative explanation is that the Al-Shahristani data reflect a genetic polymorphism in the metabolism occurring with higher frequency in the Iraqi population, which was the subject of this study. In his analyses, Stern (1997) treated the Al-Shahristani data both separately and in combination with the data from the other four studies. He reports a mean elimination constant of 0.011 for Al-Shahristani data alone; the combined data set mean elimination constant is 0.014.

The decision to select point estimates for dose conversion parameters was done with the acknowledgment that some of the variability around these parameters would be truncated. This is being compensated for by the use of a pharmacokinetic uncertainty factor. Nevertheless, it does not seem prudent to select a point estimate, which is meant to be reflective of population central tendency, from one data set only. The two central tendency estimates of Swartout and Rice (2000) and Stern (1997) are very close in value (0.013 versus 0.014); the differences are presumably due to the application of different distribution types. The value of 0.014 is used for b in the dose conversion.

Volume of blood in the body (V)

In the MSRC (U.S. EPA, 1997e), blood volume was estimated, as there were no data from the study population (the 81 pregnant women exposed in the poisoning episode in Iraq). It was noted then that blood volume is 7% of body weight, as determined by various experimental methods. MSRC assumed an increase of 20% to 30% (to about 8.5% to 9%) during pregnancy on the basis of the publication by Best (1961). Specific data for the body weight of Iraqi women were not found. Assuming an average body weight of 58 kg and a blood volume increase of 9% during pregnancy, a blood volume of 5.22 L was derived and was rounded to 5 L for the dose conversion.

Stern (1997) cited three studies (Brown et al., 1962; Retzlaff et al., 1969; Huff and Feller, 1956) wherein correlation of body weight and blood volume were demonstrated. All studies were of U.S. women, presumably not pregnant at the time of the study. The mean blood volumes for each study were 3.58 L, 3.76 L, and 3.49 L, respectively; the mean of the combined data set is 3.61 L. If one assumes a 30% increase in blood volume with pregnancy, this would be 4.67 L.

In their analysis, Swartout and Rice (2000) used data from a cohort of 20 pregnant Nigerian women (Harrison, 1966). Whole-blood volumes in the third trimester ranged from 4 to 6 L; the mean and median were both 5 L. Although 5 L is somewhat higher than the blood volume estimated from three studies of U.S. women, it is a reasonable value to use for *V*.

Body weight (bw)

The MSRC found no data on body weight for the study population and used a default value of 60 kg (rounded from 58) for an adult female (U.S. EPA, 1997e). Swartout and Rice (2000) in their distributional analysis used the body weight data collected on the cohort of 20 pregnant Nigerian women (Harrison, 1966); this was the data set that they used for blood volume. Body weight during the third trimester of pregnancy ranged from 49.5 kg to 73.9 kg, with a geometric mean of 55 kg. Stern (1997) used the Third National Health and Nutritional Survey (NHANES III) data for women 18 to 40 years old (National Center for Health Statistics, 1995). The mean weight was 66.6 kg and the 50th percentile value was 62.8 kg. The EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (U.S. EPA, 2000a) also cites NHANES III data; in the Agency document, women of childbearing age were considered to be between the ages of 15 and 44 years old. The median body weight in this group was 63.2 kg and the mean was 67.3 kg. EPA also cites the earlier analyses of Ershow and Canter (1989); they do not state the age range but give a median of 64.4 kg and a mean of 65.8 kg. The recommendation in the EPA Methodology was to use a body weight value of 67 kg for a pregnant woman on the basis of the relatively current data from NHANES III. This is the value used for body weight in the dose conversion.

4.4.2.4 Dose Conversion Using the One-Compartment Model

The parameter values are as follows:

c	=	concentration in blood (expressed as 58 μg/L)
b	=	elimination constant (expressed as 0.014 $days^{-1}$)
V	=	volume of blood in the body (expressed as 5 L)
A	=	absorption factor (expressed as 0.95, unitless decimal fraction)
f	=	fraction of daily intake taken up by blood (0.059, unitless)
bw	=	body weight (expressed as 67 kg)

$$d = \frac{c \times b \times V}{A \times f \times bw}$$

$$d = \frac{58\ \mu g/L \times 0.014\ days^{-1} \times 5L}{0.95 \times 0.059 \times 67\ kg}$$

$$d = 1.081\ \mu g/kg\text{-}day$$

rounded to 1.0 μg/kg/day. Other BMDLs expressed as ingested maternal dose can be found in Table 4-8.

4.5 CHOICE OF UNCERTAINTY FACTOR

4.5.1 Background

The RfD can be considered a threshold for a population at which it is unlikely that adverse effects will be observed. In estimating this level from either a NOAEL or a BMD, the risk assessor applies uncertainty factors; these are used to deal with both experimental and population variability and with lack of information that results in uncertainty in the risk estimate. For a discussion of uncertainty factors, refer to the Technical Support Document for Risk Assessment, Human Health Methodology for Ambient Water Quality Criteria (U.S. EPA, 2000g).

In the MSRC, EPA published qualitative discussions and quantitative analyses of uncertainty and variability in the RfD based on the Iraqi data (U.S. EPA, 1997e,g). Major sources of uncertainty identified were these: variability in susceptibility within the study cohort, variability in pharmacokinetic parameters for methylmercury (particularly biological half-life of methylmercury and the hair-to-blood ratio for mercury), response classification error, and lack of data on long term sequelae of *in utero* exposure. At that time a composite UF of 10 was applied to account for these factors and the EPA policy choice to use a UF in the absence of a two-generation reproductive bioassay.

NRC considered areas of uncertainty and variability relevant to the generation of an RfD based on data from the Faroes population and given the current state of the databases on both pharmacokinetics and effects of methylmercury. The panel concluded that not all sources of uncertainty or variability require addition of numerical UFs. NRC (NRC, 2000, p. 319) suggests that given the state of the human data on methylmercury, UFs be considered for two reasons:

- If the uncertainty could result in underestimation of the adverse effects of methylmercury exposure on human health.

- If there is reason to suspect that the U.S. population is more sensitive than the study populations to the adverse effects of methylmercury.

NRC's recommendation was that a UF of at least 10 be applied to a BMD calculated from the BNT results from the Faroe Islands study (NRC, 2000, pp. 321-322). EPA is in general agreement with NRC's conclusions and recommendations and considered them in the choice of the numerical UF. EPA's choice is to consider the RfD to be based on the group of Faroese neuropsychological measures associated with cord-blood mercury; the areas of uncertainty and variability are the same for the choice of one test result (e.g., BNT whole cohort) or the group of test results. Descriptions of areas of uncertainty and variability and choice of UF are in the following sections.

4.5.2 Toxicodynamics

Individual response to methylmercury can vary as a function of many factors: age, gender, genetic makeup, health status, nutritional influences (including interaction among dietary components), and general individual toxicodynamic variability. Individual sensitivity has been noted in the published human studies; NRC cited the example of members of the Iraqi population who seemed insensitive to high levels of mercury exposure. EPA believes there are insufficient data to conclude that the U.S. population is more or less sensitive than the reported human study populations. The U.S. population is extraordinarily diverse by any measures listed above, certainly by comparison to the Faroese population. The Faroese population is northern Caucasian, has been relatively isolated, and is thought to be descended from a small number of so-called founders who settled the islands many generations ago. In the heterogeneous U.S. population, it is entirely likely that there are individuals both more and less sensitive to methylmercury toxicity than the cohort studied in the Faroes. As the RfD must be calculated to include sensitive subpopulations, variability in response to mercury is a consideration. EPA believes there are insufficient data to support a quantitative analysis of this area of variability and uncertainty for methylmercury, but that toxicodynamic variability must be considered in the determination of the overall uncertainty factor.

4.5.3 Exposure Estimation as an Area of Uncertainty

Limitations in evaluation of exposure can be an additional source of uncertainty. As the RfD is based on a developmental outcome, there is particular concern for uncertainty in the linkage between time and intensity of exposure and critical periods of brain development. As noted before, cord-blood mercury generally reflects mercury exposure during late pregnancy and does not reflect temporal variability in exposure level. Use of any biomarker of methylmercury exposure can result in misclassification of exposure. Generally, exposure misclassification presents a bias to the null; that is, this source of error leads to decreased ability to detect a real effect. To the degree that there is exposure misclassification in the critical study, it would be expected to result in underestimation of the methylmercury effect. At this time there are not data to support a quantitative determination of this area of uncertainty.

4.5.4 Pharmacokinetic Variability

4.5.4.1 Cord:Maternal Blood Ratios

In its use of the one-compartment model for dose conversion, EPA chose to make no adjustment for potential differences between fetal and maternal blood mercury levels. Investigators have found that the placenta is not a barrier to the transfer of methylmercury from the mother to the developing fetus. Typically, there is a strong correlation between maternal blood mercury concentrations and fetal blood mercury concentrations, as shown by cord blood.

Review of the literature identified 21 studies that reported cord blood mercury and maternal blood mercury data (Amin-Zaki et al., 1974; Baglan et al., 1974; Dennis and Fehr, 1975; Pitkin et al., 1976; Kuhnert et al., 1981; Nishima et al., 1977; Lauwerys et al., 1978; Fujita and Takabatake, 1977; Kuntz et al., 1982; Tsuchiya et al., 1984; Truska et al., 1989; Sikiorski et al., 1989; Hansen et al., 1990; Soong et al., 1991; Soria et al., 1992; Ong et al., 1993; Akagi et al., 1997; Yang et al 1997; Ramirez et al., 2000; Bjerregaard and Hansen, 2000; Vahter et al., 2000). Twenty of the studies provided data in a format that could be compared with one another. The exception is Truska et al. (1989), whose published data were based on erythrocyte mercury concentrations without reported hematocrit values. Absence of these values precluded expressing mercury concentration on a μg/L or ppb whole-blood basis.

Data from 18 of the 20 studies (with a combined total of 2,676 maternal and 2,522 cord-blood samples) indicated that cord-blood mercury concentration exceeded maternal-blood mercury

concentration. Mean values ranged from a ratio of 1.04 (Fujita and Takabatake, 1977) to 2.63 (Amin-Zaki et al., 1974); the average of mean ratios was 1.55. Two studies reported cord:maternal blood ratios equal to or less than 1. Kuntz et al. (1982) (based on 57 maternal-cord blood pairs) and Sikorski et al. (1989) (based on 56 maternal-cord blood pairs) reported cord/maternal blood mercury concentration of 1.0 and 0.83, respectively.

Speciated mercury measurements were performed in 9 studies that included 550 maternal and 526 cord-blood samples. This permitted calculation of the ratios of cord blood methylmercury:maternal blood methylmercury that are presented in Table 4-10. In all nine studies, the mean values for methylmercury concentration was higher for cord blood than maternal blood. The number of subjects in these 9 studies ranged from 9 to 226 pregnant woman-fetal pairs. To deal with this variation in *n*, Table 4-10 reports both a simple average of mean ratios (cord methylmercury:maternal methylmercury = 1.68) and the mean ratio weighted by the number of subjects in the study (ratio =1.73).

Overall, these data indicate that cord-blood mercury is higher than maternal-blood mercury. The composite ratio from the studies reporting methylmercury concentrations indicates that the cord blood:maternal blood ratio is around 1.7. These values are ratios of means and do not reflect the full range of variability in the individual mother-fetal pairs. Vahter et al. (2000 reported the 5th and 95th percentiles of cord:maternal Hg to be 0.88 and 3.1. Individual data were available from Fujita and Takabatake (1997); ratios calculated from these data ranged from 0.78 to 4.36.

As indicated in Section 4.4.2.1, EPA chooses not to make a numerical adjustment between cord-blood and maternal-blood mercury. Such an adjustment factor would best be calculated after evaluation of data quality and variability within and between studies. EPA feels that this analysis would be an important contribution to reducing uncertainty in the RfD. At this time the relationship between cord blood and maternal-blood mercury is considered an area of uncertainty to be included in the determination of the UF.

Table 4-10. Ratio of Cord to Maternal Blood Methylmercury

Investigator	Number of Subjects	Ratio of Cord:Maternal Blood
Nishima et al., 1977	49 maternal, 49 fetal	2.17
Kuhnert et al., 1981	29 maternal, 29 fetal	1.34
Tsuchiya et al., 1984	226 maternal, 226 fetal	1.60
Hansen et al., 1990	37 maternal, 37 fetal	2.11
Soria et al., 1992	19 maternal, 19 fetal	1.08
Ong et al., 1993	29 maternal, 29 fetal	1.65
Akagi et al., 1997	21 maternal, 21 fetal	1.75
Yang et al., 1997	9 maternal controls, 9 fetal controls; 9 occupationally exposed mothers, 9 occupationally exposed fetuses.	1.67 - controls 1.39 - occupationally exposed
Vahter et al., 2000	112 maternal (gestation week 36), 98 fetal	1.92
Arithmetic mean of average ratios of cord:maternal methylmercury		1.68
Mean weighted by number of subjects for cord:maternal blood methylmercury		1.73

4.5.4.2 Other Areas of Pharmacokinetic Variability

There is no specific evidence of genetic polymorphisms that affect methylmercury metabolism or excretion. Human studies have established, however, that there is great variability in some of the factors affecting the delivery of ingested methylmercury to target organs. The MSRC sensitivity analysis and the publication by Swartout and Rice (2000) noted that the greatest variability resided in the hair:blood ratio (not a factor in the current dose conversion), the fraction of absorbed methylmercury found in blood (*f*), and the half-life of methylmercury in blood (the reciprocal, *b*, in the current dose conversion).

NRC presented an analysis of methods of ingested dose reconstruction from biomarker measurements. NRC noted that cord-blood mercury is closely linked kinetically to the fetal brain compartment but less closely linked to ingested dose. As described in Section 4.4.2 of this document, EPA chose a one-compartment model and measures of cord-blood mercury for back-calculation of the ingested dose of mercury. EPA also chose to use central tendency estimates for the parameters of the one-compartment model, rather than introduce an additional degree of uncertainty inherent in making choices of distribution shapes and the portion of the distribution that represents a sensitive population.

NRC presented analyses of uncertainty around dose-conversion estimates, which are summarized in Table 4-9 in Section 4.5.2.2. NRC discussed three independent analyses to characterize toxicokinetic variability in estimates of ingested dose corresponding to a BMD level in a particular biomarker, whether maternal hair or cord blood (NRC, 2000, pp. 91-95). These analyses were published by Stern (1997), Swartout and Rice (2000, after their work on EPA 1997), and Clewell et al. (1999). Each analysis used Monte Carlo simulation to combine probability distributions for each parameter of the model. For Stern (1997) and Swartout and Rice (2000), this was the one-compartment model shown in Section 4.4.2.1. Clewell et al. (1999) used a PBPK model with a fetal submodel. The analyses of the one-compartment model were done in a similar fashion; distributions for model parameters were determined from the published literature, and shapes of the distributions were set by the authors. Both analyses assumed correlations between some model parameters. Stern (1997) assumed that blood volume and body weight were correlated. Swartout and Rice (2000) made that assumption, as well as these correlations: hair-to-blood ratio and elimination rate constant, and fraction of absorbed dose in blood and body weight. The analysis based on the PBPK model also used parameter distribution values from the literature but included many more parameters than the one-compartment model (and more default distributions for model parameters).

The three published analyses all took maternal hair mercury as their starting point. NRC asked all three sets of authors to provide analyses of variability that used maternal blood as the starting point (as a surrogate for cord blood). These analyses were done by removing the hair:blood ratio from the model and running the Monte Carlo simulations.

Table 4-9 presents median estimates of ingested dose corresponding to 1 ppm maternal hair or 1 ppb maternal blood. Useful points of comparison are the ratios between the 50th percentile estimates and those at the end of the distribution (5th and 1st percentiles). Table 4-9 shows that using maternal blood as a starting point, the ratios of 50th percentile:1st percentile estimates ranges from 1.7 to 3.0. EPA's interpretation is that a factor of 3 will cover the toxicokinetic variability of 99% of the population. The uncertainty introduced by assuming cord-blood mercury is equivalent to maternal mercury provides additional justification for a toxicokinetic UF of 3. The choice of a factor of 3 is consistent with the standard EPA practice of a using a half-log to account for toxicokinetic variability.

4.5.5 Uncertainty in Choice of Critical Effect

Another critical area discussed by NRC is uncertainty around choice of a critical effect. NRC notes that developmental neurotoxicity is a sensitive indicator of methylmercury toxicity but that there is some

uncertainty as to the likelihood of other effects occurring at even lower levels of exposure. They cite indications of cardiovascular effects as well as neurotoxic effects uncovered later in life.

EPA agrees that there is a degree of uncertainty in our choice of critical effect; EPA believes this is not currently amenable to quantitative estimation but must be considered in the setting of the uncertainty factor. Summarized below are observations that support a concern that developmental neurotoxicity may not be the most sensitive indicator of methylmercury effects.

4.5.5.1 Cardiovascular Effects

There are some human data linking cardiovascular effects with exposure to elemental, inorganic, and organic forms of mercury. In addition, there are two recently published studies that show an association between low-level methylmercury exposure and cardiovascular effects. Sørensen et al. (1999) reported that in a study of 1,000 7-year-old Faroese children, diastolic and systolic blood pressures increased by 13.9 and 14.6 mm Hg, respectively, as the cord-blood mercury increased from 1 to 10 μg/L. They also reported a 47% decrease in heart rate variability (an indication of cardiac autonomic control) for the same increase in cord-blood mercury. Salonen et al. (1995) reported effects in adults from a study of 1,833 Finnish men. Over the 7-year observation period, men with hair mercury in the highest tertile (2 ppm or higher) had a 2.0 times greater risk of acute myocardial infarction than the rest of the study population.

As indicated by the Salonen (1995) study, the relatively subtle effects of methylmercury on cardiovascular indices can have public health implications. There is an analogous situation with lead exposure. Pirkle et al. (1985) reported on analyses of NHANES II data comparing the relationship between systolic and diastolic blood pressure to blood lead levels. They included in their model the 37% decrease in mean blood lead levels that was observed in white adult males between 1976 and 1980. Their calculation predicted a 4.7% decrease in the incidence of fatal and nonfatal myocardial infarction over 10 years, a 6.7% decrease in the incidence of fatal and nonfatal strokes over 10 years, and a 5.5% decrease in the incidence of death from all causes over 11.5 years.

4.5.5.2 Persistent and Delayed Neurotoxicity

Another area of concern is the onset or exacerbation of neurological deficits in aging populations exposed *in utero* or as children. There are indications of this in the followup studies of the Minamata population. These present evidence that neurological dysfunction among people who have been exposed

to methylmercury becomes more pronounced with aging. This heightened diminution of function is greater than that attributable to either age or methylmercury exposure alone. Specifically, Kinjo et al. (1993) surveyed 1,144 current patients with Minamata disease (MD) aged 40 or over and an equal number of neighbor controls matched by age and sex. MD patients have symptoms of sensory disturbance at a high prevalence rate (e.g., hypoesthesia of mouth, ~20% to 29% of subjects; hypoesthesia of limbs, ~66% to 90% of subjects; dysesthesia of limbs, ~83% to 93%; weakness, ~75% to 84%), but these problems did not systematically increase with age. However, the MD patients did show, as a function of age, increased difficulties in speaking, tremor, stumbling, and difficulties with buttoning, clothing, or hearing. Although such changes also occurred among controls, evaluation of odds ratios showed that the MD patients had higher prevalence rates than the controls for 18 separate problems including those specifically listed above. Also evaluated were "acts of daily living" (ADL) that included the abilities to independently eat, bathe, wash, dress, and use the toilet. Among subjects under age 60 there were no significant differences in ADL abilities between MD patients and controls. However, among patients aged 60 or greater there were significantly lower ADL abilities among MD patients than among age-matched controls. A conclusion of the Kinjo et al. study is that the prevalence of deficits was relatively greater in cases compared with controls as a function of increasing age. In other words, exposure to methylmercury three decades earlier accelerated the aging process in aged individuals relative to younger ones.

There has also been evaluation of the health status of people living in methylmercury-polluted areas who were not designated as MD patients. Later followup by Fukuda et al. (1999) evaluated 1,304 adults who lived in a methylmercury-polluted area near Minamata City in Kumamoto Prefecture in Japan (but were not designated MD patients) and 446 age-matched adults in a non-mercury-polluted area of Japan. All subjects were older than 40 years of age. A questionnaire survey evaluated 64 complaints that could be grouped as nonspecific, sensory, arthritic, and muscular. Complaints identified among male and female subjects that were significantly higher in methylmercury-contaminated areas included heart palpitation, dysesthesia, staggering when standing, resting and intention tremor in the hands, dizziness (especially when standing), low-tone tinnitus, low pain sensation in hands and legs, and (among women only) loss of touch sensations in hands and legs.

Animal studies lend support to the conclusion that methylmercury can have delayed effects that are uncovered with age. Spyker (1975) exposed mice during gestation and lactation to methylmercury. Offspring noted to be normal at birth developed deficits in exploratory behavior and swimming ability at 1 month; neuromuscular and immune effects were noted as the animals reached 1 year of age. Rice (1989a) exposed monkeys to 50 μg/kg/day methylmercury for the first 7 years of life. The animals were

observed with motor incoordination only when they reached the age of 14; subsequent testing showed effects on somatosensory functioning (Rice and Gilbert, 1995). Rice (1998) also exposed monkeys *in utero* and for the first 4 years. Exposure to 10 to 50 μg/kg/day was observed to result in decreased auditory function compared with controls when the animals were tested at 11 and 19 years. The deficit at 19 years was relatively greater than at 11 years, providing evidence for an interaction of aging and methylmercury exposure on auditory impairment. Rats exposed to methylmercury *in utero* through 16 days of age exhibited a decline in performance in a task that required a substantial motor output at an earlier age than did control rats; high-dose rats exhibited a decline in performance at about 500 days of age compared with 950 days for controls (Newland and Rasmussen, 2000), with no differences between groups in survival time. All of these observations are consistent with a hypothesis that early life or *in utero* exposure to methylmercury can have adverse long-term sequelae that may not be detected in childhood.

4.5.5.3 Reproductive Effects

EPA has a concern for potential reproductive effects of methylmercury. There are no studies of reproductive deficits in humans exposed to low-dose methylmercury. Bakir et al. (1973) did comment on the low number of pregnant women in the Iraqi population exposed to methylmercury in treated grain. They noted that among the 6,350 cases admitted to the hospital for toxicity, they would have expected 150 pregnancies; only 31 were reported. There are no two-generation reproductive assays for methylmercury. Shorter term studies in rodents and guinea pigs have reported effects including low sperm counts, testicular tubule atrophy, reduced litter size, decreased fetal survival, resorptions, and fetal malformations (Khera, 1973; Lee and Han, 1995; Hughes and Annau, 1976; Fuyuta et al., 1978, 1979; Hirano et al., 1986; Mitsumori et al., 1990; Inouye and Kajiwara, 1988). Burbacher et al. (1988) reported decreased conception rates, early abortions, and stillbirths in *Macaca fascicularis* monkeys treated with methylmercury hydroxide; the NOAEL for this study was 0.05 mg/kg/day. In a study of male *Macaca fascicularis* (Mohamed et al., 1987), a LOAEL for sperm abnormalities was 0.05 mg/kg/day.

The MSRC did an evaluation of the potential for methylmercury to be a germ-cell mutagen. Methylmercury is clastogenic but does not appear to cause point mutations. Methylmercury is widely distributed in the body, crossing both blood–brain and placental barriers in humans. Data indicate that methylmercury administered intraperitoneally. reaches germ cells and may produce adverse effects. When Suter (1975) mated female mice to treated males, he observed a slight reduction in both numbers of implantations and viable embryos; this was true for one mouse strain but not for another tested at the

same time. When Syrian hamsters were treated intraperitoneally with methylmercury, aneuploidy but not chromosomal aberrations was seen in oocytes (Mailhes, 1983). Sex-linked recessive lethal mutations were increased in *Drosophila melanogaster* given dietary methylmercury (Ramel, 1972). Watanabe et al. (1982) noted some decrease in ovulation in hamsters treated subcutaneously with methylmercury, further indication that methylmercury is distributed to female gonadal tissue. Studies have reported increased incidence of chromosome aberrations (Skerfving et al., 1970, 1974) or sister chromatid exchange (Wulf et al., 1986) in lymphocytes of humans ingesting mercury-contaminated fish or meat. Chromosome aberrations have been reported in cats treated in vivo and in cultured human lymphocytes in vitro. Evidence of DNA damage has been shown in a number of in vitro systems. The MSRC (U.S. EPA 1997e) concluded that because there are data for mammalian germ-cell chromosome aberrations and limited data from a heritable mutation study, methylmercury is placed in a group of high concern for potential human germ-cell mutagenicity. The only factor keeping methylmercury from the highest level of concern is lack of positive results in a heritable mutation assay.

In summary, there is increasing weight of evidence for effects other than neurodevelopmental that may be associated with low-dose methylmercury exposure.

4.5.6 Choice of Uncertainty Factor

For this methylmercury RfD the two major areas of uncertainty that can be addressed with a UF are interindividual toxicokinetic variability in ingested dose estimation and pharmacodynamic variability and uncertainty. For the former, EPA relied in part on the NRC analyses of variability in the pharmacokinetic factors underlying the conversion of a biomarker level of methylmercury to an ingested daily dose of methylmercury that corresponds to that level. We chose not to make a numerical adjustment in the dose conversion for the potential differences in cord vs. maternal blood mercury level, but rather consider this an additional area of toxicokinetic uncertainty. A quantitative uncertainty analysis was not feasible for toxicodynamics. A common practice is to apply a threefold UF for toxicodynamic variability and uncertainty.

In the calculation of this methylmercury RfD, a composite UF of 10 is used. This is to account for the following factors:

- Pharmacokinetic variability and uncertainty in estimating an ingested mercury dose from cord blood. A factor of 3 is applied for this area.

- Pharmacodynamic variability and uncertainty. A factor of 3 is applied for this area.

There are additional areas of concern in this risk estimate that lend support to an overall factor of 10. These include the following: inability to quantify long-term sequelae, lack of a two-generation reproductive effects assay, and issues on selection of critical effect (concern that there may be observable methylmercury effects at exposures below the BMDL). Section 4.5.5 discusses some of the concerns on selection of the critical effect. In this context one must also consider the analyses of the Faroese neuropsychological data wherein the observations in the most highly exposed subgroup were excluded from the model. Associations remained significant when the part of the cohort with maternal hair mercury concentrations greater than 10 ppm was excluded from the analyses. This indicates that it would be reasonable to expect some percentage of the population to show effects at or below 10 ppm hair mercury or at levels at or below 40 ppb cord blood. Given the overall robustness of the methylmercury database, but in consideration of the above areas of uncertainty, a composite factor of 10 is warranted.

4.6 CALCULATION OF THE RfD

The critical endpoint is drawn from the series of neuropsychological test results reported from the Faroese cohort. The BMDLs calculated on these endpoints are in Table 4-8. The ingested doses in μg/kg bw/day that correspond to the BMDLs range from 0.447 to 1.92. The ingested dose for the BNT whole-cohort BMDL is 1.081 μg/kg bw/day, rounded to 1.0 μg/kg bw/day.

For methylmercury, the RfD is calculated as follows:

$$RfD = \frac{BMD}{UF \times MF}$$

$$= \frac{1.0\ \mu g/kg-day}{10}$$

$$= 1 \times 10^{-4}\ mg/kg-day$$

$$= 0.1\ \mu g/kg/day.$$

As shown in Table 4-5, an RfD of 0.1 μg/kg bw/day reflects the range of neuropsychological test results in the Faroese children exposed *in utero*. These test scores are all indications of neuropsychological processes that are involved with the ability of a child to learn and process information. In the studies so far published on subtle neuropsychological effects in children, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling. That is, there are currently no data that would support the derivation of a child (vs. general population) RfD. This RfD is applicable to lifetime daily exposure for all populations including sensitive subgroups. It is not a developmental RfD per se, and its use is not restricted to pregnancy or developmental periods.

5.0 EXPOSURE ASSESSMENT

5.1 OVERVIEW OF RELATIVE SOURCE CONTRIBUTION ANALYSIS

When a water quality criterion is based on noncarcinogenic effects, anticipated exposures from sources other than drinking water and fish ingestion are taken into account so that the entire RfD is not attributed to drinking water and freshwater/estuarine fish consumption alone. The amount of exposure attributed to each source compared with total exposure is called the relative source contribution (RSC) analysis. The RfD used in calculating the criterion incorporates the RSC to ensure that the criterion is protective enough, given the other anticipated sources of exposure. The method of accounting for nonwater exposure sources is described in more detail in the revised 2000 Human Health Methodology (U.S. EPA, 2000a).

The method of determining the RSC differs depending on several factors, including (1) the magnitude of total exposure compared with the RfD, (2) the adequacy of the exposure data available, (3) whether more than one guidance or criterion is to be set for a contaminant, and (4) whether there is more than one significant exposure source for the chemical and population of concern. The population of concern for methylmercury is discussed in Section 5.2. The sources of exposure to methylmercury and estimates of exposure used to determine the RSC for the identified population are discussed in Sections 5.3 through 5.4. Section 5.5 summarizes the exposure uncertainties based on data adequacy. Finally, Section 5.6 provides the RSC estimates for methylmercury.

5.2 POPULATION OF CONCERN

Methylmercury is a highly toxic contaminant that can cause a variety of adverse health effects. Toxicity has been observed in adults exposed through consumption of contaminated food. Toxic effects and subtle neuropsychological effects have been seen in children exposed *in utero* when their mothers consumed contaminated food while pregnant. The RfD (see section 4) is based on changes in neuropsychological measures in children exposed *in utero*. The choice was made to use a developmental endpoint, as this appeared to be the most sensitive indicator of a methylmercury effect. As discussed in section 4, there is concern that other less-studied effects may occur at lower doses. There is also concern (based on recent reports on the Minamata, Japan, population) that exposure *in utero* or in childhood could result in subtle impairments that would not be detectable until middle age or older.

The RfD for methylmercury was not calculated to be a developmental RfD only. It is intended to serve as a level of exposure without expectation of adverse effects when that exposure is encountered on a daily basis for a lifetime.

In the studies on subtle neuropsychological effects in children published so far, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling. That is, there are currently no data that would support the derivation of a child RfD versus a general population RfD.

Therefore, the population at risk evaluated for the methylmercury criterion is adults in the general population, not only the developing fetus or child.

5.3 OVERVIEW OF POTENTIAL FOR EXPOSURE

The sources and fate of methylmercury are discussed in detail in Volume III of the *Mercury Study Report to Congress* (MSRC) (U.S. EPA, 1997b). The MSRC exposure assessment is in Volume IV (U.S. EPA, 1997c). A brief summary of the information in that document is presented here. Methylmercury occurs naturally in the environment. It is readily produced from inorganic mercury in fresh and marine surface waters and sediments through the methylating action of certain microorganisms. Bacterial methylation rates appear to increase under anaerobic conditions, elevated temperatures, and low pH. Methylmercury generally constitutes no more than 25% of the total mercury in surface water; typically, less than 10% is observed (U.S. EPA, 1997b). According to the MSRC, mercury cycles in the environment as a result of natural and anthropogenic activities. Most of the mercury in the atmosphere is elemental mercury vapor, which can remain there for as much as 1 year and, due to atmospheric mobilization, can be widely dispersed and transported thousands of miles from likely sources of emission (U.S. EPA, 1997b). However, the MSRC also clearly states that methylmercury is the chemical species of concern due to its fate and transport to waterbodies and sediments, and its subsequent bioaccumulation in the aquatic food web.

Because the source of most mercury is deposition from atmospheric mercury emissions, ingestion is an indirect route of exposure. The MSRC included numerous computer-simulated estimates of mercury exposure for selected population scenarios, based on fate and transport models (see U.S. EPA, 1997b,c). These are summarized throughout this chapter in the *Predicted Concentrations* subsections. Further exposure assessment information is presented in Volumes III and IV of the MSRC (U.S. EPA, 1997b,c)

and a characterization of human health from methylmercury exposure is discussed in detail in Volume VII (U.S. EPA, 1997g). That exposure assessment information is summarized throughout this chapter. The primary source of human exposure to methylmercury is through consumption of contaminated fish and seafood. This reflects the tendency of aquatic organisms to rapidly absorb methylmercury and to store it for long periods of time in their muscle tissue, thus accumulating it to levels that are potentially toxic to humans who eat fish and shellfish. The concentrations of methylmercury in fish tissue are highly variable across water bodies. Within a water body, methylmercury concentration generally increases with fish size and trophic level.

Derivation of the water quality criterion requires that intake of methylmercury from other sources of exposure be evaluated for comparison with intake from water and/or freshwater and estuarine fish. In addition to its occurrence in water and freshwater and estuarine fish, methylmercury occurs in soil, air, marine fish and other seafood, and nonfish foods. Intake of these media thus represent potential pathways for exposure. Other potential routes include occupational exposure and erosion of dental amalgams. Estimates of intake from these sources are presented in Section 5.4 below. Assessment of these sources of methylmercury clearly indicates that substantially all exposure to methylmercury occurs from the ingestion of contaminated fish. The other sources of exposure (water, nonfish foods, air, and soil) are all several orders of magnitude less than exposures from fish consumption.

5.4 ESTIMATES OF OCCURRENCE AND EXPOSURE FROM ENVIRONMENTAL MEDIA

This section reports data available for the estimation of methylmercury intake from relevant exposure sources. Exposure may occur from several environmental sources including soil, sediment, ambient surface water, drinking water, food products, and air. Human exposures are estimated by combining information on the occurrence of methylmercury in environmental media with intake rates for these media. Information on intake assumptions, environmental concentrations, and estimated exposure are reported by medium below.

Table 5-1. Exposure parameters used in derivation of the water quality criterion

Parameter	Population			Source
	Children (0-14 years)	Women of Childbearing Age (15-44 years)	Adults in the General Population	
Body Weight, kg	30	67	70	U.S. EPA (2000a)
Drinking Water Intake, L/day	1.0	2.0	2.0	U.S. EPA (2000a)
Freshwater/Estuarine Fish Intake, gm/day	156.3[b]	165.5[b]	17.5[c]	U.S. EPA (2000a)
Inhalation, m^3/day	10.4	11	20	U.S. EPA (1994, 1997h)[d]
Soil Ingestion, g/day	0.0001, 0.01[a]	0.00005	0.00005	U.S. EPA (1997h)
Mean Marine Fish Intake, kg/day	74.9[b]	91.04[b]	12.46[c]	U.S. EPA (2000b)
Median Marine Fish Intake, kg/day	59.71[b]	75.48[b]	0[c]	U.S. EPA (2000b)
90th Percentile Marine Fish Intake, g/day	152.29[b]	188.35[b]	49.16[c]	U.S. EPA (2000b)

[a]Pica child soil ingestion
[b]For children and women of childbearing age, intake rates are estimates of "consumers only" data (as described in U.S. EPA, 2000b).
[c]For adults in the general population, intake rates are estimates of all survey respondents to derive an estimate of long-term consumption (U.S. EPA).
[d]Inhalation rates for children and women of childbearing age from U.S. EPA, 1997h. Inhalation rates for adults in the general population from U.S. EPA (1994).

5.4.1 Exposure Intake Parameters

Exposure parameters selected for derivation of the water quality criterion should reflect the population to be protected. Default values for most exposure parameters are provided in the 2000 Human Health Methodology (U.S. EPA, 2000a). Where necessary, values for parameters not specified in the Methodology were obtained from the Exposure Factors Handbook (U.S. EPA, 1997h). Parameter values used to estimate intake of methylmercury by children aged 0-14 years, women of childbearing age, and adults in the general population are summarized in Table 5-1.

5.4.2 Intake from Drinking Water/Ambient Water

In cases where the water quality criterion is based on fish intake only, drinking water intake is accounted for as a separate exposure. In these instances, information on treated drinking water, if available, is the relevant information to use when accounting for other sources of exposure. Measured concentrations for methylmercury in drinking water and raw surface and ground source waters have been reported in the MSRC (U.S. EPA, 1997c). Predicted concentrations and ingestion rates summarized in this section are based on computer simulation models described in Volume IV of the MSRC (U.S. EPA, 1997c).

5.4.2.1 Measured Concentrations in Water

Raw Surface Water. Studies in the United States and Europe suggest that the concentrations of methylmercury in raw surface water are highly variable (U.S. EPA, 1997b). Properties reported to influence the levels of methylmercury in water bodies include proximity to a point source of mercury, pH, anoxia, dissolved organic carbon, and the presence of wetlands (U.S. EPA, 1997b). Estimates of the percent of total mercury in surface waters that exists as methylmercury are available from a number of studies. The available data suggest that methylmercury generally constitutes less than 20% of the total mercury in the water column (Kudo et al., 1982; Parks et al., 1989; Bloom and Effler, 1990; Watras et al., 1995a). In lakes without point source discharges, methylmercury frequently constitutes 10% or less of total mercury in the water column (Lee and Hultberg, 1990; Bloom et al., 1991; Lindqvist, 1991; Porcella et al., 1991; Watras and Bloom, 1992; Driscoll et al., 1994, 1995; Watras et al., 1995b). U.S. EPA (1997b) reported the use of Monte Carlo simulation to derive a point estimate of 0.078 for the fraction of total mercury present as methylmercury in the epilimnion (water column above the thermocline) of lakes for the purpose of estimating a bioaccumulation factor (BAF) for trophic level 4. Speciation data used as input for the simulation are shown in Table 5-2.

Data for measured concentrations of methylmercury and total mercury in ambient water as presented in the MSRC (U.S. EPA, 1997b) are summarized in Table 5-3. Since publication of the MSRC, Krabbenhoft et al. (1999) reported concentrations of total mercury and methylmercury in surface water samples collected as part of a U.S. Geological Survey (USGS) national scale pilot study to examine relations for total mercury and methylmercury in water, sediment, and fish. Water samples were collected in the summer and fall of 1998 at 106 sites from 21 basins across the United States, including Alaska and Hawaii. The sampling sites spanned the dominant east-to-west mercury deposition gradient

Table 5-2. Data Used in the Monte Carlo Simulation to Estimate the Fraction of Total Dissolved Mercury in the Epilimnion Present as Methylmercury

Fraction of Total Mercury Present as Methylmercury	Location	Reference
0.046	Pallette Lake, WI	Bloom et al. (1991)
0.054	Oregon Pond, NY	Driscoll et al. (1995)
0.059	Lake Michigan	Mason and Sullivan (1997)
0.089	Clear Lake, CA	Suchanek et al. (1993)
0.089	Onondaga Lake, NY	Henry et al. (1995)
0.092	Iso Valkjarvi, Finland	Rask and Verta (1995)
0.15	22 lake aggregate, WI	Watras et al. (1995a,b)

Source: U.S. EPA (1997c, Appendix D)

and represented a wide range of environmental settings. The study authors reported that most (number not reported) samples were collected from streams. Total mercury was measured using U.S. EPA Method 1631 with detection by cold vapor atomic fluorescence spectroscopy (CVAFS). Methylmercury was analyzed by distillation and aqueous phase ethylation, with detection by CVAFS. The detection limits for total mercury and methylmercury were 0.04 ng/L and 0.025 ng/L, respectively (Olson and DeWild, 1999). Of the 106 total sites, 21 were classified as background or reference sites. The mean concentration for methylmercury at background sites was 0.13 ng/L, which represented 3.4% of the mean total mercury concentration. When all sites were considered, the mean methylmercury concentration (104 sites) was 0.15 $\pm$ 0.26 ng/L (range 0.01 to 1.481 ng/L). The median value was 0.06 ng/L. The difference in mean and median values was attributed to high mercury concentrations at sites impacted by mining activities, which resulted in a skewed distribution. Methylmercury constituted 1% to 11% of total mercury concentration in the 21 study basins.

Other measured concentrations of total mercury and methylmercury in fresh water as reported in the MSRC (U.S. EPA, 1997b) are summarized in Table 5-3. Reported values for methylmercury measured at two sites in the United States ranged from less than 0.004 ng/L to 0.06 ng/L. The New Jersey Department of Environmental Protection and Energy (NJDEPE) (1993) reported total mercury concentrations for lakes of 0.04 to 74 ng/L and values of 1 to 7 ng/L for rivers and streams. Based on the

Table 5-3. Measured Methylmercury Concentrations in Surface Fresh Water

Study Description	Total Mercury (ng/L)	Methylmercury (ng/L)	Methylmercury % of Total	Reference
Lake Crescent, WA	0.163	<0.004	<2.5	Bloom and Watras (1989)[a]
Little Rock Lake (reference basin)	1.0-1.2	0.045-0.06	mean of 5	Watras and Bloom (1992)[a]
Lake Michigan (total)	7.2 microlayer 8.0 at 0.3m 6.3 at 10m	NA	NA	Cleckner et al. (1995)[a]
Lake Champlain	(filtered) 3.4 microlayer 3.2 at 0.3m 2.2 at 15m	NA	NA	Cleckner et al. (1995)[a]
Lakes Rivers and Streams	0.04 - 74 1 - 7	NA	NA	NJDEPE (1993)[a]
USGS National Mercury Pilot Study (predominately streams)	3.43 Background 16.6 All sites	0.13 Background 0.15 All sites	3.4 1 - 11	Krabbenhoft et al. (1999)

[a] As reported in U.S. EPA (1997c)
NA Not available

U.S. EPA (1997b) Monte Carlo estimate for speciation (0.078), these values would correspond to approximate methylmercury concentrations of 0.003 to 6 ng/L for lakes and 0.078 to 0.55 ng/L for rivers and streams. The MSRC did not indicate whether the NJDEPE (1993) data represented measures of central tendency.

Ground Water. Nationally aggregated data for mercury or methylmercury concentrations in ground water were not reported in the MSRC (U.S. EPA, 1997b). Local estimates of concentration are available from three studies. Krabbenhoft and Babiarz (1992) reported mercury levels of 2 to 4 ng/L in near-surface ground water in remote areas of Wisconsin, with a maximum of 0.3 ng/L (roughly 7.5% to 15% of total mercury concentration) occurring as methylmercury. Bloom et al. (1989) reported a value of 0.3 ng/L for total mercury in a Washington state well. In contrast to these comparatively low concentrations, Dooley (1992) reported total mercury levels up to and exceeding 2,000 ng/L in southern New Jersey domestic wells.

Drinking Water. Much of the data reported for total mercury concentration in drinking water is below the detection limit of 100 ng/L associated with older methods of analysis (U.S. EPA, 1997b). Lindqvist and Rodhe (1985) estimated that the concentration range of mercury in drinking water is the same as rain, with an average level of total mercury in drinking water of 25 ng/L. NJDEPE (1993) reported a range of 0.3 to 25 ng/L for total mercury in U.S. drinking and tap water. Speciation data for mercury in drinking water are not available, but may be similar to those observed for rain water (U.S. EPA, 1997c). The percentage of total mercury that is methylmercury in rain water ranged from 0.1% to 6.3% in two studies reported by Lee and Iverfeldt (1991) and Fitzgerald et al. (1991). The high end of this range approaches the point estimate of 7.8% derived for the fraction of methylmercury in the water column of lakes using Monte Carlo simulation (U.S. EPA, 1997b). Assuming that 7.8% of the total mercury is methylmercury (U.S. EPA, 1997b), these data suggest a crude estimate of methylmercury concentration in drinking and tap water ranging from 0.023 ng/L to 1.95 ng/L.

5.4.2.2 Predicted Concentrations in Water

U.S. EPA (1997b) reported the results of watershed fate and transport modeling conducted to predict the background concentration of mercury in water bodies. Atmospheric concentrations and deposition rates were used as inputs to the IEM-2M model. The IEM-2M model is composed of two integrated models that simulate mercury fate using mass balance equations that describe processes in watershed soils and a shallow lake. Using this approach, background levels of total dissolved mercury concentrations in the water column of 0.9 and 0.2 ng/L were predicted for hypothetical Eastern and Western U.S. sites, respectively. More than 80% of the total mercury in the water column was predicted to occur as the inorganic divalent species. As indicated above, the fraction of the predicted background concentration occurring as methylmercury was 7.8% (U.S. EPA, 1997b).

In the MSRC, the background values reported above were used as inputs to a localized model analysis that examined the impact of a variety of anthropogenic emission sources (municipal waste combustors, hospital medical waste incinerators, utility boilers, chlor-alkali plant) on methylmercury concentrations in the water column at distances of 2.5, 10, or 25 km from the source. This effort was undertaken because some monitoring studies suggest that measured mercury concentrations may be higher in areas adjacent to stationary industrial and combustion sources known to emit mercury (U.S. EPA, 1997b). Results of this analysis are of relevance to derivation of the water quality criterion because they include data specifically for predicted methylmercury concentrations, and thus permit comparison with measured concentrations.

The Industrial Source Code air dispersion model (ISC3) was used for simulation. Hypothetical facilities were defined to represent actual emissions from existing industrial processes and combustion sources; these were situated in hypothetical locations intended to simulate a site in either the Western or Eastern United States (U.S. EPA, 1997b). Input values for air concentrations consisted of simulated concentration results (50th and 90th percentile values) obtained using the regional Lagrangian model of air pollution (RELMAP). The assumptions and inputs utilized in this modeling effort are described in detail in Volume III of the MSRC (U.S. EPA, 1997b).

Results for predicted methylmercury concentrations in water are illustrated in Table 5-4. Predicted concentrations for dissolved methylmercury in water across all scenarios ranged from 0.014 to 1.0 ng/L. The highest predicted concentrations occurred at a location 2.5 km from a chlor-alkali plant. The predicted contribution of the hypothetical emission sources to methylmercury concentration ranged from 0 to 99% across all modeling scenarios. Although these results are meant to describe events on a local (adjacent to emission source) rather than nationwide scale, they provide a general frame of reference for comparison with measured values. The predicted range compares to the measured concentration range of 0.01 to 1.481 ng/L reported by Krabbenhoft et al. (1999) for 104 surface water samples collected at sites across the United States. The range of predicted concentrations overlapped the methylmercury concentrations in ground water (less than or equal to 0.3 ng/L, based on one study) and drinking water (0.023 to 1.95 ng/L) estimated from measurement data presented in Section 5.4.2.1.

5.4.2.3 Intake Estimates for Drinking Water and Ambient Water

Using the methylmercury concentration data in treated drinking water, and in ambient water it is possible to estimate exposure from water ingestion. For methylmercury, data on measured concentrations in ground and treated drinking water are limited. The database for surface water is somewhat more extensive. Estimates of intake based on ingestion of drinking water and ambient water are provided below.

Ambient Surface Water

A central tendency value for methylmercury in ambient surface water based on national data is available from a pilot study conducted by the U.S. Geological Survey (Krabbenhoft et al., 1999). Concentrations of methylmercury in ambient surface water ranged from a mean background level of 0.13 ng/L (or 1.3×10^{-7} mg/L) to a mean concentration for all sites of 0.15 ng/L (or 1.5×10^{-7} mg/L).

Combining the mean for methylmercury concentrations at all sites with default exposure assumptions of a 30 kg child aged 0 to 14 years who consumes 1 L/day of ambient surface water yields an estimated exposure of 5.0×10^{-9} mg/kg-day. Combining the mean value for methylmercury concentrations at all sites with default exposure assumptions of 2 L/day for water ingestion rate and 67 kg for body weight yields an exposure estimate of 4.5×10^{-9} mg/kg-day for a woman of childbearing age (15-44 years old). Adults in the general population have an estimated exposure value of 4.3×10^{-9} mg/kg-day, based on a default body weight and water intake rate of 70 kg and 2 L/day, respectively. These values are summarized in Table 5-5.

Table 5-4. Range of Predicted Dissolved Methylmercury Concentrations in Water for Hypothetical Emissions Scenarios

Site	RELMAP Percentile	Methylmercury (ng/L)		Scenario	
		Min	Max	Min	Max
Eastern	50	0.077	1.0	Large hospital incinerator, 25 km	Chlor-alkali plant, 2.5 km
Eastern	90	0.11	1.0	Multiple scenarios	Chlor-alkali plant, 2.5 km
Western	50	0.014	1.0	Multiple scenarios	Chlor-alkali plant, 2.5 km
Western	90	0.034	1.0	Multiple scenarios	Chlor-alkali plant, 2.5 km

Source: U.S. EPA (1997c)

Table 5-5. Ambient Surface Water Intake Assumptions and Estimates

Population of Concern	**Methylmercury in Ambient Surface Water[a] (mg/L)**	**Ingestion Rate[b] (L/day)**	**Body Weight[b] (kg)**	**Daily Exposure Estimate (mg/kg-day)**
Children (0-14 yr)	1.5×10^{-7}	1.0	30	5.0×10^{-9}
Childbearing Women	1.5×10^{-7}	2.0	67	4.5×10^{-9}
Adults in the General Population	1.5×10^{-7}	2.0	70	4.3×10^{-9}

[a] Methylmercury concentration is the mean for all sites in the national pilot study as reported in Krabbenhoft et al. (1999)

[b] U.S. EPA (2000a)

Drinking Water

Although drinking water concentrations can be calculated based on surface water and ground-water concentrations (U.S. EPA, 2000a), the available ground-water data were not adequate for this purpose. Therefore, exposure from drinking water was roughly estimated for women of childbearing age, children aged 0-14 years, and adults in the general population based on existing drinking and tapwater concentration data (NJDEPE, 1993). For the purpose of this estimate, it was assumed that the reported data reflected contributions from both ground water and surface water. Combining the estimated range for methylmercury concentrations in drinking water (0.0234 to 1.95 ng/L, or 2.34×10^{-8} to 1.95×10^{-6} mg/L) with default values for a 30 kg child aged 0 to 14 years consuming 1 L/day of drinking water yields an exposure estimate ranging from 7.8×10^{-10} to 6.5×10^{-8} mg/kg-day. Combining the estimated range for methylmercury concentrations in drinking water with default values of 2 L/day for drinking water intake and 67 kg for body weight yields an exposure estimate that ranges from 7.0×10^{-10} to 5.8×10^{-8} mg/kg-day for a woman of childbearing age (15-44 years old). Exposure estimates from ingesting drinking water by adults in the general population range from 6.7×10^{-10} to 5.6×10^{-8} mg/kg-day, based on a default body weight and water intake rate of 70 kg and 2 L/day, respectively. These values and intake assumptions are summarized below in Table 5-6.

Table 5-6. Drinking Water Intake Assumptions and Estimates

Population of Concern	**Methylmercury in Drinking Water (mg/L)**	**Ingestion Rate[a] (L/day)**	**Body Weight[a] (kg)**	**Daily Exposure Estimate (mg/kg-day)**
Children (0-14 yr)	2.3×10^{-8} to 1.9×10^{-6}	1.0	30	7.8×10^{-10} to 6.5×10^{-8}
Childbearing Women	2.3×10^{-8} to 1.9×10^{-6}	2.0	67	7.0×10^{-10} to 5.8×10^{-8}
Adults in the General Population	2.3×10^{-8} to 1.9×10^{-6}	2.0	70	6.7×10^{-10} to 5.6×10^{-8}

[a] U.S. EPA (2000a)

5.4.3 Nonfish Dietary Exposures

5.4.3.1 Measured Concentrations in Food Other Than Fish

Historically, measurements of mercury have not been speciated in food items other than fish, primarily because of the lack of adequate methodology (Madson and Thompson, 1998). However, the limited data available suggest that nonfish foods such as dairy products, fruits, and vegetables may potentially contribute to intake of methylmercury. Furthermore, it is possible that the agricultural practice of using fishmeal in animal feeds may result in increased levels of methylmercury in nonfish foods (ATSDR, 1999). This section examines the available data on mercury and methylmercury concentrations in nonfish human food items.

Information on the concentration of total mercury in dietary items is available from the *Total Diet Study* (TDS) conducted by the U.S. Food and Drug Administration (U.S. FDA). The TDS is an on-going nationwide program that determines the levels of nutrients and selected contaminants in foods for the purpose of estimating intakes of these substances by the U.S. population. A total of 839 samples for 47 food items were collected and analyzed for total mercury during the period from 1991 to 1996 (U.S. FDA, 1999). Of the reported results, 756 (90%) were below the detection limit for mercury (0.01 to 0.02 mg/kg depending on food item) and 30 (3.6%) were considered to contain trace amounts of mercury. These trace values represent the best estimates of those who analyzed the data, but in all cases are below the nominal limit of quantitation.

Examination of the data for the 41 nonfish dietary items analyzed (6 items were fish) indicates that the total mercury concentration was below the detection limit for most samples. These samples were assigned a concentration of zero for statistical analysis (U.S. FDA, 1999). Trace amounts of total mercury were found in one sample each (out of 18 total samples for each item) of fried beef liver, cooked oatmeal, and boiled spinach. The maximum detected concentration of mercury in nonfish dietary items was 0.03 mg/kg in fried beef liver. The reported median concentrations for total mercury in all individual nonfish dietary categories were zero. Based on these data, the central tendency estimate for methylmercury intake from nonfish dietary items is zero. For comparison, the mean mercury concentration from all 47 food categories (containing both fish and nonfish dietary items) was 0.006 mg/kg (U.S. FDA, 1999).

The MSRC (U.S. EPA, 1997b) also summarized data for methylmercury concentrations reported in local studies. Measured concentrations of methylmercury in garden produce and crops are summarized in Table 5-7. Because the database for methylmercury content in these foods is limited, information is also presented from studies that report total mercury concentrations. In general, the level of methylmercury in agricultural produce is low, with the highest concentration (30 ng/g dry weight) observed in leafy vegetables. Plants grown in the presence of elevated soil or atmospheric concentrations of mercury are reported to contain elevated concentrations of total mercury (U.S. EPA, 1997b). Temple and Linzon (1977) sampled the mercury content of fresh fruits and vegetables around a large chlor-alkali plant in an urban-residential neighborhood. Among garden produce, leafy crops accumulated the highest levels of mercury. One lettuce sample contained 99 ng/g wet weight of mercury (background: <0.6 ng/g), and a sample of beet greens contained 37 ng/g wet weight (background: 3 ng/g). Tomatoes and cucumbers within 400 m of the chlor-alkali plant averaged 2 and 4.5 ng/g wet weight of mercury, respectively, compared with measured background levels of 1 ng/g.

Because the mercury content in plants tends to be low, livestock typically accumulate little mercury from forage or silage (U.S. EPA, 1997b). However, use of fishmeal as food for poultry and other livestock may result in increased mercury levels in these animals (ATSDR, 1999). Measured concentrations of mercury and methylmercury in meat products are summarized in Table 5-8. Although the database is limited, the available data suggest that methylmercury concentrations in meats are generally low in comparison with levels observed in fish (U.S. EPA, 1997b).

Pedersen et al. (1994) monitored the level of mercury in wine, beer, soft drinks, and various juices. Total mercury levels in these beverages were at or below the detection limit of 6 μg/L in all samples tested.

Infant postnatal exposure to methylmercury through ingestion of breast milk is a pathway of potential concern. As noted in Section 3.4, methylmercury is excreted in breast milk (Bakir et al., 1973; Sundberg and Oskarsson, 1992). The ratio of mercury in breast milk to mercury in whole blood was approximately 1:20 in women exposed to methylmercury via contaminated grain in Iraq between 1971 and 1972 (Bakir et al., 1973). Skerfving (1988) found that 16% of mercury in human breast milk is methylmercury. Note that the MSRC found the data on breast milk to be insufficient to support estimation of exposure by this route.

Table 5-7. Measured Mercury Concentrations in Garden Produce and Crops

Study Description	Total Mercury (ng/g dry wt)	Methylmercury (ng/g dry wt)	Methylmercury (mg/kg dry wt)	% Methylmercury	Reference
NY Garden Conditions: Leafy Vegetables	64-139	9.5-30	9.5×10^{-3} - 30×10^{-3}	15-23	Cappon (1987)
NY Garden Conditions: Tuberous Plants	11-36	0.3-6.6	0.3×10^{-3} - 6.6×10^{-3}	11-36	
NY Garden Conditions: Cole[a]	50-64	8.8-12	8.8×10^{-3} - 12×10^{-3}	18	
NY Garden Conditions: Fruiting vegetables	2.9-27	0-2.4	0 - 2.4×10^{-3}	0-9.1	
NY Garden Conditions: Beans	4.3	0	0	0	
Maize	1.7 - 7.3	NA	NA	NA	Szymaczak and Grajeta (1992)

NA Not available

[a] Members of the plant genus *Brassica* including cabbage, broccoli, and cauliflower.

Source: U.S. EPA (1997c)

Table 5-8. Measured Mercury Concentration in Meats

Study Description	Total Mercury (ng/g wet weight)	Approx. Total Mercury (ng/g mercury dry weight)[1]	Approx. Total Mercury (mg/kg mercury dry weight)	% Methyl-mercury	Reference
Saginaw River, MI "Roaster" Ducks (n=6)	48	124.7	124.7×10^{-3}	NA	U.S. EPA (1992a)
Wild Deer (Northern Wisconsin)	5-14	13-36	13×10^{-3} - 36×10^{-3}	11-57 %	Bloom and Kuhn (1994)
Beef: Raw	< 1	< 2.6	$<2.6 \times 10^{-3}$	> 10%	
Beef: Lunch Meat	21	54.5	54.5×10^{-3}	4%	
Beef: Frank	<1	< 2.6	$<2.6 \times 10^{-3}$	> 60%	
Beef Muscle: Control Group	2-3	5.2 - 7.8	5.2×10^{-3} - 7.8×10^{-3}	NA	Vreman et al. (1986)*
Beef Muscle: Exposed Group	1-4	2.6 - 10.4	2.6×10^{-3} - 10.4×10^{-3}	NA	
Beef Liver: Control Group	3000 - 7000	7800 - 18000	7.8 - 18.0	NA	
Beef Liver: Exposed Group	9000 - 26000	23400- 67000	23.4 - 67.0	NA	
Pork: Raw and Sausage	< 1	< 2.6	$<2.6 \times 10^{-3}$	0-70%	Bloom and Kuhn (1994)
Chicken: Raw and Lunch Meat	< 1 to 29	< 2.6 to 75.4	$<2.6 \times 10^{-3}$ - 75.4×10^{-3}	20-67%	
Turkey: Lunch Meat	< 1	< 2.6	$<2.6 \times 10^{-3}$	>20%	

* Exposed animals received 1.7 mg mercury/day as mercury acetate; intake for controls was approximately 0.2 mg mercury/day.
[1] Based on an assumed water content of 0.615, which is average for beef (Baes et al., 1984).
Source: U.S. EPA (1997c)

5.4.3.2 Predicted Concentrations in Foods Other than Fish

U.S. EPA (1997d) reported predicted concentrations in fruits, vegetables, beef, pork, poultry, dairy products, and eggs. As described in previous sections on predicted concentrations in various media, this effort was undertaken because some monitoring studies suggest that measured mercury concentrations may be higher in areas adjacent to stationary industrial and combustion sources known to emit mercury (U.S. EPA, 1997b). Results of this local study are of relevance to derivation of the water quality criterion because they include data specifically for predicted methylmercury concentrations, and thus permit comparison with measured concentrations.

The Industrial Source Code air dispersion model (ISC3) was used for the computer simulation to estimate nonfish dietary exposure. Model plants (defined as hypothetical facilities which were developed to represent actual emissions from existing industrial processes and combustion sources), were situated in hypothetical locations intended to simulate a site in either the Western or Eastern United States (U.S. EPA, 1997b). Input values for air concentrations consisted of simulated concentration results (50^{th} and 90^{th} percentile values) obtained using the regional Lagrangian model of air pollution (RELMAP). The assumptions and inputs utilized in this modeling effort are described in detail in Volume III of the MSRC (U.S. EPA, 1997b).

Predicted concentrations in a variety of nonfish foods are reported in Table 5-9. Because the computer models used to generate these concentrations incorporated a point source for mercury emissions, these predictions likely approach a worst-case scenario for methylmercury levels in foods. Based on a large hospital waste incinerator scenario in the Eastern United States (50th percentile), concentrations of methylmercury (expressed on a dry-weight basis) ranged from 0.095 ng/g to 7.1 ng/g in fruits and vegetables, with the highest concentration observed in leafy vegetables. Concentrations of methylmercury animal products ranged from 0.0013 ng/g to 4.2 ng/g, with the highest concentrations observed in beef and dairy products. The hypothetical facility was considered to contribute less than 10% to the total plant mercury concentration (U.S. EPA, 1997b). The local source was considered to contribute 7% to 11% of the total mercury in beef, dairy products, and pork and 41% of total mercury in poultry and eggs (U.S. EPA, 1997b).

5.4.3.3 Intake Estimates for Food Other Than Fish

Data from the U.S. FDA TDS (described in Section 5.4.3.1) suggest that nonfish dietary items generally account for a very small fraction of total mercury intake. For the purpose of estimating methylmercury intake from nonfish foods, the central tendency estimate of methylmercury concentration is assumed to be zero. Thus, the average daily intake is zero mg/kg-day for adults in the general

Table 5-9. Predicted Methylmercury Concentrations in Produce and Animal Products Based on a Large Hospital Waste Incinerator Scenario

Item	Total Mercury (ng/g dry wt.)	% Methylmercury	Methylmercury (ng/g dry wt.)
Produce			
Root vegetables	1.9	5	0.095
Fruits	35	5	1.7
Fruiting vegetables	35	5	1.7
Leafy vegetables	34	21	7.1
Animal Products			
Beef	8.6	19	1.6
Beef liver	22	19	4.2
Dairy	11	19	2.1
Pork	0.007	18	0.0013
Poultry	0.12	3	0.0036
Eggs	0.12	3	0.0036
Lamb	3.9	19	0.74

[a]Data based on ISC simulation for receptors at a humid site 2.5 km from a large hospital hazardous materials incinerator (HMI) and input from RELMAP (East 50th Percentile).
Source: U.S. EPA (1997b)

population, children, and women of childbearing age. This estimate is in agreement with WHO (1990), which reported that nonfish foods accounted for 0% of average daily intake of methylmercury.

Methylmercury intake from animal products and produce has been estimated by computer model simulation for four hypothetical high-end exposure scenarios: rural subsistence farmer (adult and child), rural home gardener (adult and child), urban high-end adult, and high-end fisher (adult and child) (U.S. EPA, 1997c). These predicted methylmercury intakes are presented in Table 5-10. Methylmercury intake from animal products was estimated only for the rural subsistence farmer. Intake from animal products and produce was not considered in the remaining scenarios. The subsistence farmer was anticipated to represent a very high-end exposure scenario. Simulation of intake for these scenarios employed a body-weight exposure assumption for children (i.e., 17 kg) that differs from the currently recommended value (i.e., 30 kg) for derivation of water quality criterion values (see Table 5-1). Estimated exposure from produce for several high-end scenarios ranged from 2.3×10^{-7} mg/kg-day for the

high-end urban adult to 5.8 x 10^{-5} mg/kg-day for the adult high-end fisher. Estimated exposures from animal products for the rural subsistence farmer scenario were 2.1 x 10^{-6} mg/kg-day and 5.3 x 10^{-6} mg/kg-day for an adult and child, respectively. These model-predicted estimates support the finding of generally low methylmercury intake from nonfish foods indicated by measurement data from the TDS (U.S. FDA, 1999) and the conclusion in the MSRC that substantially all exposure to methylmercury is from fish consumption.

5.4.4 Fish Consumption Estimates

The MSRC concluded that most human exposure to methylmercury is from food and that it is primarily from fish consumption (U.S. EPA, 1997g). Ingestion of contaminated fish is also reported by many other authors to be the only significant source of methylmercury exposure to the general human population (Stern, 1993; Swedish EPA, 1991; WHO, 1990). This conclusion is based on the observation that in many nonfish foods, the mercury content is typically near detection limits and is comprised mainly of inorganic species (WHO, 1990). In contrast, most of the mercury in fish is methylated.

This section provides information on measured and predicted tissue concentrations of methylmercury in freshwater fish and marine fish, and estimates of intake for several target populations. The MSRC presented data for freshwater fish and marine fish. The MSRC did not include a separate evaluation of estuarine fish, although the data on marine species presented in the MSRC (from the National Marine Fisheries Service) include some estuarine species. Sections 5.4.4.1 and 5.4.4.2, below, summarize the major studies presented in the MSRC for freshwater fish. Section 5.4.4.3 presents an estimate of intake for both freshwater and estuarine species. Although the intake estimate is based on the freshwater fish methylmercury concentrations only, EPA believes that the freshwater fish concentrations are similar to the concentrations in these estuarine species presented in the MSRC. EPA, therefore, believes that calculating an intake estimate using the freshwater/estuarine default consumption rates provides a reasonable approximation of combined freshwater/estuarine fish methylmercury exposure. A more accurate estimate of marine fish methylmercury intake has been made (Section 5.4.4.7) since this source of exposure is included in the RSC estimate that is factored into the final water quality criterion calculation.

Table 5-10. Predicted Methylmercury Intake from Dietary Items Based on Five Hypothetical High-End Exposure Scenarios

Parameter	Exposure Scenario[a]										
	Rural Subsistence Farmer		Rural Home Gardener		Urban				High End Fisher		Recreational Angler
	Adult	Child	Adult	Child	Adult Average	Adult High-end	Child Average	Child High-end	Adult	Child	Adult
Body Weight (kg)	70	17	70	17	70	70	17	17	70	17	70
Fraction of Total Mercury From All Sources[b] That Is Methylmercury[c] (%)	10	13	6	6	2	6	2	2	99	99	100
Total Methylmercury Ingestion-All Modeled Sources[b] (mg/kg-day)	4.1E-06	6.9E-06	5.9E-07	7.8E-07	4.0E-09	2.4E-07	3.2E-08	1.2E-06	1.1E-03	1.6E-03	5.6E-04
Fraction of Total Mercury in Produce That Is Methylmercury[d] (%)	6	6	6	6	NA	6	NA	NA	6	6	NA
Methylmercury Intake From Produce (mg/kg-day)	1.7E-06	1.4E-06	5.8E-07	6.6E-07	NA	2.3E-07	NA	NA	5.8E-05	6.6E-07	NA
Fraction of Total Mercury in Animal Products that is Methylmercury[e] (%)	19	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylmercury Intake From Animal Products (mg/kg-day)	2.1E-06	5.3E-06	0	0	NA	NA	NA	NA	0	NA	NA

[a]Data based on ISC simulation for receptors at a humid site 2.5 km from a large hospital medical waste incinerator (HMI) and input from RELMAP (East 50th Percentile)
[b]All sources includes intake from fish, water, soil, produce, and animal products.
[c]Predicted fraction of total mercury that is ingested from all sources as methylmercury.
[d]Predicted fraction of total mercury that is ingested from produce as methylmercury.
[e]Predicted fraction of total mercury that is ingested from animal products as methylmercury.
NA Not available
Source: U.S. EPA (1997c)

5.4.4.1 Measured Concentrations in Freshwater Fish

Data for mercury concentrations in freshwater fish have been previously compiled and evaluated by EPA in Volume IV of the MSRC (U.S. EPA, 1997c). The discussion below provides information on the national studies considered and the database selected by U.S. EPA after careful consideration of data quality issues to provide concentration data for estimating human exposure to methylmercury (U.S. EPA, 1997c).

Two national studies were considered by U.S. EPA (1997c) for estimation of mercury concentrations in freshwater finfish populations. Lowe et al. (1985) reported mercury concentrations in fish from the National Contaminant Biomonitoring Program. The freshwater fish data were collected between 1978-1981 at 112 stations located across the United States. Mercury was measured by a flameless cold vapor technique, with a detection limit of 0.01 μg/g wet weight. Most of the sampled fish were taken from rivers (93 of the 112 sample sites were rivers); the other 19 sites included larger lakes, canals, and streams. Fish weights and lengths were consistently recorded. The mercury concentrations measured in this study are shown in Table 5-11. Several varieties of fish were sampled. Carp, large mouth bass, and white sucker were most common. The geometric mean mercury concentration of all sampled fish was 0.11 μg/g wet weight; the minimum and maximum concentrations reported were 0.01 and 0.77 μg/g wet weight, respectively. The highest reported mercury concentrations (0.77 μg/g wet weight) occurred in a northern squawfish collected from the Columbia River. Mean mercury concentrations (whether geometric or arithmetic mean not specified) by species are reported in the MSRC (U.S. EPA, 1997c).

A national study of chemical residues in freshwater fish was conducted by U.S. EPA (1992b) and also reported by Bahnick et al. (1994). As reported in the MSRC (U.S. EPA, 1997c), five bottom-feeding species (e.g., carp) and five game fish species (e.g., bass) were sampled at each of the 314 sampling sites in the United States. These sites were selected based on proximity to either point or nonpoint pollution sources. Thirty-five "remote" sites among the 314 total sites were included to provide nonimpacted background pollutant concentrations. The study primarily targeted sites that were expected to be impacted by increased dioxin levels. The point sources proximate to sites of fish collection included the following: pulp and paper mills, Superfund sites, publicly owned treatment works (POTWs), and other industrial sites. Data describing fish age, weight, and sex were not consistently collected. Whole body mercury concentrations were determined for bottom feeders, and mercury concentrations in fillets were analyzed for the game fish. Total mercury levels were analyzed using flameless atomic absorption,

with reported detection limits of 0.05 μg/g early in the study (465 samples analyzed prior to 1990) and 0.0013 μg/g later in the study (195 samples), as the analytical technique improved. Nondetects were reported as a zero value and averaged as zeros. The estimated standard deviation for replicate samples was 0.047 μg/g in the concentration range of 0.08 to 1.79 μg/g. Mercury was detected in fish collected from 92% of the sample sites. Concentration data are provided in Table 5-12. The maximum mercury level detected was 1.8 μg/g, and the mean concentration in 669 fish samples across all sites was 0.26 μg/g. The highest measurements occurred in walleye, largemouth bass, and carp. The mercury concentrations in measured in fish around POTWs were the highest among all point source data; the median value for mercury concentration was 0.61 μg/g.

The intake estimates presented in this document, similar to the MSRC, are based on the mean concentration values from the studies described above; that is, the fish mercury concentration data based on the Bahnick et al. (1994) and Lowe et al. (1985) studies were used for the estimates. However, the MSRC also includes summary data from numerous other studies that indicate significantly higher levels of methylmercury in freshwater fish. For example, concentrations of methylmercury in bass, crappie, northern pike, and trout of 2.0, 1.39, 1.71, and 1.19 μg/g, respectively, represent a few of the higher species concentrations reported (see U.S. EPA, 1997d, Table 4-48).

Measurements of elevated levels of mercury in fish have been reported elsewhere. For example, the North East States Coordinated Air Use Management (NESCAUM) summarized data from New England's freshwater fish in the "Mercury Study: A Framework for Action" by the Northeast States and Eastern Canadian Provinces (1998) (see Table 5-11).

Additional data are available for New York State (Simonin and Meyer, 1998). In New York State, maximum mercury concentrations over 2 ppm were seen for the following species: walleye (3.2 ppm), striped bass (5.4 ppm), white perch (3.2 ppm) Northern pike (2.1 ppm), smallmouth bass (3.34 ppm), largemouth bass (2.39 ppm), rock bass (2.7 ppm), drum (1.4 ppm), channel catfish (2.0 ppm), sunfish (1.2 ppm), American eel (1.6 ppm), Lake trout (2.7 ppm), white sucker (1.2 ppm), black crappie (1.4 ppm), and carp (5.8 ppm).

5.4.4.2 Predicted Concentrations in Freshwater Fish

As previously indicated, the MSRC included numerous computer-simulated estimates of mercury exposure for selected population scenarios (U.S. EPA, 1997c). These included predicted concentrations

in Tier 4 (predatory) fish based on exposure modeling. The Industrial Source Code air dispersion model (ISC3) was used for simulation of methylmercury concentrations in water and biota near mercury emissions sources. Model plants (large and small municipal waste combustors, large and small hazardous materials incinerators, coal and oil-fired utility boilers, chlor-alkali plant), defined as hypothetical facilities which were developed to represent actual emissions from existing industrial processes and combustion sources, were situated in hypothetical locations intended to simulate a site in either the Western or Eastern United States (U.S. EPA, 1997b). Input values for air concentrations consisted of simulated concentration results (50^{th} and 90^{th} percentile values) obtained using the regional Lagrangian model of air pollution (RELMAP). The assumptions and inputs utilized in this modeling effort are described in detail in Volume III of the MSRC (U.S. EPA, 1997b).

Fish tissue methylmercury concentrations of 5.3×10^{-1} µg/g and 9.7×10^{-2} µg/g were predicted for the simulated Eastern and Western sites, respectively, in scenarios where the hypothetical emission sources had zero percent impact on local mercury levels (i.e., the predicted concentration resulted only from background levels of mercury in the environment and regional anthropogenic sources). These levels are of the same order of magnitude as the mean measured values of 0.11 and 0.26 µg/g (1.1×10^{-1} and 2.6×10^{-1} µg/g) reported by Lowe et al. (1985) and Bahnick et al. (1994) respectively. The maximum predicted tissue concentration of 68 µg/g was associated with the Eastern site chlor-alkali plant scenario.

5.4.4.3 Intake Estimates from Freshwater/Estuarine Fish

The mercury concentration data reported in U.S. EPA (1992b) and Bahnick et al. (1994) were selected to determine a rough estimate of methylmercury intake from freshwater and estuarine fish. In contrast to the data reported by Lowe et al. (1985), the selected study provides an arithmetic mean as a measure of central tendency. These data have previously been used by U.S. EPA (1997d) to calculate methylmercury intake estimates under different fish ingestion scenarios. In this section, new estimates of methylmercury intake are calculated in accordance with technical guidance provided in the 2000 Human Health Methodology (U.S. EPA, 2000a). Using the mean mercury concentration of 0.26 µg mercury/g fish wet weight (or mg/kg) reported by U.S. EPA (1992b) and Bahnick et al. (1994), and assuming that approximately 100 percent is methylmercury (U.S. EPA, 1997d), the average estimated methylmercury concentration in freshwater/estuarine fish is 0.26 mg/kg.

Table 5-11. Freshwater Fish Mercury Concentrations from Lowe et al. (1985) and Northeast States and Eastern Canadian Provinces (1998)

Lowe et al. (1985)	
Fish Species	***Mean Mercury Concentration (μg/g Wet Wt)***
Bass	0.157
Bloater	0.093
Bluegill	0.033
Smallmouth Buffalo	0.096
Carp, Common	0.093
Catfish (channel, largemouth, rock, striped, white)	0.088
Crappie (black, white)	0.114
Freshwater Drum	0.117
Northern Squawfish	0.33
Northern Pike	0.127
Perch (white and yellow)	0.11
Sauger	0.23
Sucker (bridgelip, carpsucker, klamath, largescale, longnose, rivercarpsucker, tahoe)	0.114
Trout (brown, lake, rainbow)	0.149
Walleye	0.1
Mean of Measured Fish	0.11[a]
Northeast States and Eastern Canadian Provinces (1998)	
Fish Species	***Maximum Mercury Concentration in ppm***
Largemouth bass	8.94
Smallmouth bass	5.0
Yellow perch	3.15
Chain pickerel	2.81
Lake trout	2.70
Walleye	2.04
Brown bullhead	1.10
Brook trout	0.98

[a] Geometric mean; U.S. EPA (1997c) did not specify whether means for individual species or species categories were geometric or arithmetic means.
Source: U.S. EPA (1997c), Northeast States and Eastern Canadian Provinces (1998).

To estimate daily exposure from methylmercury in freshwater/estuarine fish, average body weights and high-end fish ingestion rates (90th percentile) for the populations of concern are estimated, as recommended in the 2000 Human Health Methodology. Default intake values for fish intake by children, women of child-bearing age, and adults in the general population are provided in U.S. EPA (2000a). These intake values were estimated from the on-going, nationally based Continuing Survey of Food Intake for Individuals (CSFII) conducted by the U.S. Department of Agriculture. The CSFII is conducted annually, and dietary data from all 50 States are collected (U.S. EPA, 2000a). The estimates of intake based on CSFII incorporated data for both consumers and nonconsumers of fish, and represent intake of all fish whether store-bought or sport-caught (U.S. EPA, 2000a). The freshwater/estuarine fish ingestion rates for children, women of child-bearing age, and adults in the general population are estimated to be 156.3 g/day, 165.5 g/day, and 17.5 g/day, respectively (U.S. EPA, 2000a). Note that the estimates for both children and women of childbearing age are based on short-term consumption, whereas the estimate for adults in the general population is based on average long-term consumption.

Table 5-12. Freshwater Fish Mercury Concentrations from Bahnick et al. (1994).

Species	**Mean Mercury Concentration (μg/g Wet Wt)**
Carp	0.11
Sucker (white, redhorse, spotter)	0.167
Catfish (channel and flathead)	0.16
Bass (white, largemouth, smallmouth)	0.38
Walleye	0.52
Northern Pike	0.31
Crappie	0.22
Brown Trout	0.14
Mean of Measured Fish	0.26

Source: U.S. EPA (1997c)

The recommended body weights for children 0 to 14 years, women of childbearing age, and adults in the general population are 30 kg, 67 kg, and 70 kg, respectively (U.S. EPA, 2000a). Based on these exposure assumptions, the daily exposure estimates of methylmercury intake from ingestion of freshwater/estuarine fish for children, women of childbearing age, and adults in the general population are 1.4×10^{-3} mg/kg-day, 6.4×10^{-4} mg/kg-day, and 6.5×10^{-5} mg/kg-day, respectively. Input assumptions and calculated daily exposure estimates for freshwater/estuarine fish are summarized in Table 5-13.

5.4.4.4 Measured Concentrations in Marine Fish and Shellfish

The MSRC (U.S. EPA, 1997b,c) has summarized data on concentrations of total mercury and methylmercury in marine fish and shellfish. Analyses of total mercury concentrations in marine fish and shellfish have been carried out over the past two to three decades. Data describing methylmercury concentrations in marine fish are predominantly based on the National Marine Fisheries Service (NMFS) database, the largest publicly available database on mercury

Table 5-13. Freshwater/Estuarine Fish Intake Assumptions and Estimates

Population of Concern	Mercury in Fish[a] (mg/kg)	Methyl-mercury/ Mercury in Fish[b] (%)	Methyl-mercury in Fish (mg/kg)	Ingestion Rate[c] (kg/day)	Body Weight[c] (kg)	Daily Exposure Estimate (mg/kg-day)
Children	0.26	100	0.26	0.1563	30	1.4×10^{-3}
Women of Childbearing Age	0.26	100	0.26	0.1655	67	6.4×10^{-4}
Adults in the General Population	0.26	100	0.26	0.0175	70	6.5×10^{-5}

[a] U.S. EPA (1992b) and Bahnick et al. (1994)
[b] U.S. EPA (1997c)
[c] U.S. EPA (2000a)

concentrations in marine fish. In the early 1970s, the NMFS conducted testing for total mercury in more than 200 seafood species of commercial and recreational interest (Hall et al., 1978). The determination of mercury in fish was based on flameless (cold vapor) atomic absorption spectrophotometry following chemical digestion of the fish sample. These analytical methods are described in Hall et al. (1978).

The NMFS Report provides data on number of samples, the number of samples where mercury was not detected ("nondetects"), and mean, standard deviation, minimum, and maximum detected mercury levels (in parts per million wet weight) for 1,333 combinations of fish/shellfish species, variety, location caught, and tissue (Hall et al., 1978). This database consists of 777 fish/shellfish species for which mercury concentration data are provided. This represents 5,707 analyses of fish and shellfish tissues for total mercury, of which 1,467 or 26%, were reported at nondetectable levels. A discussion of the issues associated with evaluation and use of nondetect data for methylmercury in the NMFS database is provided in the MSRC (U.S. EPA, 1997c). A summary of NMFS concentration data is provided in Table 5-14.

Two additional databases for mercury concentration in marine fish and shellfish are cited in the MSRC (U.S. EPA, 1997d). These are the *Report on the Chance of U.S. Seafood Consumers Exceeding "The Current Daily Intake for Mercury and Recommended Controls"* (U.S. FDA, 1978) and a report by Stern et al. (1996) that examined exposure of New Jersey residents to mercury via fish consumption. Although concentration data from these databases are reported in the MSRC (U.S. EPA, 1997c), detailed descriptions and evaluations of study quality are not provided.

The intake estimates presented in this document, similar to the MSRC, are based on the mean concentration values from the studies described above; that is, the fish mercury concentration data based on the NMFS, Stern et al., and U.S. FDA studies were used for the estimates. However, the MSRC also includes summary data from numerous other studies that indicate significantly higher levels of methylmercury in marine fish. For example, concentrations of methylmercury in mackerel, pompano, shark, snapper, and swordfish of 2.9, 8.42, 4.53, 2.17, and 2.72 μg/g, respectively, represent a few of the higher species concentrations reported (see U.S. EPA, 1997c).

5.4.4.5 Other Measured Concentration Data for Marine Fish and Shellfish

Additional national-scope information on methylmercury in marine biota is available from Project Mussel Watch. Project Mussel Watch measures concentrations of organic and trace metal contaminants

in fresh, whole soft-parts of bivalve mollusks (i.e., mussels and oysters) at more than 240 coastal and estuarine sites. Data are currently available from 1986 through 1993 and are summarized in the MSRC (U.S. EPA, 1997b). Average concentrations along the North Atlantic, Eastern Gulf, and Pacific coasts (0.15, 0.14, and 0.11 μg/g dry weight, respectively) are higher than those collected along the Middle Atlantic, South Atlantic, and Western Gulf coasts (0.06, 0.09, and 0.08 μg/g dry weight, respectively). The highest concentrations exceeded 1.0 μg/g dry weight and were collected along the Western Gulf and Pacific coasts (1.80 and 1.01 μg/g dry weight, respectively).

Annual Mussel Watch data on mercury concentrations in bivalve mollusks at specific sites have been aggregated to national geometric means for the purpose of analyzing temporal trends (O'Conner and Beliaeff, 1995). The national means do not show any temporal trend in mercury concentrations in mussels and oysters for the period 1986-1993. Temporal trend analysis was also conducted on a site-by-site basis for 154 Mussel Watch sites for which there were data for at least 6 years during the period of 1986-1993 (O'Conner and Beliaeff, 1995). Seven sites exhibited an increasing trend in mercury concentrations, and eight sites exhibited a decreasing trend in mercury concentrations, with 95% statistical confidence.

5.4.4.6 Predicted Concentrations in Marine Fish and Shellfish

The computer simulations conducted by EPA and reported in the MSRC (U.S. EPA, 1997c) did not provide predictions for methylmercury concentrations in marine fish or shellfish.

5.4.4.7 Intake Estimates from Marine Fish and Shellfish

In accord with technical guidance provided in U.S. EPA (2000a), mean, median, and 90th percentile concentrations of methylmercury in marine fish were used to estimate daily exposure from methylmercury in marine fish. Species-specific mean concentrations of mercury in marine fish from the National Marine Fisheries Service (NMFS, 1978) are presented in EPA's MSRC (U.S. EPA, 1997c). These data are summarized in Table 5-14. For species where concentration was not reported in NMFS (1978), concentrations were estimated from data reported by Stern et al. (1996), U.S. FDA Compliance Testing data, or U.S. FDA (1978) as cited in U.S. EPA (1997c).

Table 5-14. Average Mercury Concentrations in Marine Fish and Shellfish

Species	Concentration[a] (µg Hg/g Wet Wt.)	Species	Concentration (µg Hg/g Wet Wt.)
Finfish			
Anchovy	0.047	Pompano*	0.104
Barracuda, Pacific	0.177	Porgy*	0.522[b]
Cod*	0.121	Ray	0.176
Croaker, Atlantic	0.125	Salmon*	0.035
Eel, American	0.213	Sardines*	0.1
Flounder*[,e]	0.092	Sea Bass*	0.135
Haddock*	0.089	Shark*	1.327
Hake	0.145	Skate	0.176
Halibut*	0.25	Smelt, Rainbow*	0.1
Herring	0.013	Snapper*	0.25
Kingfish	0.10	Sturgeon	0.235
Mackerel*	0.081	Swordfish*	0.95[c]
Mullet	0.009	Tuna*	0.206
Ocean Perch*	0.116	Whiting (silver hake)*	0.041
Pollock*	0.15	Whitefish*	0.054[d]
Shellfish			
Abalone	0.016	Oysters	0.023
Clam*	0.023	Scallop*	0.042
Crab*	0.117	Shrimp	0.047
Lobster*	0.232	Other shellfish*	0.012[b]
Molluscan Cephalopods			
Octopus*	0.029	Squid*	0.026

Source: U.S. EPA (1997c).

*Denotes species used in calculation of methylmercury intake from marine fish for one or more populations of concern, based on existence of data for consumption in the CSFII (U.S. EPA, 2000b).

[a] Mercury concentrations are from NMFS (1978) as reported in U.S. EPA (1997d) unless otherwise noted, measured as µg of total mercury per gram wet weight of fish tissue.

[b] Mercury concentration data are from Stern et al. (1996) as cited in U.S. EPA (1997c).

[c] Mercury concentration data are from U.S. FDA Compliance Testing as cited in U.S. EPA (1997c).

[d] Mercury concentration data are from U.S. FDA (1978) as cited in U.S. EPA (1997c).

[e] Mercury data for flounder were used as an estimate of mercury concentration in marine flatfish in marine intake calculations

A consumption-weighted mean concentration of mercury for all marine fish was calculated as follows. Each of the marine species selected for inclusion in the analysis was weighted based on species-specific U.S. population intake rates among the three populations of concern (U.S. EPA, 2000b). This weighting system accounts for variability of consumption among different species and across different populations of concern. The consumption weighting factor for each of the selected marine species was calculated as follows. The consumption rates for individual marine species were summed to give a total consumption rate for a particular population of concern. The weighting factor was then calculated as the quotient of the species-specific consumption rate divided by the total consumption rate:

$$\text{Weighting factor for species A} = \frac{\text{Species A consumption rate (g/day)}}{\text{Sum of consumption rates for all selected species (g/day)}}$$

For each population of concern, the average mercury concentration for each species was multiplied by its consumption weighting factor. This product was then summed across all selected marine species to estimate the mean concentration of mercury in all marine fish for that particular population of concern:

$$\text{Mean conc}(\mu g/g) = \sum [\text{species-specific conc}(\mu g/g) \times \text{species-specific weighting factor}]$$

Assuming that approximately 100% of the mercury in marine fish is present as methylmercury (U.S. EPA, 1997c), the weighted-average methylmercury concentrations in marine fish consumed by each of the populations of concern are 0.167 mg/kg, 0.147 mg/kg, and 0.157 mg/kg for children (aged 0-14 years), women of childbearing age, and adults in the general population, respectively.

Specific body weights and several fish ingestion rates (arithmetic mean, median and 90th percentile) for the populations of concern were used to estimate daily exposure from methylmercury in marine fish. Marine fish intake values for children, women of childbearing age, and adults in the general population are provided in U.S. EPA (2000b). For children and women of childbearing age, these intake values were estimated using 3 years of "consumers only" data (1994-1996) from the on-going, nationally based Continuing Survey of Food Intake for Individuals (CSFII) conducted by the U.S. Department of Agriculture. Intake values for adults in the general population were obtained using all survey respondents to derive an estimate of long-term consumption. The marine fish ingestion rates for children, women of childbearing age, and adults in the general population are presented in Table 5-15.

The current default body weights for children 0 to 14 years, women of childbearing age, and adults in the general population are 30 kg, 67 kg, and 70 kg, respectively (U.S. EPA, 2000a). Based on these exposure assumptions, the mean daily exposure estimates of methylmercury intake from ingestion of marine fish for children, women of childbearing age, and adults in the general population are 4.1×10^{-4} mg/kg-day, 2.0×10^{-4} mg/kg-day, and 2.7×10^{-5} mg/kg-day, respectively. The median daily exposure estimates of methylmercury intake from ingestion of marine fish for children, women of childbearing age, and adults in the general population are 3.2×10^{-4} mg/kg-day, 1.6×10^{-4} mg/kg-day, and 0 mg/kg-day, respectively. In addition, the 90th percentile daily exposure estimates of methylmercury intake from ingestion of marine fish for children, women of childbearing age, and adults in the general population are 8.5×10^{-4} mg/kg-day, 4.1×10^{-4} mg/kg-day, and 1.1×10^{-4} mg/kg-day, respectively. Input assumptions and calculated daily exposure estimates for marine fish are summarized in Table 5-16.

5.4.5 Respiratory Exposures

5.4.5.1 Measured Concentrations in Air

Outdoor Air. Vapor-phase elemental mercury is the predominant form of mercury in the atmosphere and constitutes up to 98% of the total mercury concentration (U.S. EPA, 1997b). Increased

Table 5-15. Marine Fish Ingestion Rates

Population of Concern	Mean Intake (kg/day)	Median Intake (kg/day)	90th Percentile Intake (kg/day)
Children	0.07490	0.05971	0.15229
Women of Childbearing Age	0.09104	0.07548	0.18835
Adults in the General Population	0.01246	0	0.04916

Source: U.S. EPA (2000b)

concentrations of the divalent form of mercury may be present near emission sources. Small fractions of particulate mercury and methylmercury may also be present. Atmospheric mercury concentrations in the United States are generally very low (U.S. EPA, 1997b). U.S. EPA (1993) as cited in the MSRC summarized information on total mercury concentrations in outdoor air and reported ranges of 1 to 4 ng/m^3 for rural areas and 10 to 170 ng/m^3 for urban areas. Methylmercury concentrations from these samples constituted 0% to 21% of the total mercury concentration, with percentage values reported to generally be on the low end of this range. A measure of central tendency was not provided with this estimate. Particulate mercury typically constituted less than 4% of total atmospheric mercury in rural areas, although this fraction was increased in urban areas. The current background mercury concentration over the Northern Hemisphere is considered to be between 1.5 and 2.0 ng/m^3 (Expert Panel on Mercury Atmospheric Processes, 1994). A background concentration of 1.6 ng/m^3 was reported by Fitzgerald (1994). This value was subsequently used by U.S. EPA (1997b) to model mercury fate in watershed soils and surface waters.

Bloom and Fitzgerald (1988) measured vapor-phase mercury concentrations in outdoor air samples collected from Long Island Sound, CT. Total mercury concentrations ranged from 1.4 to 5.3 ng/m^3. The fraction of total mercury present as methylmercury was estimated to be 0% to 1%. During the month of October, the mean methylmercury concentration was 12 pg/m^3 (range 4 to 38 pg/m^3). This concentration represented 0.7% of the total gaseous mercury concentration. During the month of November, the measured methylmercury concentration was less than 10 pg/m^3 and from December through August, the concentration was below the detection limit of 5 pg/m^3.

Indoor Air. No data were identified for indoor air concentrations of methylmercury.

5.4.5.2 Predicted Concentrations in Air

EPA has modeled mercury air concentrations for the continental United States using RELMAP simulation, meteorological data for the year 1989, and current mercury emission data. The background level of mercury in the atmosphere was assumed to be 1.6 ng/m^3. The results of this simulation are reported in (U.S. EPA, 1997b). Predicted concentrations for total mercury are given in Table 5-17. The predicted total mercury concentrations ranged from approximately 1.6 to 1.9 ng/m^3, with the highest concentrations predicted for the Eastern United States. The tabulated results indicate that total

Table 5-16. Intake Assumptions and Estimates for Marine Fish

Population of Concern[a]	Mercury in Marine Fish (mg/kg)	Methylmercury/ Mercury in Marine Fish %	Methylmercury in Marine Fish (mg/kg)	Body Wt. (kg)	Mean Daily Exposure Estimate (mg-kg-day)	Median Daily Exposure Estimate (mg-kg-day)	90th%Daily Exposure Estimate (mg-kg-day)
Children	1.67E-01	100%	1.67E-01	30	4.1E-04	3.2E-04	8.3E-04
Women of Childbearing Age	1.47E-01	100%	1.47E-01	67	2.0E-04	1.6E-04	4.1E-04
Adults in the General Population	1.57E-01	100%	1.57E-01	70	2.7E-05	0.0E+00	1.1E-04

[a] Marine fish intake assumptions for the populations of concern from U.S. EPA (2000b) are summarized in Table 5-15.

Table 5-17. Percentile Analysis of RELMAP Predicted Total Mercury Concentration Results (ng/m^3) for the Continental United States

Region	Min	10th	50th	90th	Max
Continental U.S.	1.602	1.607	1.624	1.685	1.995
East of 90° W longitude	1.616	1.640	1.668	1.720	1.995
West of 90° W longitude	1.602	1.606	1.616	1.642	1.743

Source: U.S. EPA (1997b)

mercury concentration never exceeded the background level by a large percentage (25% maximum) under the conditions of this simulation. Methylmercury concentration estimates were not provided in the model output as reported in the MSRC (U.S. EPA, 1997b) but, again, is presumed to be present predominantly as elemental mercury.

5.4.5.3 Intake Estimates for Air

The primary species of mercury to which humans are exposed through inhalation is vapor-phase elemental mercury (U.S. EPA, 1997g). Thus, inhalation exposure to methylmercury is not expected to be a significant route of concern when compared to intake via fish consumption.

Assuming the background mercury concentration of 0.0016 $\mu g/m^3$ (or 1.6 ng/m^3) reported by Fitzgerald (1994), of which approximately one percent is methylmercury (Bloom and Fitzgerald, 1988), the average methylmercury concentration in air is 0.000016 $\mu g/m^3$ (or 1.6×10^{-8} mg/m^3). Estimates of daily exposure from methylmercury in air were calculated using inhalation rates and body weights specific to the populations of concern. The long-term inhalation rate based on a time-weighted average for children 0 to 14 years is estimated to be 10.4 m^3/day (U.S. EPA, 1997h). The average, long-term inhalation rates for women of childbearing age and adults in the general population are estimated to be 11 m^3/day and 20 m^3/day, respectively (U.S. EPA, 1994, 1997h). The recommended body weights for children 0 to 14 years, women of childbearing age, and adults in the general population are 30 kg, 67 kg, and 70 kg, respectively (U.S. EPA, 2000a). Based on these exposure input assumptions, the daily exposure estimates from methylmercury in air for children 0 to 14 years, women of childbearing age, and adults in the general population are 5.5×10^{-9} mg/kg-day, 2.6×10^{-9} mg/kg-day, and 4.6×10^{-9} mg/kg-day, respectively. These input assumptions and calculated daily exposure estimates for air are presented in Table 5-18.

U.S. EPA (1997c) reported inhalation exposure estimates based on ISC simulation for a humid site 2.5 km from a large hospital medical waste incinerator (HMI) and input from RELMAP (Eastern U.S., 50th percentile) (Table 5-19). The inhalation parameters used in the simulation for children (16 m^3/day) differed from the rate adopted from U.S. EPA (1997h) for calculation of inhalation intake from measured concentrations (see Table 15-1). Estimated intake for all five exposure scenarios was zero mg/kg-day. This prediction supports the finding of low methylmercury intake via inhalation as calculated from measured concentrations.

Table 5-18. Inhalation Exposure Intake Assumptions and Estimates

Population of Concern	Mercury in Air[a] (mg/m^3)	Methyl-mercury/ Mercury in Air[b] (%)	Methyl-mercury in Air (mg/m^3)	Inhalation Rate[c] (m^3/day)	Body Weight[d] (kg)	Daily Exposure Estimate (mg/kg-day)
Children (0-14 yr)	1.6×10^{-6}	1	1.6×10^{-8}	10.4	30	5.5×10^{-9}
Women of Childbearing Age	1.6×10^{-6}	1	1.6×10^{-8}	11	67	2.6×10^{-9}
Adults in the General Population	1.6×10^{-6}	1	1.6×10^{-8}	20	70	4.6×10^{-9}

[a] Fitzgerald (1994) as cited in U.S. EPA (1997b).
[b] Bloom and Fitzgerald (1988) as cited in U.S. EPA (1997b).
[c] Inhalation rates from U.S. EPA (1994, 1997h).
[d] Current default body weight values from U.S. EPA (2000a).

Table 5-19. Predicted Methylmercury Intake from Air for Five Hypothetical High-End Exposure Scenarios

Parameter	Exposure Scenario[a]										
	Rural Subsistence Farmer		Rural Home Gardener		Urban				High End Fisher		Recrea-tional Angler
	Adult	Child	Adult	Child	Adult Aver-age	Adult High-end	Child Aver-age	Child High-end	Adult	Child	Adult
Inhalation Rate (m^3/day)	20	16	20	16	20	20	16	16	20	16	20
Contact Rate for Inhalation (hr/day)	24	24	24	24	24	16	24	24	24	24	24
Body Weight (kg)	70	17	70	17	70	70	17	17	70	17	70
Methylmercury Intake (mg/kg-day)	0	0	0	0	0	0	0	0	0	0	0

[a]Data based on ISC simulation for a receptors at a humid site 2.5 km from a large Hospital medical waste incinerator (HMI) and input from RELMAP (East 50th Percentile).
Source: U.S. EPA (1997c)

5.4.6 Soil/Sediment Exposures

5.4.6.1 Measured Concentrations in Soil/Sediment

The available data for measured methylmercury and total mercury concentrations in soils and sediments are summarized in Table 5-20, including a small number of studies that provide some data that are national in scope. In general, soil mercury levels are usually less than 200 ng/g in the top soil layer, but values exceeding this level are not uncommon, especially in areas affected by anthropogenic activities (U.S. EPA, 1997b). Soil mercury levels vary greatly with depth, with nearly all the mercury found in the top 20 cm of soil. Mercury levels are positively correlated with the percentage of organic matter in soil (Nriagu, 1979).

Some information is available on estimated typical or background levels of total mercury in U.S. soils and may be used with speciation data to estimate soil methylmercury concentrations. The MSRC (U.S. EPA, 1997b) states that approximately 1 to 3% of the total mercury in surface soil is methylmercury. The other 97% to 99% of total soil mercury can be considered to be largely Hg(II) complexes, although a small fraction of mercury in typical soil will be Hg^0 (Revis et al., 1990). The methylmercury percentage has been observed to exceed 3% in garden soil with high organic content under slightly acidic conditions (Cappon, 1987). Computer simulations of mercury fate and transport predict that methylmercury constitutes 2% of the total mercury in watershed soils (U.S. EPA, 1997b).

Davis et al. (1997) reported a range of 50 to 200 ng/g for total mercury concentrations in nonmercuriferous soils and sediments in background areas not directly impacted by volcanic emissions or anthropogenic releases. The authors stated that methylmercury typically constitutes 0.01% to 2 % of the total mercury concentration. Supporting information on the derivation of this estimate was not provided by the authors. The MSRC (U.S. EPA, 1997b) cited data from NJDEPE (1993) that indicates that typical U.S. soils contain 8 to 117 ng/g of total mercury. Neither an estimate of mean mercury concentration nor speciation data were provided in the description of this study as summarized in the MSRC. Assuming that approximately 2% of the total mercury concentration is present as methylmercury, these data suggest that typical U.S. soils contain 0.16 to 2.3 ng/g as methylmercury.

Shacklette and Boerngen (1984) reported mean concentrations, geometric standard deviations, and ranges for total mercury in soils and other surficial materials based on samples collected at 1318 sites across the conterminous United States. The geometric mean concentration for the conterminous United States was 58 ± 2,520 ng/g (ppb), and the estimated arithmetic mean was 89 ng/g. Additional data

indicate that the mean concentration of mercury in soils varies by region. In soils from the Western United States (west of the 96th meridian), the geometric mean concentration was 46 ± 2,330 ng/g (range <10 to 4,600 ng/g) and the estimated arithmetic mean was 65 ng/g. In soils from the Eastern United States (east of the 96th meridian), the geometric mean concentration was 81 ± 2,520 ng/g (range 10 to 3,400 ng/g), with an estimated arithmetic mean of 120 ng/g. Speciation data were not reported by these authors. Assuming that methylmercury constitutes approximately 2% of the total mercury concentration, the geometric and arithmetic mean levels of mercury present as methylmercury in soils in the conterminous United States would be approximately 1.2 ng/g and 1.8 ng/g, respectively.

Additional data are available on soil mercury and methylmercury concentrations for sites in the United States. As reported in the MSRC (U.S. EPA, 1997b), methylmercury concentrations in soil samples at locations in New York and Washington ranged from 0.3 to 22.9 ng/g dry weight and constituted 0.5% to 5.3% of the total soil mercury content. No other information on these studies was provided.

As characterized in the MSRC (U.S. EPA, 1997b), sediment mercury levels are typically higher than soil levels, and concentrations exceeding 200 ng/g are not unusual. Sediment mercury levels follow the same trends as soil in regards to depth, humic matter, and methylmercury percentage. There is some evidence suggesting that the methylmercury percentage increases with increasing total mercury contamination (Parks et al., 1989). Concentrations of mercury and (where available) methylmercury are tabulated in Table 5-20.

Table 5-20. Concentrations of Total Mercury and Methylmercury in Soil and Freshwater Aquatic Sediments

Location	Total Mercury (ng/g dry wt)	Methylmercury (ng/g dry wt)	% Methylmercury	Reference
Soils				
Discovery Park, Seattle, WA	29-133	0.3 - 1.3	0.6 - 1.5	Lindqvist et al. (1991)[a]
Wallace Falls, Cascades, WA	155 - 244	1.0 - 2.6	0.5 - 1.2	Lindqvist et al. (1991)[a]
Control Soil New York State	117	4.9	4.2	Cappon, (1981)[a]
Compost New York State	213	7.3	3.3	Cappon, (1987)[a]
Garden Soil New York State	406	22.9	5.3	Cappon, (1987)[a]
Soil and Other Surficial Materials in Conterminous U.S.	Conterminous U.S. 58 (geo mean) 89 (arith mean) Western U.S. 46 (geo mean) 65 (arith mean) Eastern U.S. 81 (geo mean) 120 (arith mean)	NA	NA	Shacklette and Boerngen (1984)
Typical U.S. Soils	8 - 117	NA	NA	NJDEPE (1993)[a]
Typical background levels in nonmercuriferous soils	50 - 200	0.01 - 2	NA	Davis et al. (1997)
Freshwater Aquatic Sediments				
80 Minnesota Lakes	34 -753 mean 174	NA	NA	Sorenson et al. (1990)[a]
North Central Wisconsin lakes	90 -190	NA	NA	Rada et al. (1989)[a]
Little Rock Lake, Wisconsin	10 - 170	NA	NA	Wiener et al. (1990)[a]
U.S. Lake sediment mean ranges	70 - 310	NA	NA	NJDEPE (1993)[a]

Location	Total Mercury (ng/g dry wt)	Methylmercury (ng/g dry wt)	% Methylmercury	Reference
U.S. GS National Pilot Study	105 Background 211 All sites	2.1 Background 1.87 All sites	0.1 1	Krabbenhoft et al. (1999)

[a] As cited in U.S. EPA (1997b)

5.4.6.2 Predicted Concentrations in Soil

The MSRC (U.S. EPA, 1997b) reported the results of watershed fate and transport modeling conducted to predict the concentration of mercury in watershed soils. Atmospheric concentrations and deposition rates were used as inputs to the IEM-2M model. The IEM-2M model is composed of two integrated models that simulate mercury fate using mass balance equations which describe processes in watershed soils and a shallow lake. Using this approach, total mercury concentrations of 47 and 8 ng/g were predicted for soils at hypothetical Eastern and Western U.S. sites, respectively. These predicted concentrations for total mercury in soils are lower than the measured concentrations reported by Shacklette and Boergen (1984) for conterminous and regional U.S. soils. More than 90% of the total mercury in soil was predicted to occur as the inorganic divalent species. The fraction of the predicted background concentration occurring as methylmercury was 2% for the Eastern site (U.S. EPA, 1997c), suggesting a soil methylmercury concentration of 0.9 ng/g based on modeling predictions for speciation. Corresponding speciation data was not reported for the Western site.

5.4.6.3 Intake Estimates for Soil/Sediment

The primary species of mercury in soil is largely considered to be Hg(II) complexes, although a small fraction of mercury in typical soil will be Hg^0 (Revis et al., 1990). Thus, ingestion exposure to methylmercury in soil is not expected to be a significant route of concern when compared to exposure via fish ingestion.

Assuming the background mercury arithmetic mean concentration of 89 ng/g (or 0.089 mg/kg) reported by Shacklette and Boerngen (1984), of which approximately 2% is methylmercury (U.S. EPA, 1997b,c; Cappon, 1987; Davis et al., 1997), the average estimated methylmercury concentration in soil is 1.78 ng/g (or 0.00178 mg/kg). To estimate daily exposure from methylmercury in soil, ingestion rates and body weights for populations of concerns must also be estimated. The average incidental soil ingestion rate for children is estimated to be 1×10^{-4} kg/day (U.S. EPA, 1997h). In addition, the average soil ingestion rate for pica children is estimated to be 1×10^{-2} kg/day (U.S. EPA, 1997h). The average soil ingestion rates for women of child-bearing age and the general adult population are both estimated to

be 5 x 10^{-5} kg/day (U.S. EPA, 1997h). The default body weights for children 0 to 14 years, women of child-bearing age, and adults in the general population are 30 kg, 67 kg, and 70 kg, respectively (U.S. EPA, 2000a). Based on these exposure input assumptions, the daily exposure estimates from methylmercury in soil for children, pica children, women of child-bearing age, and adults in the general population are 5.9 x10^{-9} mg/kg-day, 5.9 x 10^{-7} mg/kg-day, 1.3 x10^{-9} mg/kg-day, and 1.3 x10^{-9} mg/kg-day, respectively. These input assumptions and calculated daily exposure estimates for soil are presented in Table 5-21.

Table 5-21. Summary of Soil Ingestion Intake Assumptions and Estimates

Population of Concern	**Mercury in Soil[a] (mg/kg)**	**Methyl-mercury/ Mercury in Soil[b] (%)**	**Methyl-mercury in Soil (mg/kg)**	**Ingestion Rate[c] (kg/day)**	**Body Weight[d] (kg)**	**Daily Exposure Estimate (mg/kg-day)**
Children	0.089	2	0.00178	0.0001	30	5.9 x10^{-9}
Pica Children	0.089	2	0.00178	0.01	30	5.9 x10^{-7}
Women of Childbearing Age	0.089	2	0.00178	0.00005	67	1.3 x10^{-9}
Adults in the General Population	0.089	2	0.00178	0.00005	70	1.3 x10^{-9}

[a] Shacklette and Boerngen for the conterminous U.S. (1984).
[b] U.S. EPA (1997b,c); Cappon (1987) as cited in U.S. EPA (1997b); Davis et al. (1997).
[c] U.S. EPA (1997h).
[d] U.S. EPA (2000a).

Estimates of soil ingestion based on exposure modeling reported in the MSRC (U.S. EPA, 1997c) are summarized in Table 5-22. Predicted exposures are based on an ISC model simulation for a receptors at a humid site 2.5 km from a large hospital medical waste incinerator (HMI) and input from RELMAP (East 50th Percentile). Soil intake among the hypothetical receptors was highest for the urban pica child (1.2×10^{-6} mg/kg-day). The remaining estimates ranged from 3×10^{-9} to 2.4×10^{-8} mg/kg-day. These approximations are comparable to exposure estimates based on measured concentrations of mercury in soils in Table 5-21 when the twofold difference in assumed soil ingestion rate is considered.

5.4.7 Occupational and Other Exposures

Occupational Exposure. Occupational exposures are not routinely factored into the derivation of water quality criterion but may be considered on a chemical-specific basis. Information on occupational exposure to mercury has been summarized in the MSRC (U.S. EPA, 1997c). OSHA (1975) estimated that approximately 150,000 U.S. workers are exposed to mercury in at least 56 occupations. More recently, Campbell et al. (1992) reported that about 70,000 workers are annually exposed to mercury. Occupational settings in which exposure to mercury may occur include chemical and drug synthesis, hospitals, laboratories, dental practices, instrument manufacture, and battery manufacture (NIOSH, 1977). Jobs and processes involving mercury exposure include manufacture of measuring instruments (barometers, thermometers, etc.), mercury arc lamps, mercury switches, fluorescent lamps, mercury broilers, mirrors, electric rectifiers, electrolysis cathodes, pulp and paper, zinc carbon and mercury cell batteries, dental amalgams, antifouling paints, explosives, photographs, disinfectants, and fur processing.

Inorganic mercury accounts for nearly all occupational exposures (U.S. EPA, 1997c). Airborne elemental mercury vapor is the main pathway of concern, particularly in those industries with the greatest number of mercury exposures. Occupational exposure to methylmercury appears to be insignificant or rare. Thus, occupational exposures are not considered relevant to the derivation of ambient water criteria for methylmercury.

Table 5-22. Predicted Mercury Intake from Soil for Five Hypothetical High-End Exposure Scenarios

Parameter	Exposure Scenario[a]										
	Rural Subsistence Farmer		Rural Home Gardener		Urban				High-End Fisher		Recreational Angler
					Adult		Child				
	Adult	Child	Adult	Child	Average	High-end	Average	Pica	Adult	Child	Adult
Soil Ingestion Rate (g/day)	0.1	0.2	0.1	0.2*	0.1	0.1	0.2*	7.5	0.1	0.2	0.1
Body Weight (kg)	70	17	70	17	70	70	17	17	70	17	70
Total Mercury Intake (mg/kg/day)	1.5E-07	1.2E-06	1.5E-07	1.2E-06	2.0E-07	2.0E-07	1.6E-06	6.1E-05	1.5E-07	1.2E-06	1.5E-07
Fraction of Total Mercury That Is Methylmercury (%)	2	2	2	2	2	2	2	2	2	2	2
Methylmercury Intake (mg/kg/day)	3.0E-09	2.4E-08	3.0E-09	2.4E-08	4.0E-09	4.0E-09	3.2E-08	1.2E-06	3.0E-09	2.4E-08	3.0E-09

[a]Data based on ISC simulation for a receptors at a humid site 2.5 km from a large hospital medical waste incinerator (HMI) and input from RELMAP (East 50th Percentile).

*Soil ingestion rates for rural home gardener and urban child (average) were not available. An ingestion rate of 0.2 g/day was assumed based on the soil ingestion rates for the rural subsistence farmer and high-end fisher children.

Source U.S. EPA (1997c)

Exposure from Dental Amalgam. Gradual erosion of dental amalgam represents a pathway by which many people are routinely exposed to extremely small amounts of mercury. Dental amalgam fillings contain approximately 50% mercury by weight. The mercury in the amalgam is continuously released over time. Speciation data indicate that release occurs primarily as elemental mercury vapor (Begerow et al., 1994). Exposure to methylmercury via this route is thus expected to be insignificant. Therefore, exposure to methylmercury via this pathway is not considered relevant to RSC analysis for derivation of the water quality criterion.

5.5 EXPOSURE DATA ADEQUACY AND ESTIMATE UNCERTAINTIES

After identifying relevant exposure pathways and obtaining available data for quantifying exposure via each pathway, it is important to consider whether the data are adequate to describe exposure estimates for each exposure medium. The adequacy of the contaminant concentration data, in part, determines the specific method with which the RSC estimates will be determined. Important factors include sample size, accurate representation of the sample (e.g., whether sample selection was biased and whether data are current), the accuracy in the sample analysis procedures (i.e., whether errors occurred during measurement), and the sensitivity of the measurement relative to the environmental levels of concern (i.e., whether detection limits are low enough such that the concentration can be detected in most samples within a data set). Additional discussion on data adequacy is provided in the 2000 Human Health Methodology (U.S. EPA, 2000a).

5.5.1 Adequacy of Intake Estimate for Drinking Water

Ground water. Nationally distributed data for methylmercury or total mercury in ground water were not located. The MSRC (U.S. EPA, 1997b) reports data from three local studies in the United States. However, supporting information on sample size, detection limits, analytical methodology, and other information relevant to data adequacy are not provided in the MSRC. Therefore, these data (as presented in the MSRC) do not satisfy the adequacy requirements of the 2000 Human Health Methodology.

Drinking Water. The MSRC (U.S. EPA, 1997b) cited a typical level of 25 ng/L for total mercury concentration in drinking and tap water (Lindqvist and Rodhe, 1985). A range of 0.3 to 25 ng/L for total mercury in drinking water was also reported (NJDEPE, 1993). The presentation of these data in the MSRC did not provide information on the composition of this water (e.g., fraction from ground water and surface water) or treatment status. Furthermore, the presentation of data in the MSRC did not

provide information on the method of calculation or a detailed description of data quality (including source of data, sample size, detection limits, and analysis procedures) for this estimate. Thus, the data for drinking water (as presented in the MSRC) are considered sufficient only for a rough estimate of intake. Yet, using the higher-end value of 25 ng/L results in an estimate within the range estimated for surface water.

Raw surface water. National data for surface water concentrations (primarily stream data) are available from the U.S. Geological Survey National Pilot Study of Mercury Contamination (Krabbenhoft et al., 1999). Water samples were collected in the summer and fall of 1998 and thus are representative of current concentrations. Sampling occurred at 106 sites clustered in 21 basins across the United States, including Alaska and Hawaii. Data from 104 sites were used to determine values for mean, median, maximum, and minimum methylmercury concentrations. The sampling sites spanned the dominant east-to-west mercury deposition gradient and represented a wide range of environmental settings. Total mercury and methylmercury were measured using sensitive analytical methodology (U.S. EPA Method 1631). The detection limits for total mercury and methylmercury were reported in a separate document (Olson and DeWild, 1999) referenced in the report. Some samples were collected at sites impacted by mining activity. The high concentration of mercury in samples collected at those sites resulted in a positively skewed distribution, and this is reflected in the difference between the arithmetic mean and median values for samples collected at all sites (0.15 $\pm$ 0.26 ng/L vs. 0.06 ng/L, respectively). The measures of central tendency from this study compare favorably to a methylmercury concentration of 0.07 ng/L in surface water predicted by IEM-2M computer simulation (U.S. EPA, 1997b). The data reported by Krabbenhoft et al. (1999) are therefore considered to be adequate to estimate intake from surface water.

5.5.2 Intake from Nonfish Dietary Sources

Data for measured methylmercury concentrations in nonfish foods are available from several local studies and one national study. Estimates of methylmercury concentration in selected produce and animal products are also available from computer simulations (U.S. EPA, 1997c). Data from the local studies provide supporting information on methylmercury speciation and concentration in a variety of foods, but are considered too limited in scope for estimation of intakes for use in RSC analysis. Information on mercury content of fish and nonfish foods is available from the Total Diet Study (1991-1997) conducted by U.S. FDA (1999). This is an on-going, nationally based study conducted for determining intake of nutrients and contaminants by the U.S. population. Based on data adequacy requirements of the 2000 Human Health Methodology (U.S. EPA, 2000a), the sample size of the U.S.

EPA study is sufficient for calculation of central tendency and 90th percentile values. Detection limits and the number of samples with mercury concentrations below detection the limit are reported by food item. The procedure for treating these samples for statistical analysis is reported. These data are thus considered adequate to estimate central tendency and high-end intakes from nonfish food items.

5.5.3 Intake From Fish

The MSRC (U.S. EPA, 1997c) assessed data sources for estimates of both freshwater and marine fish intake. Reliable mercury concentration data are available from databases maintained for marine fish and shellfish by the National Marine Fisheries Service (NMFS, 1978) and two databases for freshwater fish (Lowe et al., 1985; Bahnick et al., 1994). These studies are national in scope, in contrast to many studies that have a local or regional focus. In addition, the studies were not initiated in response to specific incidents of mercury contamination, and thus may avoid potential bias toward high values. Results in these studies are reported as total mercury. However, the MSRC concluded, based on research conducted by Bloom (1992) and Morgan et al. (1994), that over 90% of the mercury present in fish and seafood is methylmercury. Thus, total mercury concentrations are considered appropriate for evaluation of methylmercury exposure in human populations. Detailed information on mercury concentration by species and statistical considerations in use of the available data are presented in U.S. EPA (1997c).

Issues relating to data adequacy for methylmercury concentrations in marine fish and shellfish have been addressed in the MSRC (U.S. EPA, 1997c). Although the NMFS data were initially compiled beginning in the 1970s, comparisons of the mercury concentrations identified in the NMFS database with compliance samples obtained by the U.S. FDA indicate that the NMFS data are appropriate to use in estimating intake of mercury from marine fish at the national level of data aggregation. Cramer (1994) reported on *Exposure of U.S. Consumers to Methylmercury from Fish* and noted that recent information from NMFS indicated that the fish mercury concentrations reported in the 1978 report do not appear to have changed significantly. The U.S. FDA also monitors methylmercury concentration in seafood. Cramer (1994) observed that results of recent U.S. FDA surveys indicate results parallel to earlier findings by U.S. FDA and NMFS. The National Academy of Sciences' National Research Council's Subcommittee on Seafood Safety (1991) also assessed the applicability of the NMFS 1978 database to current estimates of mercury concentrations in fish. This subcommittee similarly concluded that the mercury concentrations in the 1978 database differed little in from the U.S. FDA compliance samples estimating mercury concentrations in fish. An assessment of the NMFS database by persons with expertise in analytical chemistry and patterns of mercury contamination in the environment indicates that temporal patterns of mercury concentrations in fish do not preclude use of this database in current risk

assessment activities (EPA's Science Advisory Board's ad hoc Mercury Subcommittee; Interagency Peer Review Group, External Peer Review Group).

An issue raised by some reviewers of the MSRC (U.S. EPA, 1997c) concerned use of data in the NMFS database where mercury concentration was below the analytical detection limit. A detailed analysis of the methods for reporting and analyzing nondetect data (U.S. EPA, 1997c, Appendix C) indicated that differences among methods used to handle nondetect samples had negligible impact on the reported mean concentrations in marine fish tissue. Additional information on analytical and statistical considerations in use of the NMFS data is available in EPA's MSRC (U.S. EPA, 1997d). Overall, EPA finds that these data are adequate for estimating exposure from marine fish for derivation of the methylmercury water quality criterion.

Two compilations of data on mercury concentrations in freshwater fish were considered for use in development of the water quality criterion for methylmercury. The strengths and weaknesses of these studies have been evaluated and reported in the MSRC (U.S. EPA, 1997c). The studies reported by Lowe et al. (1985) and by Bahnick et al. (1994) appear to be systematic, national collections of fish pollutant concentration data. However, higher mercury concentrations in fish have been detected in other studies, and the values obtained in the Lowe et al. (1985) and Bahnick et al. (1994) studies should be interpreted as approximations of the mean concentrations in freshwater finfish (U.S. EPA, 1997c). The mean mercury concentrations for each study in all fish sampled vary by a factor of two. The mean mercury concentration reported by Lowe et al. (1985) was 0.11 μg/g, whereas the mean mercury concentration reported by Bahnick et al. (1994) was 0.26 μg/g. The basis for these differences in methylmercury concentrations is unknown. Differences in sampling of fish by trophic position, size, or age might have been responsible for the differences in mean mercury concentrations reported in the two studies. Older and larger fish, which occupy higher trophic positions in the aquatic food chain, would be expected to have higher mercury concentrations. The type of water body from which fish were collected may also influence fish mercury concentrations. Most of the fish collected by Lowe et al. (1985) were from rivers. The fate and transport of mercury in river systems is not as well characterized as in small lakes. In comparison, most of the data reported by Bahnick et al. (1994) were collected with a bias toward more contaminated/industrialized sites, although sampled sites were not specifically contaminated with mercury. Thus, it is possible that there is more mercury available to the aquatic food chains at the sites sampled by Bahnick et al. (1994). Another possibility is that the higher mercury concentrations reported by Bahnick et al. (1994) when compared with those reported by Lowe et al. (1985) reflect increases in mercury contamination over the time period between the studies. Trend data for methylmercury concentrations in freshwater fish over time do not exist, although there are data for fish

collected from coastal and estuarine sites (U.S. EPA, 1997c) as discussed above and in Section 5.4.4.5. Those data suggest that there are no clear temporal trends in tissue mercury concentrations in fish and shellfish over the past two decades. Overall, the data from either study were considered adequate for calculating central tendency and high-end estimates of methylmercury intake from freshwater fish.

5.5.4 Intake from Air

The MSRC (U.S. EPA, 1997b) reported concentration ranges for mercury in urban and rural air. Information on geographic location, sample sizes, and detection limits were not provided. A range of 0 to 21% for methylmercury speciation was presented without an estimate of central tendency. Thus, these data as presented in the MSRC do not satisfy the adequacy requirements of the 2000 Human Health Methodology. A value of 1.6 ng/m^3 was presented in the MSRC as representative of national background levels for total mercury. Details on the derivation of this concentration were not provided; however, this value was considered of sufficient reliability to be used as input for fate and transport modeling reported in the MSRC (U.S. EPA, 1997b,c). Concentration measurements and exposure modeling data presented in the MSRC (U.S. EPA, 1997c) were also evaluated as an alternative estimate of methylmercury concentration in air. Many factors (including selection of modeling equations, input assumptions, and source data) in the modeling analysis affect the predicted concentrations and resulting exposures. These factors are summarized and discussed in U.S. EPA (1997b,c,g). No data were located for methylmercury concentrations in indoor air. Thus, this potential source of exposure was not considered in the estimate of intake from air.

The information available on both measured and predicted air concentrations of methylmercury from the MSRC is insufficient to fully determine data adequacy for estimating central tendency and high-end exposures to methylmercury via inhalation. Estimates of inhalation exposure are presented, although they are considered to represent rough approximations of actual (or likely) intake. Yet, the available data summarized in the MSRC (including the computer-simulated estimates) indicate that exposure to methylmercury in ambient air is negligible.

5.5.5 Intake From Soil

Three studies report aggregate values for measured soil mercury concentration. Shacklette and Boerngen (1984) reported arithmetic and geometric mean concentrations, geometric standard deviations, and ranges for total mercury in soils and other surficial materials based on samples collected at 1,318 sites across the conterminous United States. Sample size for these estimates is adequate, and the data are

representative of concentrations in the United States, although detailed information on analytical methodology, detection limit, and the number and statistical treatment of samples below detection limit was not provided.

Davis et al. (1997) reported a range of 50 to 200 ng/g for total mercury concentration and an estimate of the percent present as methylmercury in nonmercuriferous soils and sediments in background areas not directly impacted by volcanic emissions or anthropogenic releases. However, supporting information on the derivation of this estimate was not provided by the authors. The MSRC (U.S. EPA, 1997b) cited data from NJDEPE (1993) which indicates that typical U.S. soils contain 8 to 117 ng/g of total mercury. Information necessary for assessment of data adequacy was not provided in the summary of this study.

Additional data are available on soil mercury and methylmercury concentrations for sites in the United States. The MSRC (U.S. EPA, 1997b) summarized two reports on methylmercury speciation in soils collected at sites in New York and Washington state. Because each of these studies addressed soil concentrations in only one state, they were not considered adequate for estimating methylmercury exposure from soil.

Computer simulation data for predicted soil concentration, methylmercury speciation, and exposure estimates are available for comparison to measured values. Predicted concentrations were calculated on a regional (Eastern and Western U.S.) basis. As noted by U.S. EPA (1997b,c,g), many factors in the simulation analysis (including modeling equations, input assumptions, and source data) potentially affect the predicted concentrations.

Overall, the currently available soil concentration data are considered adequate to obtain central tendency and high-end estimates of exposure. Although some information was not readily available from the summarized studies in the MSRC (e.g., detection limits), the estimates of exposure from soil ingestion presented in this document are considered adequate given the sampling size (especially the Shacklette and Boerngen study) and geographic representativeness. There is also a clear indication from all available studies that the amount of methylmercury in soil that is methylmercury is approximately 2%.

5.6 TOTAL EXPOSURE ESTIMATES

Total exposure (calculated as the sum of exposure from water, freshwater and estuarine fish, marine fish, nonfish foods, air, and soil) for the three population groups in comparison to the RfD is shown in

Table 5-23. To evaluate potential differences in exposure from ambient water and drinking water, total exposure was calculated using methylmercury exposure estimates for each source. Because the contribution of ambient water or drinking water intake to total exposure is negligible in comparison to the sum of intake from other sources, there is no difference in the total exposure estimated using these two alternatives.

The contribution of exposure from different media as a percentage of total exposure for three types of individuals is summarized in Tables 5-24 through 5-26. Daily exposure estimates on a mg/kg-day basis are presented in Tables 5-27 through 5-29. The information in these tables reflects use of three different intake assumptions for consumption of marine fish: mean, median and 90th percentile.

Table 5-23. Total Exposure Compared with the RfD for Methylmercury

Population of Concern	Exposure Parameters								Total Exposures with Ambient Water (mg/kg-day)			Total Exposures with Drinking Water (mg/kg-day)		
	Body Weight (kg)	Drinking Water Intake (L/day)	Fresh/ Estuarine Fish Intake (kg/day)	Inhalation (m^3/day)	Soil Ingestion (kg/day)	Mean Marine Fish Intake (kg/day)	Median Marine Fish Intake (kg/day)	90% Marine Fish Intake (kg/day)	Marine Mean[a]	Marine Median[b]	Marine 90%[c]	Marine Mean[a]	Marine Median[b]	Marine 90%[c]
Adults in the General Population	70	2.0	0.0175	20	0.00005	0.01246	0	0.04916	9.2×10^{-5}	6.5×10^{-5}	1.8×10^{-4}	9.2×10^{-5}	6.5×10^{-5}	1.8×10^{-4}
Women of Childbearing Age	67	2.0	0.1655	11	0.00005	0.09104	0.07548	0.18835	8.4×10^{-4}	8.0×10^{-3}	1.1×10^{-3}	8.4×10^{-4}	8.0×10^{-3}	1.1×10^{-3}
Children Age 0-14 Years	30	1.0	0.1563	10.4	0.0001 0.01[d]	0.0749	0.05971	0.15229	1.7×10^{-3}	1.6×10^{-3}	2.1×10^{-3}	1.7×10^{-3}	1.6×10^{-3}	2.1×10^{-3}
RfD									1.0×10^{-4} mg/kg-day			1.0×10^{-4} mg/kg-day		

[a] For adults in the general population, intake rates are estimates of all survey respondents to derive an estimate of long-term consumption.
[b] For children and women of childbearing age, intake rates are estimates of "consumers only" data (as described in U.S. EPA, 2000b).
[c] All freshwater/estuarine fish intake rates are based on the 90th percentile from the CSFII data (U.S. EPA, 2000b).
[d] Total exposure calculated using marine mean exposure estimate.
[e] Total exposure calculated using marine median exposure estimate.
[f] Total exposure calculated using marine 90th percentile exposure estimate.
[g] Pica child soil ingestion

Table 5-24. Percent of Total Exposures Using Marine Mean Intakes and Default Exposure Percentages for Three Types of Individuals[a]

Exposure Route	Fish and Water Criterion[b]			Fish-Only Criterion[c]		
	Exposure as a Percent of Total Exposure			Exposure as a Percent of Total Exposure		
	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years
Freshwater/Estuarine Fish	70.6490	76.1903	76.0230	70.6047	76.1848	76.0200
Water				0.0608	0.0069	0.0038
Marine Fish	29.3446	23.8093	23.9764	29.3281	23.8078	23.9755
Diet (Nonfish foods)	0	0	0	0	0	0
Air	0.005	0.0003	0.0003	0.005	0.0003	0.0003
Soil	0.0014	0.0002	0.0003	0.0014	0.0002	0.0003

[a] Exposures are based upon default body weight values (Table 5-1) and do not include pica child soil ingestion.
[b] Ambient surface water exposure estimates used in the fish and water criterion.
[c] Drinking water exposure estimates used in the fish only criterion.

Table 5-25. Percent of Total Exposures Using Marine Median Intakes and Default Exposure Percentages for Three Types of Individuals [a]

Exposure Route	Fish and Water Criterion[b]			Fish-Only Criterion[c]		
	Exposure as a Percent of Total Exposure			Exposure as a Percent of Total Exposure		
	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years
Freshwater/Estuarine Fish	99.9909	79.9997	80.2464	99.9047	79.9938	80.2431
Water				0.0862	0.0073	0.0040
Marine Fish	0	19.9998	19.7539	0	19.9984	19.7522
Diet (Nonfish foods)	0	0	0	0	0	0
Air	0.0071	0.0003	0.0003	0.0071	0.0003	0.0003
Soil	0.0020	0.0002	0.0004	0.0020	0.0002	0.0004

[a] Exposures are based upon default body weight values (Table 5-1) and do not include pica child soil ingestion.
[b] Ambient surface water exposure estimates used in the fish and water criterion.
[c] Drinking water exposure estimates used in the fish only criterion.

Table 5-26. Exposure from Various Routes as a Percent of Total Exposure Using Marine 90th % Intakes and Default Exposure Percentages for Three Types of Individuals [a]

Exposure Route	Fish and Water Criterion[b]			Fish-Only Criterion[c]		
	Exposure as a Percent of Total Exposure			Exposure as a Percent of Total Exposure		
	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years	Adults in the General Population	Women of Childbearing Age	Children Age 0-14 Years
Freshwater/Estuarine Fish	37.1431	60.9523	61.0326	37.1297	60.9488	61.0307
Water				0.0319	0.0055	0.0031
Marine Fish	62.8535	39.0473	38.9668	62.8349	39.0453	38.9657
Diet (Nonfish foods)	0	0	0	0	0	0
Air	0.0026	0.0002	0.0003	0.0026	0.0002	0.0003
Soil	0.0007	0.0001	0.0003	0.0007	0.0001	0.0003

[a] Exposures are based upon default body weight values (Table 5-1) and do not include pica child soil ingestion.
[b] Ambient surface water exposure estimates used in the fish and water criterion
[c] Drinking water exposure estimates used in the fish only criterion.

Table 5-27. Daily Exposure Estimates from All Media Using Marine Mean Intakes for Individuals From Three Populations of Concern

Population of Concern	Summary of Exposure (mg/kg-day)[a]							
	Ambient Water	**Drinking Water[b]**	**Nonfish Dietary Items**	**Freshwater/ Estuarine Fish**	**Marine fish**	**Air**	**Soil**	**Total Exposure**
Children Age 0-14 Years	5.0×10^{-9}	6.5×10^{-8}	0	1.3×10^{-3}	4.2×10^{-4}	5.5×10^{-9}	5.9×10^{-9}	1.7×10^{-3}
%Total Exposure	0.0003%	0.0038%	0.0000%	76.0198%	23.9755%	0.0003%	0.0003%	
Women of Childbearing Age	4.5×10^{-9}	5.8×10^{-8}	0	6.4×10^{-4}	2.0×10^{-4}	2.6×10^{-9}	1.3×10^{-9}	8.4×10^{-4}
%Total Exposure	0.0005%	0.0069%	0.0000%	76.1844%	23.8076%	0.0003%	0.0002%	
Adults in General Population	4.3×10^{-9}	5.6×10^{-8}	0	6.5×10^{-5}	2.7×10^{-5}	4.6×10^{-9}	1.3×10^{-9}	9.2×10^{-5}
%Total Exposure	0.0047%	0.0608%	0.0000%	70.6014%	29.3267%	0.005%	0.0014%	

[a] Refer to exposure parameters listed in Table 5-1.

[b] Upper-bound concentration for methylmercury used in calculation.

Table 5-28. Daily Exposure Estimates From All Media Using Marine Median Intakes for Individuals From Three Populations of Concern

Population of Concern	Exposure (mg/kg-day)[a]							
	Ambient Water	**Drinking Water[b]**	**Nonfish Dietary Items**	**Freshwater/ Estuarine Fish**	**Marine fish**	**Air**	**Soil**	**Total Exposure**
Children Age 0-14 Years	5.0×10^{-9}	6.5×10^{-8}	0	1.3×10^{-3}	3.2×10^{-4}	5.5×10^{-9}	5.9×10^{-9}	1.6×10^{-3}
%Total Exposure	0.0003%	0.0040%	0.0000%	80.2429%	19.7521%	0.0003%	0.0004%	
Women of Childbearing Age	4.5×10^{-9}	5.8×10^{-8}	0	6.4×10^{-4}	1.6×10^{-4}	2.6×10^{-9}	1.3×10^{-9}	8.0×10^{-4}
%Total Exposure	0.0006%	0.0073%	0.0000%	79.9933%	19.9983%	0.0003%	0.0002%	
Adults in General Population	4.3×10^{-9}	5.6×10^{-8}	0	6.5×10^{-5}	0	4.6×10^{-9}	1.3×10^{-9}	6.5×10^{-5}
%Total Exposure	0.0066%	0.0861%	0.0000%	99.8983%	0.0000%	0.0071%	0.0020%	

[a] Refer to exposure parameters listed in Table 5-1.

[b] Upper-bound concentration for methylmercury in drinking used in calculation.

Table 5-29. Daily Exposure Estimates from All Media Using Marine 90th Percentile Intakes for Individuals from three Populations of Concern

Population of Concern	Exposure (mg/kg-day)[a]							
	Ambient Water	**Drinking Water[b]**	**Nonfish Dietary Items**	**Freshwater/ Estuarine Fish**	**Marine fish**	**Air**	**Soil**	**Total Exposure**
Children Age 0-14 Years	5.0×10^{-9}	6.5×10^{-8}	0	1.3×10^{-3}	8.5×10^{-4}	5.5×10^{-9}	5.9×10^{-9}	2.1×10^{-3}
%Total Exposure	0.0002%	0.0031%	0.0000%	61.0305%	38.9656%	0.0003%	0.0003%	
Women of Childbearing Age	4.5×10^{-9}	5.8×10^{-8}	0	6.4×10^{-4}	4.1×10^{-4}	2.6×10^{-9}	1.3×10^{-9}	1.1×10^{-3}
%Total Exposure	0.0004%	0.0055%	0.0000%	60.9485%	39.0451%	0.0002%	0.0001%	
Adults in General Population	4.3×10^{-9}	5.6×10^{-8}	0	6.5×10^{-5}	1.1×10^{-4}	4.6×10^{-9}	1.3×10^{-9}	1.8×10^{-4}
%Total Exposure	0.0025%	0.0319%	0.0000%	37.1288%	62.8333%	0.0026%	0.0007%	

[a] Refer to exposure parameters listed in Table 5-1.

[b] Upper-bound concentration for methylmercury used in calculation.

5.7 RELATIVE SOURCE CONTRIBUTION (RSC) ESTIMATES

5.7.1 RSC Policy Summary

As described in Section 5.1, water quality criteria for noncarcinogens account for anticipated exposures from sources other than drinking water and freshwater/estuarine fish ingestion. These exposures can include other dietary intakes, air, and soil. By accounting for other exposures, the entire RfD is not attributed to drinking water and freshwater/estuarine fish consumption alone. The relative source contribution (RSC) approach apportions the RfD to ensure that the water quality criterion is sufficiently protective, given the other anticipated sources of exposure. Thus, accounting for nonwater exposure sources results in a more stringent water quality criterion than if those sources were not considered. Details of the RSC approach (the Exposure Decision Tree) are described in more detail in the 2000 Human Health Methodology (U.S. EPA, 2000a).

The RSC determination differs from chemical to chemical depending on several factors: (a) the magnitude of total exposure compared with the RfD; (b) the adequacy of data available; (c) whether more than one guidance or criterion is to be set for the chemical in question; and (d) whether there is more than one significant exposure source for the chemical and population of concern. The target population for this methylmercury criterion is discussed in Section 5.2; the sources of methylmercury exposure, exposure estimates, and data adequacy are discussed in Sections 5.3 through 5.5.

5.7.2 Target Population for RSC/Rationale for Approach to Methylmercury

The target population for the RSC estimate is the general population. The health risk measure, the RfD, is intended to be protective of the whole population, including (but not restricted to) sensitive subpopulations. This is not a developmental RfD *per se*. Even though the critical endpoint was neurotoxic effects observed in children exposed *in utero*, application of the RfD is not restricted to pregnancy only, or to developmental periods only.

As discussed in the 2000 Human Health Methodology, the RSC policy approach allows for use of a subtraction method to account for other exposures when one health-based criterion is relevant for the chemical in question. In this circumstance, other sources of exposure can be considered "background" and can be subtracted from the RfD. Such is the case with methylmercury; that is, there are no health-based criteria, pesticide tolerances, or other regulatory activities to warrant apportionment using the alternate percentage method.

5.7.3 Data Adequacy for RSC Estimate

Section 5.4 describes information on levels of occurrence and provides estimates of exposure to methylmercury in ambient surface water, drinking water, fish, nonfish foods, air, soil, and sediment. The information in Section 5.4 indicates that, for almost all media sources, the sampling data meet the adequacy requirements (e.g., sample sizes, representativeness) for describing both central tendency and high-end concentrations for those sources (Box 3 of the Methodology Decision Tree approach [U.S. EPA, 2000a]). Thus, the data summarized for ambient surface water concentrations, nonfish dietary concentrations, marine fish concentrations, and soil concentrations are adequate to use for estimating overall exposure and RSC. Available data on methylmercury in ground water and estimates of methylmercury in drinking water are not as adequate, as defined by the data adequacy requirements in the 2000 Human Health Methodology. However, the estimates made for both ground water and drinking water in Section 5.4.2.3 indicate levels no higher in magnitude than the surface water estimates, even when using most high-end values. Information on ambient air concentrations summarized from the MSRC failed to indicate sample sizes, geographic representativeness, or detection limits and, thus, are not considered adequate in terms of the Methodology's Decision Tree (Box 3) requirements. However, 98% of mercury in ambient air occurs in the form of vapor-phase elemental mercury, according to the MSRC. Therefore, exposures to methylmercury in ambient air are probably negligible. This assumption is supported by the estimates presented in Section 5.4.5, including the MSRC model simulations predicting exposures of zero near a waste incinerator.

5.7.4 RSC Estimate/Apportionment of the RFD

Once it has been determined that the data are adequate to describe exposure intakes for relevant exposure sources and that there are no other health-based criteria to apportion, exposure intakes from sources other than the source addressed by the criterion are subtracted from the RfD (Box 12 of the Decision Tree, see U.S. EPA, 2000a). Based on the available data, human exposures to methylmercury from all media sources except freshwater/estuarine and marine fish are negligible, both in comparison to exposures from fish and compared to the RfD. Estimated exposure from ambient water, drinking water, nonfish dietary foods, air, and soil are all, on average, at least several orders of magnitude less than those from freshwater/estuarine fish intakes. Nonfish sources of intake are in the range of 10^{-5} to 10^{-9} μg methylmercury/kg body weight-day for adults in the general population. The combined methylmercury exposure intakes from water ingestion, (nonfish) diet, air, and soil represent approximately 0.07% of total estimated exposure to methylmercury (and less than 1/100 of 1% of the RfD) for adults in the general

population. Therefore, these exposures are not factored into the RSC because they will not quantitatively affect the final criterion value.

Ingestion of marine fish is a significant contributor to total methylmercury exposure. The MSRC (U.S. EPA, 1997c) indicates that in the general population of fish consumers, those that consume freshwater/estuarine species of fish are also consumers of marine species of fish. EPA has, therefore, made the assumption in the derivation of the methylmercury fish tissue criterion. In making this assumption, EPA does not believe that, by and large, the high-end consumer of freshwater/estuarine fish is also a high-end consumer of marine fish. The Agency believes that it is more appropriate, and a reasonably conservative assumption, to use the average intake rate (approximately 12.5 g/day) for the marine fish component of the RSC estimate.

The marine fish exposure source is estimated using species-specific mean methylmercury fish tissue data from NMFS (see Section 5.4.4.4) and calculating species-weighted intakes from the CSFII consumption rates (see Section 5.4.4.7). Following the MSRC (U.S. EPA, 1997c), nearly 100% of the mercury in marine fish was assumed to be present as methylmercury. The RSC estimate from marine fish has been calculated with an overall assumed average intake of 12.46 g/day of marine fish based on the CSFII, for all respondents aged 18 and over. The estimated weighted-average methylmercury concentration in marine fish is 0.157 mg methylmercury/kg fish, and the estimated average exposure to methylmercury from marine fish is 2.7×10^{-5} mg methylmercury/kg body weight-day. This exposure represents 27% of the RfD.

All exposure intake values estimated for methylmercury are presented in Table 5-30. The RSC factor in this case is determined by adding the estimated intakes that are quantitatively relevant for methylmercury; that is, only the intake from marine fish consumption of 2.7×10^{-5} mg/kg-day has any affect on the calculation. This amount is subtracted from the RfD of 0.1 µg methylmercury/kg body weight-day or 1.0×10^{-4} mg methylmercury/kg body weight-day. The remainder of the RfD is used to calculate the fish tissue residue concentration in terms of the assumed body weight and freshwater/estuarine fish ingestion. This results in an amount of methylmercury that is allowable in freshwater/estuarine fish and that will not exceed the RfD, considering the additional exposure from marine fish consumption.

Table 5-30. Exposure estimates for methylmercury and percent of total exposure based on adults in the general population

Exposure Source	Exposure Estimate (mg/kg-day)	Percent of Total Exposure	Percent of RfD
Ambient water intake	4.3×10^{-9}	0.0047	0.004
Drinking water intake[a]	5.6×10^{-8}	0.0605	0.006
Nonfish dietary intake	0	0	0
Marine fish intake	2.7×10^{-5}	29.33	27
Air intake	4.6×10^{-9}	0.005	0.005
Soil Intake	1.3×10^{-9}	0.0014	0.001
Total intake	9.2×10^{-5}	100	27.01

[a] This represents the high-end of the range of estimates. Because the contribution of ambient water or drinking water intake to total exposure is so negligible in comparison to the sum of intake from other sources, there is no difference in the total exposure estimated using either of these two alternatives.

6.0 METHYLMERCURY BIOACCUMULATION

6.1 INTRODUCTION

Aquatic organisms can accumulate and retain certain chemicals in their bodies when exposed to these chemicals through water, their diet and other sources. This process is called bioaccumulation. In order to prevent harmful exposures to waterborne pollutants through the consumption of contaminated fish and shellfish, national 304(a) water quality criteria for the protection of human health must address the process of chemical bioaccumulation in aquatic organisms. For deriving national 304(a) ambient water column criteria to protect human health, EPA accounts for potential bioaccumulation of pollutants in fish and shellfish through the use of national bioaccumulation factors (BAFs). A national BAF is a ratio (in L/kg) which relates the concentration of a chemical in water to its expected concentration in commonly consumed aquatic organisms in a specified trophic level. The magnitude of bioaccumulation by aquatic organisms varies widely depending on the chemical but can be extremely high for some highly persistent and hydrophobic chemicals. For such highly bioaccumulative chemicals, concentrations in aquatic organisms may pose unacceptable human health risks from fish and shellfish consumption even when concentrations in water are too low to cause unacceptable health risks from drinking water consumption alone. These chemicals may also biomagnify in aquatic food webs, a process whereby chemical concentrations increase in aquatic organisms of each successive trophic level due to increasing dietary exposures (e.g., increasing concentrations from algae, to zooplankton, to forage fish, to predator fish). Methylmercury is a chemical that bioaccumulates and biomagnifies to a relatively high extent. Methylmercury BAFs for upper trophic level freshwater and estuarine fish and shellfish typically consumed by humans generally range between 500,000 and 10,000,000 (Glass et al., 1999; Lores et al., 1998; Miles and Fink, 1998; Monson and Brezonik, 1998; Watras et al., 1998; Mason and Sullivan, 1997).

6.2 ISSUES IN DEVELOPING METHYLMERCURY BAFS

The fates of mercury and methylmercury in the environment are complex processes affected by numerous biotic and abiotic factors that are subjects of ongoing research by various government, private, and academic groups around the world. Methylation of mercury is a key step in the entrance of mercury into food chains. The biotransformation of inorganic mercury species to methylated organic species in water bodies can occur in the sediment and the water column. Inorganic mercury can be absorbed by aquatic organisms but is generally taken up at a slower rate and with lower efficiency than is

methylmercury. Methylmercury continues to accumulate in fish as they age. Predatory organisms at the top of aquatic and terrestrial food webs generally have higher methylmercury concentrations because methylmercury is typically not completely eliminated by organisms and is transferred up the food chain when predators feed on prey; for example, when a largemouth bass feeds on a bluegill sunfish, which fed on aquatic insects and smaller fish, all of the prey could contain some amount of methylmercury that gets transferred to the predator. Nearly 100% of the mercury that bioaccumulates in upper trophic level fish (predator) tissue is methylmercury (Bloom, 1992; Akagi, 1995; Kim, 1995; Becker and Bigham, 1995).

Numerous factors can influence the bioaccumulation of mercury in aquatic biota. These include, but are not limited to, the acidity (pH) of the water, length of the aquatic food chain, temperature, and dissolved organic material. Physical and chemical characteristics of a watershed, such as soil type and erosion or proportion of area that is wetlands, can affect the amount of mercury that is transported from soils to water bodies. Interrelationships among these factors are poorly understood and are likely to be site-specific. No single factor (including pH) has been correlated with extent of mercury bioaccumulation in all cases examined. Two lakes that are similar biologically, physically, and chemically can have different methylmercury concentrations in water, fish, and other aquatic organisms (Cope et al., 1990; Grieb et al., 1990; Jackson, 1991; Lange et al., 1993). For more in-depth discussions about the chemical, physical, and biological interactions affecting methylmercury bioaccumulation in aquatic organisms see the *Mercury Study Report to Congress* (MSRC), Volume III and Volume III Appendix D (U.S. EPA, 1997c), and the compilation of papers in *Mercury Pollution: Integration and Synthesis* (Watras and Huckabee, 1994).

To derive section 304(a) water quality criteria for the protection of human health, EPA needs to conduct a human health risk assessment on the pollutant in question and to gather information on the target population's exposure to the pollutant. Traditionally, EPA has expressed its section 304(a) water quality criteria guidance to protect human health in the form of pollutant concentrations in ambient surface water. To account for human exposure through the aquatic food pathway when deriving a water column-based water quality criterion, EPA uses national BAFs (U.S. EPA 2000). A BAF is a ratio (in L/kg) that relates the concentration of a chemical in water to its expected concentration in commonly consumed aquatic organisms in a specified trophic level (U.S. EPA 2000). A national BAF is meant to be broadly applicable to all waters in the United States, whereas a site-specific BAF is based on local data and integrates local spacial and temporal factors that can influence bioaccumulation. For pollutants that biomagnify, such as methylmercury, EPA's preferred approach for deriving national BAFs for use in deriving section 304(a) water quality criteria is to use empirical field data collected in the natural

environment. EPA prefers this approach because BAFs derived with field data integrate the chemical, biological, and physical factors that can affect bioaccumulation in fish and shellfish. With this preference in mind, EPA explored the feasibility of developing field-derived national methylmercury BAFs for each trophic level of the aquatic food chain consumed by humans (i.e., trophic levels 2-4). Using Agency guidance on BAFs contained in the 2000 Human Health Methodology and procedures outlined in Volume III, Appendix D of the peer-reviewed MSRC (U.S. EPA, 1997c), EPA empirically derived draft national methylmercury BAFs for each trophic level of the aquatic food chain. The draft national BAFs were single value trophic level-specific BAFs calculated as the geometric mean of field data collected across the United States and reported in the open literature as well as other publically available reports. These draft methylmercury BAFs were compiled in a draft internal report and submitted to a panel of external scientific experts for peer review. The Appendix contains a summary of the internal BAF report and BAF peer review report. The entire internal draft methylmercury BAF report and peer review report can be obtained from the Water Docket W-00-20.

Within any given trophic level, the individual empirically derived draft methylmercury BAFs generally ranged up to two orders of magnitude. This range in BAFs reflects the various biotic factors (such as food chain interactions and fish age/size) and abiotic factors (such as pH and dissolved organic carbon). The large range in the individual empirically derived draft methylmercury BAFs results in uncertainty as to the ability of single trophic level-specific national methylmercury BAFs to accurately predict bioaccumulation of methylmercury in general across the waters of the United States. Presently, it is EPA's understanding that the mechanisms that underlie many of the influencing factors are not well understood and can not be accurately predicted. As the science of methylmercury improves, in the future it may be possible predict or model these processes and use such information to more accurately predict bioaccumulation. Until such time, EPA is unable to improve the predictive power of the methylmercury BAFs by universally accounting for influencing factors. This is not the case for other highly bioaccumulative pollutants; for example polychlorinated biphenyls (PCBs). For such pollutants, EPA has methods that improve the predictive capability of empirically derived or model predicted BAFs (such as normalizing fish tissue concentrations to lipid and normalizing ambient water concentrations to dissolved and particulate organic carbon). EPA is actively involved in, and will continue to support, various types of research aimed at better understanding the fate of mercury in the environment and the processes that underlie methylmercury bioaccumulation. EPA hopes that results of new research will enable better predictions of methylmercury bioaccumulation.

The BAF peer reviewers recognized the need for methylmercury BAFs and were supportive of most aspects of the methodology used to derive the draft national methylmercury BAFs. The peer reviewers did have issues with certain data used to derive the methylmercury BAFs and certain assumptions about food chain relationships. Overall, most of the peer reviewers believed that derivation of single-value trophic level-specific national BAFs for methylmercury that would be generally applicable to all waters of the United States under all conditions is difficult at best, and perhaps impossible. This opinion was based on consideration of the highly site-specific nature of methylmercury bioaccumulation in aquatic environments and the large range in the empirically derived draft methylmercury BAFs. These peer reviewers recommended developing methylmercury BAFs on a more local or regional scale, if not on a site-specific basis. Although EPA generally agrees with this suggestion, the data needed to derive BAFs at more localized scales across the U.S. are not available. See Appendix A for a summary of the internal BAF report and the BAF peer review report.

6.3 CONSIDERATION OF A FISH TISSUE RESIDUE CRITERION

After considering the various issues about mercury fate in the environment, the recent report by the National Research Council (NRC, 2000) on the toxicological effects of mercury, and the methylmercury BAF peer review comments, EPA concluded that it is more appropriate at this time to derive a fish tissue (including shellfish) residue water quality criterion for methylmercury rather than a water column-based water quality criterion. EPA believes a fish tissue residue water quality criterion for methylmercury is appropriate for many reasons. A fish tissue residue water quality criterion integrates spatial and temporal complexity that occurs in aquatic systems and that affect methylmercury bioaccumulation. A fish tissue residue water quality criterion in this instance is more closely tied to the CWA goal of protecting the public health because it is based directly on the dominant human exposure route for methylmercury. The concentration of methylmercury is also generally easier to quantify in fish tissue than in water and is less variable in fish and shellfish tissue over the time periods in which water quality standards are typically implemented in water quality-based controls, such as NPDES permits. Thus, the data used in permitting activities can be based on a more consistent and measurable endpoint. Finally, this approach is consistent with the way in which fish advisories are issued. Fish advisories for mercury are also based on the amount of methylmercury in fish tissue that is considered acceptable, although such advisories are usually issued for a certain fish or shellfish species in terms of a meal size. A fish tissue residue water quality criterion should enhance harmonization between these two approaches for protecting the public health.

Because EPA did not use national, empirically derived methylmercury BAFs to establish today's section 304(a) recommended methylmercury water quality criterion, EPA has deferred further efforts to derive national BAFs for methylmercury at this time. EPA notes, however, that there may be adequate field data for some waterbodies or geographical regions on which to base accurate predictive, site-specific methylmercury BAFs. EPA may reconsider developing national methylmercury BAFs in the future once more field data is available for a broader range of species and aquatic ecosystems, or once more information is available describing the mechanisms that affect bioaccumulation. Such information could enable EPA to more accurately predict methylmercury bioaccumulation on a broader scale given a certain total mercury concentration in water.

7.0 WATER QUALITY CRITERION CALCULATION

7.1 EQUATION FOR TISSUE RESIDUE CONCENTRATION AND PARAMETERS USED

The equation for calculating the methylmercury fish tissue residue criterion is:

$$TRC = \frac{BW \times (RfD - RSC)}{\sum_{i=2}^{4} FI_i}$$

Where:

TRC	=	Fish tissue residue criterion (mg methylmercury/kg fish) for freshwater and estuarine fish
RfD	=	Reference dose (based on noncancer human health effects) of 0.0001 mg methylmercury/kg body weight-day
RSC	=	Relative source contribution (subtracted from the RfD to account for marine fish consumption) estimated to be 2.7×10^{-5} mg methylmercury/kg body weight-day
BW	=	Human body weight default value of 70 kg (for adults)
FI	=	Fish intake at trophic level (TL) i (i = 2, 3, 4); total default intake is 0.0175 kg fish/day for general adult population. Trophic level breakouts for the general population are: TL2 = 0.0038 kg fish/day; TL3 = 0.0080 kg fish/day; and TL4 = 0.0057 kg fish/day.

This yields a methylmercury TRC value of 0.3 mg methylmercury/kg fish (rounded to one significant digit from 0.288 mg methylmercury/kg fish).

This equation is essentially the same equation used in the 2000 Human Health Methodology to calculate a water quality criterion, but is rearranged to solve for a protective concentration in fish tissue rather than in water. Thus, it does not include a BAF or drinking water intake value (as discussed above, exposure from drinking water is negligible). The TRC of 0.3 mg methylmercury/kg fish is the concentration in fish tissue that should not be exceeded based on a total consumption of 0.0175 kg fish/day.

7.2 SITE-SPECIFIC OR REGIONAL ADJUSTMENTS TO CRITERIA

Several parameters in the Water Quality Criterion equation can be adjusted on a site-specific or regional basis to reflect regional or local conditions and/or specific populations of concern. These include the fish consumption rates and the RSC estimate. States and authorized Tribes can also choose to apportion an intake rate to the highest trophic level consumed for their population or modify EPA's default intake rate based on local or regional consumption patterns. EPA strongly encourages States and authorized Tribes to consider developing a criterion using local or regional data over the default values if they believe that they would be more appropriate for their target population. States and authorized Tribes are encouraged to make such adjustments using the guidance provided in the 2000 Human Health Methodology (U.S. EPA, 2000a).

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APPENDIX A

SECTION I. DRAFT NATIONAL METHYLMERCURY BIOACCUMULATION FACTORS

This appendix is a brief summary of the initial effort conducted to determine the feasibility of deriving draft National bioaccumulation factors for methylmercury. This appendix is based on the draft bioaccumulation report. The complete version of the original draft bioaccumulation factor report, with more in-depth discussions of the methodology, a list of the references cited, rationales for using data, and an uncertainty discussion can be obtained from the Water Docket W-00-20.

This appendix does not reflect comments or changes suggested by the peer reviewers. No changes were made to the draft report that served as the basis for this appendix. Data interpretations, findings, or conclusions discussed in this appendix are preliminary and may be changed in the future.

Introduction

The methylmercury bioaccumulation factors (BAFs) were estimated using guidance presented in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (U.S. EPA, 2000a; hereafter "the 2000 Human Health Methodology") and supplemented with methods presented in the Mercury Study Report to Congress (MSRC; U.S. EPA, 1997c). The generalized equation for estimating a BAF is as follows:

$$BAF = \frac{C_t}{C_w} \qquad \textbf{Equation-1}$$

where:

C_t = Concentration of the chemical in the wet tissue (either whole organism or specified tissue)

C_w = Concentration of chemical in water

Literature searches were conducted to obtain data on bioaccumulation, concentrations of different forms of mercury in water, percent methylmercury in tissue, and mercury predator-prey data. The data sources primarily included articles from peer reviewed journals published between 1990 and April of 1999 and publicly available reports (e.g., State, Federal, or trade/industry group reports; dissertations;

proceedings from professional meetings). Data from a variety of aquatic ecosystems (i.e., lakes, rivers, estuaries) and on lower trophic levels was specifically looked for since the MSRC focused only on lakes (primarily northern oligotrophic lakes) and trophic levels 3 and 4 fish.

BAFs are used in the ambient water quality criteria (AWQC) equation to estimate human mercury exposure from consumption of contaminated fish. Equation 2 is the generalized AWQC equation for a noncarcinogen and shows where the BAF fits into the calculation.

$$AWQC = RfD \times RSC\left[\frac{BW}{DI + \sum_{i}^{x}(FI \times BAF_i)}\right] \qquad \textbf{Equation 2}$$

Where:

RfD = reference dose for noncancer human health effects

RSC = relative source contribution to account for non-water sources of exposure

BW = human body weight

DI = drinking water intake

FI = fish intake

BAF_i = bioaccumulation factor for chemical "i".

The methylmercury BAFs that would be used in the above equation are presented in the accompanying table A-9, and are calculated as the geometric mean BAF of all BAFs calculated for a given trophic level.

Attachment A at the end of this appendix also contains the general comments made by the external peer reviewers on the draft national methylmercury BAFs.

Methods for Estimating Bioaccumulation Factors

Three approaches were used to derive draft BAFs that could be used to derive draft national methylmercury BAFs. These are direct, indirect, and conversion (modified direct) approaches. Each of

these approaches has its own limitations, biases, and uncertainties associate with it. These approaches and the BAFs derived using them are summarized below.

EPA's BAF derivation guidance is based on a data hierarchical preference approach. Under the hierarchy, the preferred method for deriving a BAF for an organometallic compound such as methylmercury is to use field-measured data to directly calculate a BAF (i.e., the direct method). BAFs estimated using this direct approach are calculated using the simple ratio of the chemical concentration in tissue and water. When such field data do not exist, or if the available field data are considered unreliable, the next preferred method in the hierarchy estimates a BAF by multiplying a bioconcentration factor (BCF) by a food chain multiplier (FCM) (i.e., the indirect method). The FCM is a factor used to account for food chain interactions and biomagnification. EPA has used this indirect method to estimate BAFs to support the development of wildlife criteria values in the Great Lakes Water Quality Initiative or GLWQI (EPA, 1993) and in the MSRC (EPA, 1997). With few exceptions, field-derived FCMs were calculated using concentrations of methylmercury in predator and prey species using the following equations:

$$FCM_{TL2} = BMF_{TL2} \qquad \text{Equation-3}$$

$$FCM_{TL3} = (BMF_{TL3})\,(BMF_{TL2}) \qquad \text{Equation-4}$$

$$FCM_{TL4} = (BMF_{TL4})\,(BMF_{TL3})\,(BMF_{TL2}) \qquad \text{Equation-5}$$

where:

FCM = Food chain multiplier for designated trophic level (TL2, TL3, or TL4)
BMF = Biomagnification factor for designated trophic level (TL2, TL3, or TL4)

The basic difference between FCMs and BMFs is that FCMs relate back to trophic level one, whereas BMFs always relate back to the next lowest trophic level. Biomagnification factors are calculated from methylmercury tissue residue concentrations determined in biota at a site according to the following equations:

$$BMF_{TL2} = C_t, TL2) / (C_t, TL1) \qquad \text{Equation-6}$$

$$BMF_{TL3} = (C_t, TL3) / (C_t, TL2) \qquad \text{Equation-7}$$

$$BMF_{TL4} = (C_t, TL4) / (C_t, TL3) \qquad \text{Equation-8}$$

where:

C_t = concentration of chemical in tissue of appropriate biota that occupy the specified trophic level (TL2, TL3, or TL4).

With the indirect BAF approach, it is important that when either selecting predator prey field data from the literature or when conducting a site-specific field study to obtain such data, that the feeding relationships between predator and prey are based on functional feeding relationships. It should be verified that a given predator is feeding on a given prey item at the location in question so that the BMFs and FCMs reflect actual trophic transfer of the chemical as close as possible. Usually, it is not enough to simply know that organisms are from two different trophic levels. Unfortunately, for the analyses presented here, much of the available data obtained from the published literature were insufficient to document functional feeding relationships. Thus, BAFs derived using the indirect approach were not used in determining the draft national methylmercury BAFs, but are presented only for comparison purposes.

In the MSRC, in cases where the direct empirical BAF derivation method could be used, but the available data was for a form of mercury other than dissolved methylmercury, a modified direct approach was also used. The modified direct approach was used when either the water data or organism tissue data was not in the methylmercury form (e.g., total mercury, dissolved total mercury, total methylmercury) but could be converted to methylmercury using translating factors. Data for mercury in water was converted to dissolved methylmercury by using chemical translators (see Section II of this Appendix). Mercury in tissue reported as total mercury was converted to methylmercury by multiplying by a factor that estimates the fraction of total mercury present in the methylated form (i.e., fmmf translator). The fmmfs were developed from field studies where both total mercury and methylmercury were measured in biota tissue.

Using the methods outlined above, BAFs were estimated initially by trophic level for lakes (lentic aquatic systems), rivers and streams (lotic aquatic systems), and estuaries. An ecosystem-based approach to deriving the BAFs was used because differences in general bioaccumulation trends would be expected among the aquatic ecosystems due to inherent differences in methylation processes, food web dynamics,

mercury loadings, and watershed interactions, among other factors. However, due to the lack of data in terms of both quality and quantity, no clear differences in bioaccumulation trends were observed between lentic and lotic ecosystems based on the available data (see Figure A-3). Based on qualitative and semi-quantitative comparisons of the data, no significant difference was found between the lentic and lotic BAFs. Thus, they were combined for each trophic level to obtain the trophic level-specific draft national BAFs. A near complete lack of adequate data prohibited derivation of draft national BAFs for estuarine systems.

Summary of BAFs for Methylmercury in Lentic Ecosystems

Table A-1 compares the BAFs estimated using the two primary approaches (direct and indirect) methods for estimating BAFs for trophic levels 2, 3, and 4 species. Although the BAFs based on the indirect approach are not used in the national draft BAF calculations because they are not based on verifiable functional predator-prey feeding relation ships, they are nonetheless useful for comparing and assessing general tends in bioaccumulation. Other than the BAF_2, the BAFs are within a factor of two of one another. Both the direct and indirectly estimated BAFs show an expected increase in methylmercury bioaccumulation with increasing trophic position. This suggests that if functional predator-prey feeding relationships can be developed, that indirect BAFs could provide reasonably good approximations of methylmercury bioaccumulation in organisms in the field.

Table A-1: Summary of Bioaccumulation Factors for Methylmercury Mercury in Lentic Ecosystems

Parameter	Methylmercury (1)	
	Direct ($L \cdot kg^{-1}$)	Indirect ($L \cdot kg^{-1}$)
BCF	5.9×10^4	NA
BAF_2	8.6×10^4	3.1×10^5
BAF_3	1.3×10^6	2.2×10^6
BAF_4	6.8×10^6	1.1×10^7

(1) All values are geometric means

Summary of BAFs for Methylmercury in Lotic Ecosystems

Table A-2 compares the lotic BAFs estimated using the direct and indirect methods. The BAFs based on the indirect approach are not used in the draft national BAF calculation because they are not based on verifiable functional predator-prey feeding relation ships; they are nonetheless useful for comparing and assessing general tends in bioaccumulation. As was the case with the lentic indirectly estimated BAFs, the indirect lotic BAFs are close approximations of the directly estimated BAFs (within a factor of 3 or less). Also, as was observed for lentic ecosystems, both the direct and indirectly estimated lotic BAFs show an expected increase in methylmercury bioaccumulation with increasing trophic position. This suggests that if functional predator-prey feeding relation ships can be developed,

Table A-2: Summary of Dissolved Methylmercury Bioaccumulation Factors for Lotic Ecosystems

Parameter	Methylmercury (1)	
	Direct ($L \cdot kg^{-1}$)	Indirect ($L \cdot kg^{-1}$)
BCF	1.2×10^4	NA
BAF_2	4.4×10^5	1.9×10^5
BAF_3	1.6×10^6	5.6×10^5
BAF_4	2.5×10^6	3.2×10^6

(1) values are geometric means

that indirect BAFs could provide reasonably good approximations of methylmercury bioaccumulation in organisms in the field.

Methylmercury BAFs Translated from Other Mercury Forms

Converted BAFs (that is, in terms of other mercury forms) were derived for dissolved methylmercury using translator factors (see Section II, Chemical Translators for Mercury and Methylmercury) and by using factors to convert total mercury measured in organism tissues to methylmercury in tissues.

Mercury Translators

For those studies that met the data quality objectives but did not analyze or report water mercury concentrations in the dissolved methylmercury form, the reported form of mercury was converted to the mean fraction of dissolved methylmercury (f_d $MeHg_d$) by using one or more of the "translators" listed in Table A-3. Section II below discusses the methodology and data used to derive the translators. Section II of this appendix also provides partition coefficients (K_D) that were not necessary for this analysis, but that can be used along with total suspended solids information to estimate the desired fraction of mercury in water.

Table A-3: Summary of Mercury Translators for Mercury in Water

f_d value	Lentic	Lotic
f_d Hg_d/Hg_t	0.600	0.370
f_d $MeHg_d/Hg_t$	0.032	0.014
f_d $MeHg_d/MeHg_t$	0.613	0.490

Conversion Factors for Mercury in Organism Tissue

Similar to the water data, if mercury in biota tissue (muscle or whole body) was reported as total mercury then the appropriate mean (arithmetic) estimate of the fraction present in the methylated form (fmmf) for the respective trophic level was used to convert it to methylmercury. Table A-4 summarizes the fmmfs used to estimate converted BAFs.

Table A-4: Summary of fmmfs for Lentic and Lotic Ecosystems

Trophic Level	Lentic	Lotic
1	0.18	0.05
2	0.44	0.49
3	1.00	1.00
4	1.00	1.00

Summary and Comparison of Converted BAFs and BCFs derived for Lentic and Lotic Ecosystems

Methylmercury translator factors (see Section II, *Chemical Translators for Mercury and Methylmercury*) were used to estimate dissolved methylmercury BCFs and BAFs in lotic and lentic ecosystems. Table A-5 summarizes the converted BAFs. The converted lentic BAFs range from approximately 2 to 37 times greater than the converted lotic BAFs.

Figures A-1 and A-2 compare the direct and converted estimates of BAFs and BCFs for lentic and lotic ecosystems, respectively. Although the data sets are relatively small, the ranges of converted BAFs are in agreement with BAFs directly estimated. Tables A-6 and A-7 summarize and compare the point estimates of each data set. In lentic ecosystems, the difference between the mean directly estimated BAFs and mean converted BAFs is generally less than a factor of two. For lotic ecosystems, the difference is slightly larger, ranging from a factor of two to a factor of seven, with an overall mean difference of four. This information suggests that the converted BAFs in each ecosystem are good estimates of directly measured BAFs for all trophic levels. However, because the set of BAFs estimated using the two different approaches are small for each ecosystem, insufficient data were available to perform any rigorous statistical evaluation to determine if a significant difference exists between the BAFs of each system. Nonetheless, graphically the data suggest that the direct and converted BAFs can be combined to derive overall BAFs for each trophic level in each ecosystem. The BAFs based on the combined data sets are presented in Table A-8.

Figure A-3 compares the combined data sets (e.g., directly-measured and converted BAFs and BCFs) for lentic and lotic ecosystems. While the lotic BAFs clearly span a greater range than the lentic BAFs, the differences between the mean lotic BAFs and the mean lentic BAFs for each trophic level are fairly small (differences range between 1 and 5). To investigate if there were significant differences between the BAFs for the two ecosystems significant, a student's T-test was performed on the combined data for each trophic level-specific BAF and BCF using the computer software WINKS (Texasoft, 1999). Although differences in mercury bioaccumulation between lentic and lotic ecosystems could be expected due to differences in mercury loading characteristics, bioavailability, food web dynamics, and methylation processes, among other factors, no significant statistical differences ($p>0.05$) were found between the lentic and lotic BAFs and BCFs. Furthermore, a closer inspection of the converted lentic BAF_4 data for several Minnesota Lakes (Glass et al., 1999) suggests that, given a larger sample size, the lower range of field-measured lentic BAF_4 values could be similar to the lower range of values observed for lotic ecosystems. Whether these observations are artifacts of the available data or trends due to real

Table A-5: Comparison of Converted Bioaccumulation Factors for Methylmercury in Lotic and Lentic Ecosystems

Parameter	Lentic ($L \cdot kg^{-1}$)	Lotic ($L \cdot kg^{-1}$)
BCF	4.3×10^4	6.1×10^3
$_{MD}BAF_2$	1.5×10^5	6.2×10^4
$_{MD}BAF_3$	1.3×10^6	3.5×10^4
$_{MD}BAF_4$	4.1×10^6	1.4×10^6

Table A-6: Comparison of Direct and Converted Methylmercury BAFs and BCFs for Lentic Ecosystems

	$_{MD}BCF$		$_{MD}BAF_2$		$_{MD}BAF_3$		$_{MD}BAF_4$	
Value[a]	direct	converted	direct	converted	direct	converted	direct	converted
5th	12,300	13,400	16,700	47,500	322,000	466,000	3,270,000	3,800,000
50th (GM)	58,700	43,000	85,600	150,000	1,260,000	1,330,000	6,800,000	4,080,000
95th	281,000	138,000	439,000	474,000	4,900,000	3,820,000	14,200,000	4,380,000
GSD	2.59	2.26	2.70	2.01	2.29	1.90	1.56	1.04

[a] GM = geometric mean; GSD = geometric standard deviation.

Table A-7: Comparison of Direct and Converted Methylmercury BAFs and BCFs for Lotic Ecosystems

	$_{MD}BCF$		$_{MD}BAF_2$		$_{MD}BAF_3$		$_{MD}BAF_4$	
Value[a]	direct	converted	direct	converted	direct	converted	direct	converted
5th	340	1,200	15,600	3,400	261,800	45,800	283,000	55,400
50th (GM)	5,400	6,000	179,000	61,900	1,640,000	346,000	2,520,000	1,380,000
95th	85,800	29,800	2,000,000	1,130,000	10,200,000	2,620,000	22,500,000	30,300,000
GSD	5.38	2.63	4.40	3.39	3.05	3.42	3.78	6.80

[a] GM = geometric mean; GSD = geometric standard deviation.

processes is not distinguishable. Because the range of available BAF values for lentic and lotic systems overlap one another, the individual BAFs for the two systems were combined in one data set to derive the trophic level-specific draft national methylmercury BAFs.

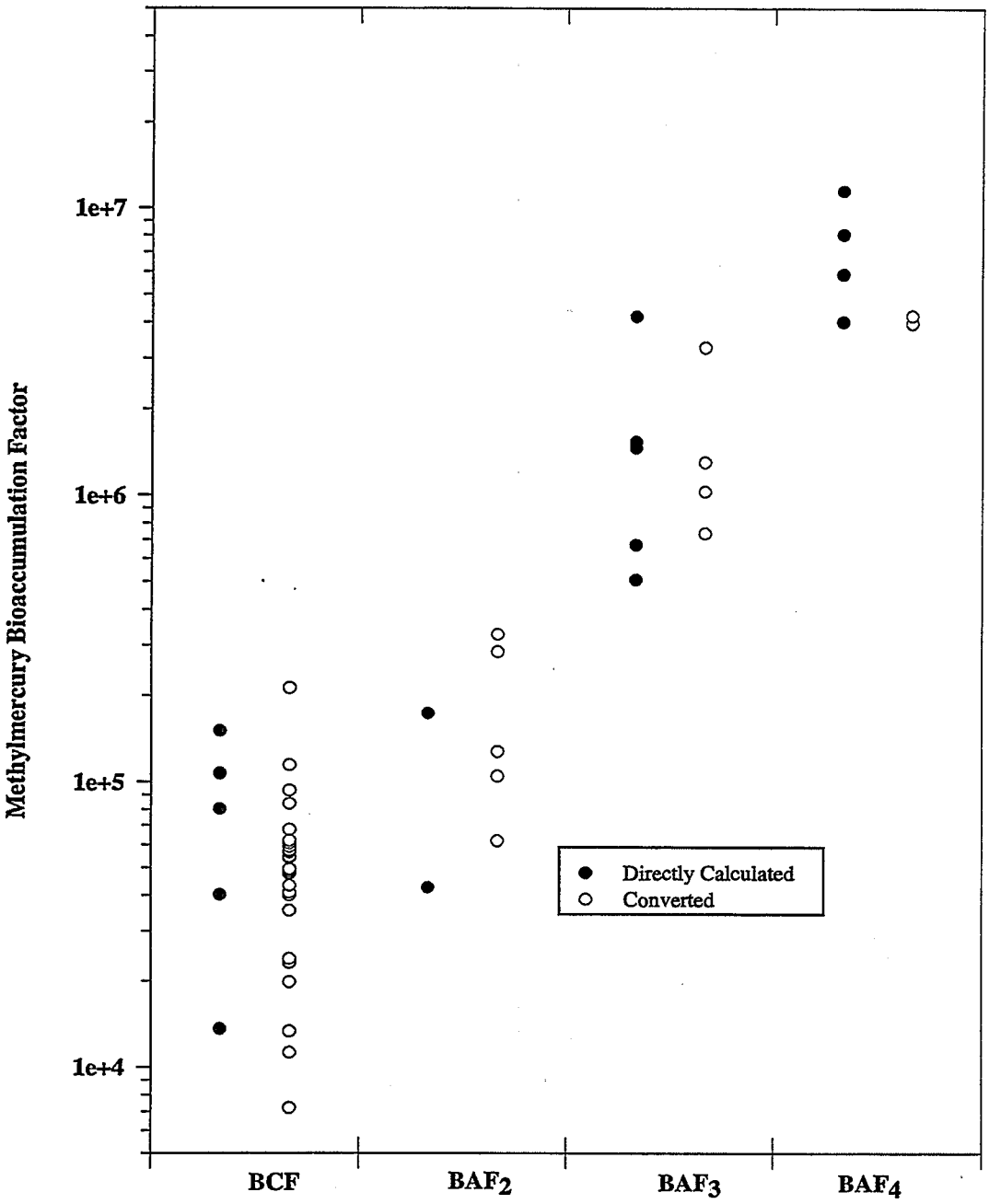

Figure A-1. Comparison of direct field-measured and converted field-measured methylmercury BCFs and BAFs for lentic ecosystems.

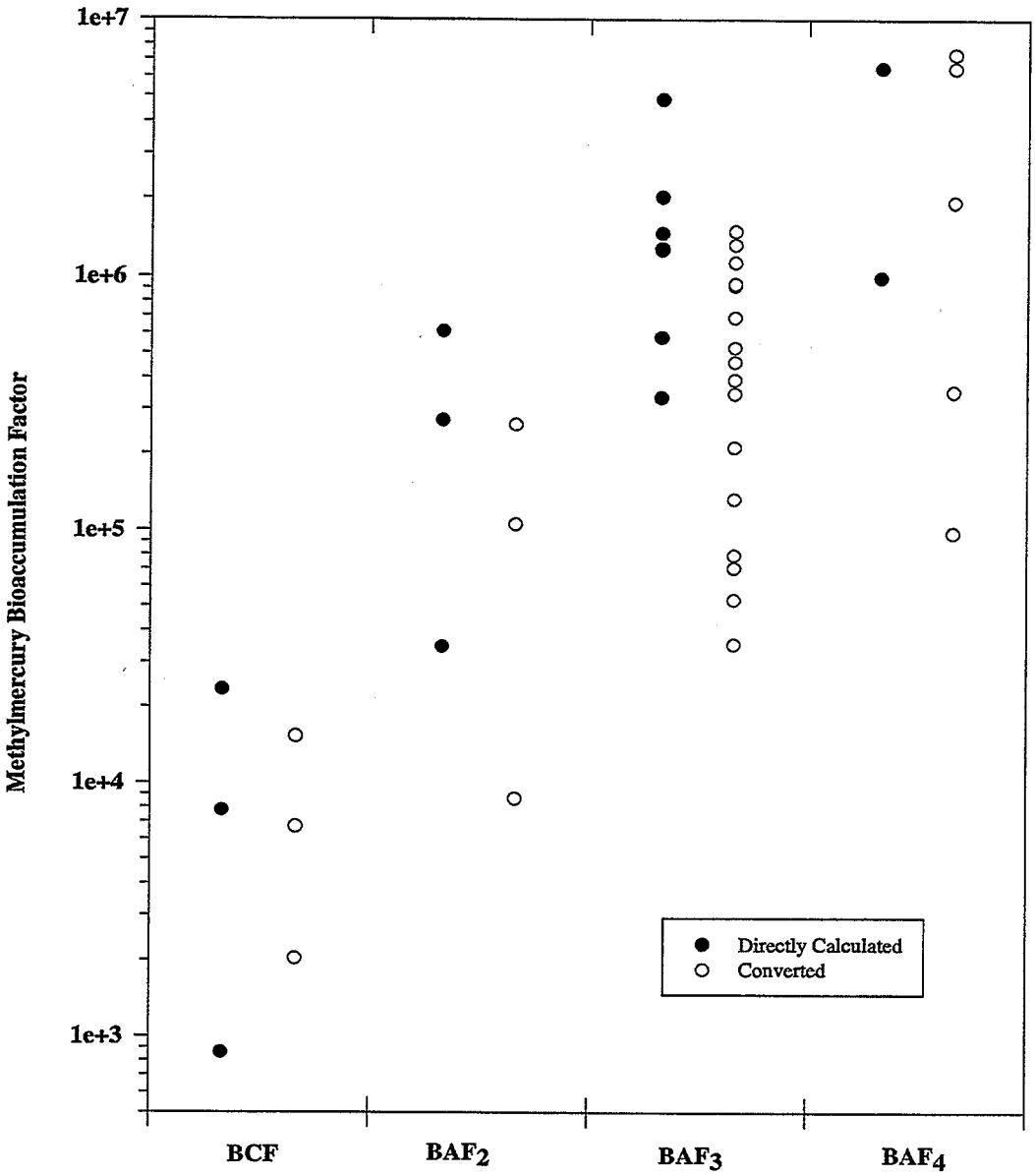

Figure A-2. Comparison of direct field-measured and converted field-measured methylmercury BCFs and BAFs for lotic ecosystems.

Table A-8: Summary of Lentic and Lotic Methylmercury BAFs and BCFs

	$_{MD}BCF$		$_{MD}BAF_2$		$_{MD}BAF_3$		$_{MD}BAF_4$	
Value[(1)a] (%)	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic
5th	13,300	800	37,000	8,000	423,000	46,000	2,800,000	73,400
50th (GM)	45,000	5,700	127,800	105,000	1,115,000	517,000	5,740,000	1,240,000
95th	153,000	43,200	440,000	1,390,000	2,930,000	5,820,000	11,800,000	20,900,000
GSD	2.10	5.14	2.12	4.80	2.02	4.36	1.55	5.57

(1) Values are based on combined direct and converted BAFs and BCFs.

[a] GM = Geometric Mean; GSD = geometric standard deviation.

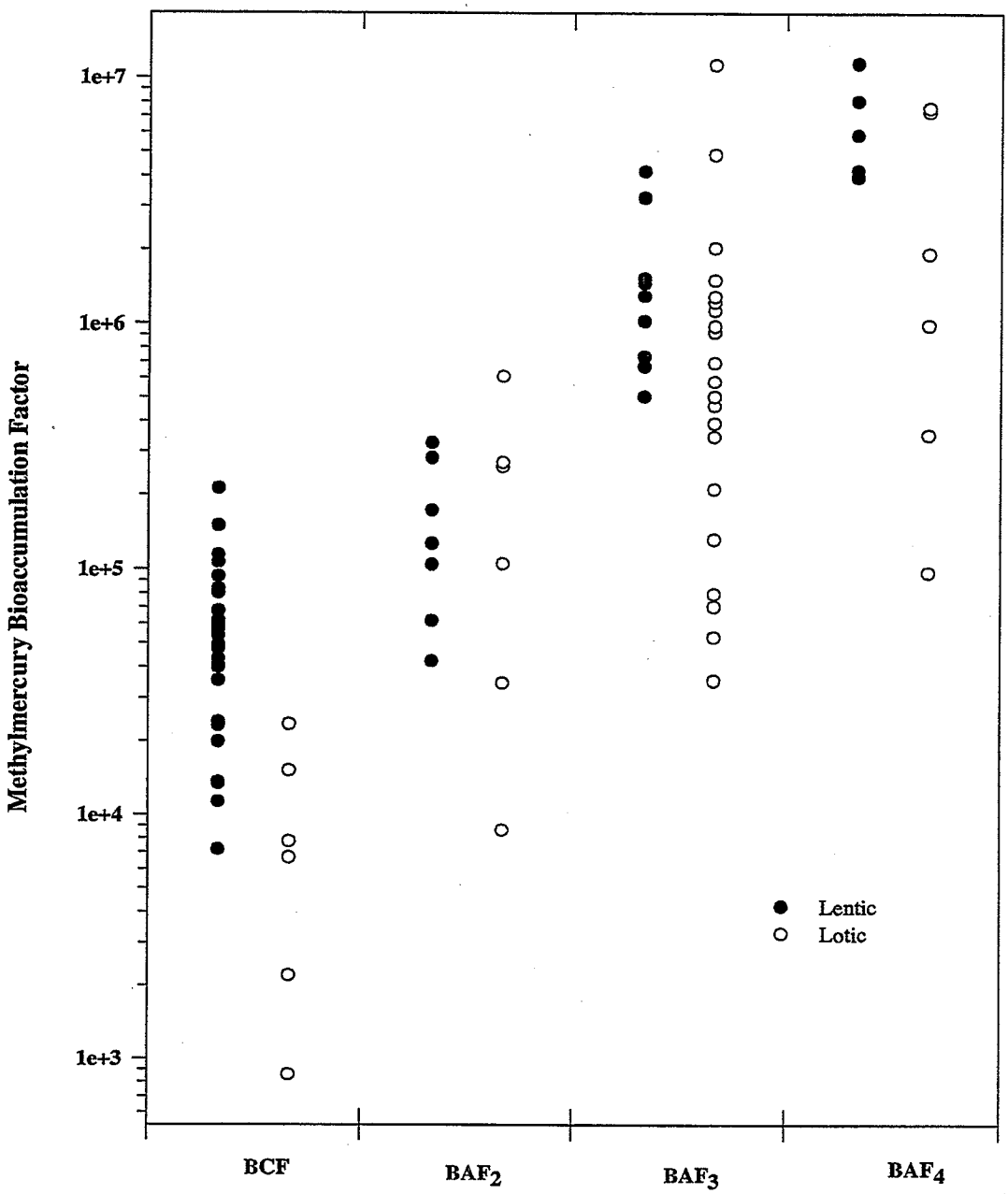

Figure A-3. Comparison of lentic and lotic methylmercury BAFs. Data includes both direct field-measured BAFs and converted field-measured BAFs.

Draft National Bioaccumulation Factors for Methylmercury

Based on the data presented above, and because the goal of the draft national BAFs is to be applicable under as many circumstances and to as many water bodies as possible, the BAFs based on the combined data sets (e.g., direct and converted, lentic and lotic) were chosen to be the empirically-derived draft national BAFs for methylmercury. The draft National BAFs, along with the draft BCF, and their empirical distributions are presented in Table A-9.

Table A-9: Summary of Draft National BAFs and BCF for Dissolved Methylmercury

Value[a]	BCF	BAF_2	BAF_3	BAF_4
5th percentile	5,300	18,000	74,300	250,000
50th (GM) percentile	33,000	117,000	680,000	2,670,000
95th percentile	204,000	770,000	6,230,000	28,400,000
GSD	3.03	3.15	3.84	4.21
Draft National Values	**3.3×10^4**	**1.2×10^5**	**6.8×10^5**	**2.7×10^6**

[a]GM = geometric mean; GSD = geometric standard deviation.

Discussion of Uncertainty and Variability in the BAF Estimates

The BAFs in this document were designed to estimate the central tendency of the concentration of mercury in fish of a given trophic level from an average concentration of dissolved mercury for water bodies located in the continental U.S. As shown in figures A1-A3, there is at least an order of magnitude in the variability of the individual BAF estimates for a given trophic level, which leads to uncertainty in the overall central tendency estimate. This is further reflected in the range of 90 percent (5th and 95th percentiles) confidence intervals. Although the empirical range of any given 90 percent confidence interval may largely overestimate the true extent of variability, the distributions do provide a rough estimate of the total uncertainty in the aggregate processes and an idea of the precision (or lack thereof) of the BAF estimates. The uncertainty in the BAF estimates is related to two basic sources. First is the uncertainty arising from natural variability, such as size of individual fish or differences in metabolic processes. Second is the uncertainty due to measurement error, such as error in measurements of mercury in water and fish samples or lack of knowledge of the true variance of a process (e.g., methylation). These two sources of uncertainty are generally referred to as "variability" and

"uncertainty", respectively. In this analysis, there was no distinction made between variability and uncertainty; they are aggregated in the final BAF distributions and point estimates. Thus, it cannot be determined where natural variability stops and uncertainty starts. However, some of the more important sources of variability and uncertainty are highlighted below in order to assist risk managers in understanding what the limitations are surrounding the BAFs, to see how the uncertainty in the BAF estimates might be reduced should they derive more data, and to assist them in decisions on development of site-specific BAFs.

Uncertainty Due to Sampling and Chemical Analysis

In many cases, water methylmercury concentrations reported in the available studies incorporated limited or no cross-seasonal variability, incorporated little or no spacial variability, and were often based on a single sampling event. Because fish integrate exposure of mercury over a life time, comparing fish concentrations to a single sample or mean annual concentrations introduces bias to the estimates. The geographic range represented by the water bodies is also limited. The available lentic data are biased towards northern oligotrophic lakes, primarily located in the Great Lakes region. The lotic BAFs are primarily based on data from canals of the Everglades (assumed to act as flowing aquatic ecosystems) and from a point-source-contaminated stream in Tennessee. Because of this general lack of data, a few studies on water bodies in other countries were included in the analysis, requiring one to assume that biotic and abiotic processes in these lakes are similar to lakes in the continental U.S.

The same sampling and analytical methods for water and tissue samples were not used in each acceptable study. Although all studies used met general requirements for data quality, studies with different analytical detection limits were combined to estimate the BAFs. The range of species used in the BAF estimates is relatively small compared to the suite of fish and invertebrates consumed by the general human population. Much of the available trophic level 4 data for both lentic and lotic ecosystems is limited to walleye, pike, or bass. For trophic level 3 much of the data is for bluegill and perch. For trophic level 2, most of the data was for zooplankton in lentic waters and for planktivorous fish in lotic waters. The lack of data complicated comparisons between the two aquatic ecosystems and introduces uncertainty into application of the BAFs.

Uncertainty Due to Estimation Method

Each of the approaches use to estimate BAFs have their own inherent uncertainties. Both the direct and indirect approaches assume that the underlying process and mechanisms of mercury bioaccumulation are the same for all species in a given trophic level and for all water bodies. The indirect approach deals with this assumption more specifically by assuming that the translators and fmmfs used to convert BAFs are equally applicable to all ecosystems. In reality, these factors are based on a limited set of data. Although the translators and fmmfs used in the analysis are consistent with those reported elsewhere (Porcella, 1994), they may over- or underestimate bioavailability and bioaccumulation in specific water bodies. Ideally, site-specific conversion factors would be used to estimate BAFs more reflective of conditions in a given water body. The approach used here aggregates all of the species-specific BAFs into a single trophic level-specific BAF; this also increases the over all variability in the BAF estimates.

Uncertainty Due to Biological Factors

Other than deriving BAFs based on organism trophic level, and initially by general water body type (i.e., lentic and lotic), there were no distinctions in the BAFs as to size/age of fish, water body trophic status, or underlying mercury uptake processes. It has been shown that methylmercury bioaccumulation for a given species can vary as a function of the ages (body size) of the organisms examined (Glass et al, 1999; Watras et al., 1998; Suchanek et al., 1993; Lange et al. 1993). As a result, it has been suggested that to reduce some of the lake-to-lake variability seen in BAFs for a given species, comparisons between water bodies should be made using "standardized" fish values (i.e., a value for a hypothetical 1 kg northern pike; Glass et al., 1999). Typically such data "normalization" is derived by linear regression of residue data collected from individuals of varying size and/or age. However, the currently available data are too limited to perform this kind of normalization; most of the water body-specific BAFs, and resulting trophic level distributions, are based on "opportunity" (whatever you catch, you include) and do not report age or size of individuals sampled.

Uncertainty Due to Universal Application of BAFs

Perhaps the greatest source of variability is that of model uncertainty. That is, uncertainty introduced by failure of the model (in this analysis a single trophic level-specific BAF) to represent significant real-world processes that vary from water body to water body. The simple linear BAF model relating methylmercury in fish to total mercury in water simplifies a number of nonlinear processes that

lead to the formation of bioavailable methylmercury in the water column and subsequent accumulation. Much of the variability in field data applicable to the estimation of mercury BAFs can be attributed to differences in biotic factors (e.g., food chain, organism age/size, primary production, methylation/demethylation rates), and abiotic factors (e.g., pH, organic matter, mercury loadings, nutrients, watershed type/size) between aquatic systems. As an example, in lake surveys conducted within a relatively restricted geographic region, large differences can exist between lakes with respect to mercury concentrations in a given species of fish (Cope et al., 1990; Grieb et al., 1990; Sorenson et al., 1990; Jackson, 1991; Lange et al., 1994; Glass et al., 1999). These observations have led to the suggestion that a considerable portion of this variability is due to differences in within-lake processes that determine the percentage of total mercury that exists as the methylated form. Limited data also indicate that within a given water body, concentrations of methylmercury are likely to vary with depth and season. Unfortunately, while the concentration of methylmercury in fish tissue is presumably a function of these varying concentrations, published BAFs are generally estimated from a small number of measured water values, whose representativeness of long-term exposure is poorly known. Furthermore, although it is known that biotic and abiotic factors control mercury exposure and bioaccumulation, the processes are not well understood, and the science is not yet available to accurately model bioaccumulation on a broad scale.

Summary

Three different approaches were use to estimate methylmercury bioaccumulation factors for use in deriving national 304(a) ambient water quality criteria for mercury. All three approaches resulted in BAFs with central tendency point estimates in good agreement with one another. Based on data comparability and EPA's national guidance for deriving BAFs, methylmercury BAFs estimated using directly measured and converted field data were used as the basis for deriving the draft national BAFs. Given the large range in the data, at this time lotic BAFs can not be distinguished from lentic BAFs, though the data suggests slightly reduced methylmercury accumulation may occur in higher trophic level organisms in lotic/wetland environments. The same trend is observed when BAFs are compared on a total mercury basis. Some of this difference might be accounted for by the lower accumulation of methylmercury at the base of the food chain in lotic/wetland ecosystems. A plausible explanation for this difference is the observation that the bioavailability of methylmercury in lentic environments (usually a low dissolved organic carbon content) may exceed the bioavailability of methylmercury in lotic/wetland environments (usually a high dissolved organic carbon content). Methylmercury and mercury have a high binding capacity to dissolved organic carbon which can affect their bioconcentration in

phytoplankton/periphyton. Watras et al. (1998) used modeling to show that BAFs based on the bioavailable fraction of methylmercury in water exceed BAFs based on the operationally defined (filtered) dissolved methylmercury in water. Bioavailability is perhaps the single most important factor affecting BAFs for mercury.

EPA fully recognizes that the approach taken to derive mercury BAFs collapses a very complicated non-linear process, which is affected by numerous physical, chemical, and biological factors, into a rather simplistic linear process. EPA also recognizes that uncertainty exists in applying a National BAF universally to all water bodies of the United States. Therefore, in the revised 2000 Human Health Methodology (EPA , 2000) we encourage and provide guidance for States, Territories, Authorized Tribes, and other stakeholders to derive site-specific field-measured BAFs when possible. In addition, should stakeholders believe some other type of model may better predict mercury bioaccumulation on a site-specific basis they are encouraged to use one, provided it is scientifically justifiable and clearly documented with sufficient data.

SECTION II. CHEMICAL TRANSLATORS FOR MERCURY AND METHYLMERCURY

Introduction

By regulation (40 CFR 122.45(c)), the permit limit, in most instances, must be expressed as total recoverable metal. Because chemical differences between the discharged effluent and the receiving water are expected to result in changes in the partitioning between dissolved and adsorbed forms of metal, an additional calculation using what is called a translator is required.

The translator is used to convert the dissolved concentration of a metal to a total metal concentration for use in waste load limit calculations. The translator is the fraction of the total recoverable metal in the downstream water that is dissolved, f_d. The translator can be used to estimate the concentration of total recoverable metal in a water body.

Methods

Two procedures were used to develop site-specific translators. The most straightforward approach for translating from a dissolved water quality criterion to a total recoverable effluent concentration is to analyze directly the dissolved and total recoverable fractions. The translator is the fraction of total recoverable metal that is dissolved. It may be determined directly by measurements of dissolved and total recoverable metal concentrations in water samples taken from the well mixed effluent and receiving water (i.e., at or below the edge of the mixing zone). In this approach, a number of samples are taken over time and an f_d value is determined for each sample:

$$f_d = Cd/Ct \quad [Eqn. 1]$$

where:

Cd = the dissolved concentration, and
Ct = the total metal concentration.

The translator is then calculated as the geometric mean (GM) of the dissolved fractions.

The second approach derives an f_d from the use of a partition coefficient K_D where usually the coefficient is determined as a function of total suspended solids (TSS) (although some other basis such as humic substances or particulate organic carbons may be used). The partition coefficient is the ratio of the particulate-sorbed and dissolved metal species multiplied by the adsorbent concentration, i.e. Cd + TSS ⇌ Cp, where Cp is the bulk particulate-sorbed concentration, and is expressed as:

$$K_D = Cp/(Cd \cdot TSS) \qquad [Eqn.2].$$

The dissolved fraction and the partition coefficient are related as shown in equation 3.

$$f_d = (1 + K_D \cdot TSS)^{-1} \qquad [Eqn.3]$$

As in the first approach, numerous samples are collected over time, and the f_d and TSS values found at the site are fit to a least squares regression, the slope of which is K_D. The established K_D is then used to determine the translator using Eqn. 3 with a TSS value representative of some critical condition, e.g., low flow conditions.

Although development of site-specific translators is recommended, EPA also envisions the possible need for national or default translators for use in translating dissolved mercury and dissolved methylmercury criteria into total mercury and methylmercury water quality permit limitations. Translators and/or related K_D values can be generated from an acceptable existing literature-derived data base. EPA's MSRC (U.S. EPA, 1997) contains extensive data, obtained primarily from lake systems, that are relevant to developing translators for mercury (e.g., percent total as methylmercury, percent total as dissolved mercury). Supplementation of these translators with additional, acceptable data from lotic and estuarine systems and update of lentic systems provides the necessary data base for the translators. To gather this data base, peer-reviewed literature papers from 1990 to present, were searched and reviewed. Since awareness of the contamination problems with mercury at low levels and the existence of analytical methods capable of accurately and precisely measuring mercury and methylmercury at low levels are relatively recent, the literature review was not conducted for publications prior to 1990. All data from the literature for use in developing the translators were required to meet the following criteria:

- Clean techniques, or equivalent, to reduce contamination were used in sampling and analysis.
- Adequate QA/QC procedures were used.
- Analytical methods used provided sufficiently low enough detection level.

Draft Translators

Table A-10 summarizes the numerous tables from the EPA internal draft BAF report (see Water-Docket W-00-20). These results are presented separately for lake, river and estuarine systems, and for each system, where sufficient data were available, both f_d and K_D values were tabulated. The K_D values were calculated using Eqn. 2. The K_D values could not be derived using the f_d-TSS correlation approach due to the limited data, i.e., multiple sampling events over time with measurements of both f_d and TSS were not conducted in most of the studies. The results are presented separately for both mercury and methylmercury. Table A-10 provides a summary of the GM values calculated for each system for f_d and K_D values, again for both mercury and methylmercury.

It is possible to calculate a "pseudo" K_D value for the partitioning of dissolved methylmercury with particulate total mercury using f_d and K_D data for a waterbody utilizing the following equation (see Attachment B for derivation and example calculation):

$$\text{"Pseudo" } K_D \text{ MeHgd/Hgt} = K_D \text{ MeHgd} \cdot \text{MeHgt} \bullet \text{Ratio Hgd/MeHg}_p \bullet \text{Ratio MeHgd/MeHg}_p$$

[Eqn. 4]

Table A-10: Summary of F_d and K_d Values for Lakes, Rivers, and Estuaries[a]

f_d and K_D Values	Lakes	Rivers	Estuaries
f_d Hg	0.60	0.37	0.353
f_d $MeHg_d/Hg_t$	0.032	0.014	0.190[b]
f_d $MeHg_d/MeHg_t$	0.613	0.49	0.612[b]
Log K_D Hg	5.43	5.06	5.52
Log K_D MeHg	5.53	4.81	NF[c]
"pseudo" Log K_D $MeHg_d/Hg_t$	6.83	6.44	NC[d]

a Values calculated as GM
b Only two sites
c No data found from the literature search
d Not able to calculate due to insufficient data

The K_D so derived is a "pseudo" value since dissolved methylmercury partitioning with particulate total mercury is just a synthetic or functional type description. These values are also given in Table A-10. The "pseudo" K_D values, however, allow for direct translation of dissolved methylmercury criteria to total mercury permit limits employing some designated TSS level. Insufficient data were found, e.g., K_DMeHg, to allow for calculation of "pseudo" K_Ds for estuaries. It should be understood that all values in Table A-10 represents values generated from the above-described literature-gleaned data base. Insufficient data were obtained to provide either reliable f_d (translator) or K_D "default" values for methylmercury for estuarine systems (only two sites). Examination of the translator values for lakes and rivers shows that in all instances the river values for both f_ds and K_Ds are lower than the lake values. The lower translator values can be generally explained by the generally higher TSS levels found in rivers as compared to lakes. For example, typical TSS values for eastern Washington state lakes are 0.5 to 5 mg/L, whereas river levels can be typically 5-50 mg/L (Pankow and McKenzie, 1991). Higher TSS levels lead to lower f_d values.

The lower K_D values for rivers vs. lakes are not as readily explainable. K_D values are not constant and are sensitive to environmental conditions and water chemistry (Sung, 1995). Inclusion of the colloidal fraction in the dissolved phase that is used in determining the K_D has been used to explain variation of K_D values and for deviation of the values from any true K_D (Pankow and McKenzie, 1991; Sung, 1995). Higher colloidal contents or higher DOC levels in the river samples compared with lake samples would produce lower apparent (as measured) K_D values. However, the following other factors have been suggested to play major roles in K_D determinations, and one or all of these may contribute significantly to the reason why the river K_Ds are less than the lake K_Ds for both mercury and methylmercury:

- Biotic or organic content of the TSS
- Dissolved organic content of the water
- Geochemistry and residual metal content of the TSS
- TSS particle size
- Pollution level existing in the waters

Regardless of the reason(s) for the differences between the lake and river values, differences do exist and are sufficiently significant that it is recommended that the two systems be treated separately with regard to translator values. Until additional data are available for estuarine systems, and a satisfactory comparison to lake and river systems can be made, it is recommended that separate values be retained for estuaries also.

One can estimate the TSS level that is represented by the f_d values for each system through the use of Eqn. 3 and employing the default K_D values provided in Table A-10. The results of calculations of these estimated levels and an example calculation are presented in Table A-11. The data show the following:

- In lakes, the f_d for mercury (0.60) would reflect TSS levels of 2.5 mg/L. The f_d for methylmercury (0.032) would reflect TSS levels of 1.8 mg/L. At TSS levels lower than these values, a greater fraction of the mercury and methylmercury would be expected to be dissolved than indicated by the f_d.

- In rivers, the f_d for mercury (0.37) would reflect TSS levels of 14.8 mg/L. The f_d for methylmercury (0.014) would reflect TSS levels of 16.3 mg/L. At TSS levels lower than these values, a greater fraction of the mercury and methylmercury would be expected to be dissolved than indicated by the f_d.

- In estuaries, the f_d for mercury (0.35) would reflect TSS levels of 5.5 mg/L.

Existing TSS levels less than those above would, in any instance, that the dissolved fraction present in the water could be greater than the value suggests.

Use of the partition coefficient approach may provide advantages over the dissolved fraction. EPA suggests (EPA, 1996) that when using dynamic simulation for Waste Load Allocation (WLA) or the Total Maximum Daily Load (TMDL) calculations and permit limit determinations, K_D allows for greater mechanistic representation of the effects that changing environmental variables have on f_d (the significance of the TSS variable has been shown in Table A-11 data and discussed above, and this variable is addressed or can be handled in the K_D approach).

Table A-11: Estimation of TSS Level at f_d Values

	Lakes		Rivers		Estuaries	
	f_d	Est. TSS, mg/L	f_d	Est. TSS, mg/L	f_d	Est. TSS, mg/L
Mercury[a]	0.60	2.5*	0.37	14.8	0.35	5.5
Methylmercury[b]	0.032	1.8	0.014	16.3	0.190	NC[c]

(a) Calculated using default K_D values and equation: $f_d = 1/(1+K_D \times TSS)$

(b) Calculated using default "pseudo" K_D values and equation: $f_d = 1/(Hg_d/HgMe_d + K_D \times TSS)$

(c) Not able to calculate; insufficient data.

* Calculation:

$f_d = 1/(1 + K_D \times TSS \times 10^{-6})$ note: 10^{-6} used to provide TSS in mg/L units

default K_DHg (lakes) = 269,153

substituting: $0.60 = 1/(1 + 269{,}153 \times TSS \times 10^{-6})$

$0.60 + 0.161 \times TSS = 1$

$0.161 \times TSS = 0.40$

$TSS = 2.5$

Although the K_D approach may be advantageous in use, employment of a default K_D value has inherent problems as does the use of a f_d. For example, mercury K_Ds have been shown to range from about 10^4 to about 10^6 (Watras et al., 1995). At an average K_D value of about 10^5 (the value found for rivers), and a critical TSS level of 10 mg/L, a translator value of 0.5 is derived from the K_D approach.

However, if the site K_D, for example, is close to the lower end of the K_D range, the translator value should be about 0.9. Thus the value is inaccurate at this site. Only at sites where the existing K_D is 10^5 or greater (at 10 mg/L TSS) would the use of the default K_D yield a translator value that does not underestimate the dissolved mercury level.

An additional problem with the use of the K_D approach is that even at a given site, K_D values can vary. Usually, K_D values decrease at a site as TSS increases, as has been shown recently for mercury and methylmercury in a Virginia river (Mason and Sullivan, 1998). In addition, the K_D translator approach necessitates that f_d correlate with TSS. A poor correlation, however, has been found to exist for many metals in a recent analysis of data obtained from State of Michigan surface waters (MDEQ, 1996).

Although the K_D approach has its advantages, the f_d approach is the most straightforward. Both approaches have their disadvantages, as discussed previously. The K_D is derived from f_d values and so the two approaches are truly linked. Therefore, preferential recommendation of either one approach over the other at present cannot be made.

Use of either f_d or K_D default values can be made as long as one recognizes the short comings of the approach taken. Perhaps the approach taken should be the one with the stronger data base, if a clear difference exists. As additional data appears in the literature, it is reasonable to assume that a fine-tuning of both the f_d and K_D default values will result. EPA recommends that translators be derived from site-specific studies when possible, but the values in Table A-10 could be used in absence of any site-specific data.

ATTACHMENT A: BAF PEER REVIEWERS' GENERAL COMMENTS

The following was excerpted from the BAF Peer Review Comments Report, August 23, 2000. See Water Docket W-00-20 for a complete version of the peer review report.

2.0 REVIEWERS' COMMENTS

2.1 General Comments

Nicolas Bloom

Overall, I found the document quite clear and well written compared to other EPA mercury documents that I have recently reviewed, a fact that made my job considerably easier. On the other hand, it seems quite clear that there is insufficient data currently available for the EPA to make any more than the broadest generalizations about methyl mercury bioaccumulation factors. The current greater than one order of magnitude spread in estimated BAFs will not be very useful in any actual case, although it serves to describe the situation in general terms. The EPA should be impelled to proceed by instigating research and/or requiring site-specific bioaccumulation factors to be developed until such time that a sufficient database is accumulated to allow some meaningful resolution between BAFs from different water body types, climates, and trophic levels.

I oppose the general use of the confusingly similar terms "lentic" and "lotic," which although probably clear to fish ecologists, never-the-less provide endless confusion to the rest of us. I conducted a poll of the 51 employees of our aquatic sciences research company, and no one could define these words correctly, although a few did say that they had heard of them back in college. Additionally, even though physically, the term "lentic" can be used to lump together the Everglades with a swiftly moving glacial stream, I see no logical biogeochemical reason to do so.

There is also the overwhelming sense, in the description of the trophic levels considered, that the only valid food chain model being considered is the water to plankton to zooplankton to fish model. However, many systems (i.e., Lavaca Bay, TX) are dominated by a sediment porewater to benthic invertebrates to fish model, which means that sediment issues (methyl concentrations, methylation depth profiles, redox condition, seasonality, etc.) loom way more important that water column concentrations.

James Hurley

First and foremost, the development of a national AWQC for methylmercury must be based on sound data with strict quality control/quality assurance to ensure that the calculation of bioaccumulation factors (BAFs) is scientifically valid. This is a difficult task when conducting literature searches for data that form the backbone of the report. Among the data chosen, methods must be comparable to allow transferability. Individual investigators also apply different definitions of biological assemblages and food chain pathways. This makes the task of synthesizing appropriate data a difficult task at best.

My overall concern with data used for determination of the national BAF is that not one study from which data was obtained for this report was actually with the specific purpose of generating MeHg-based BAFs through all trophic levels. I fully understand that EPA also recognizes this problem and commend them for assembling the data presented. However, I do think that EPA should consider a research effort designed to produce results directly related to their MeHg BAF goals. This would ensure that sample types and methodologies were consistent with the overall goal of development of national BAFs for methylmercury. Development of a scientifically sound BAF is a critical step in development of a management plan for this Level I contaminant in the U.S.

In addition to developing a field effort, EPA should also consider development of dedicated laboratory studies that address Hg and MeHg partitioning and transport in trophic levels 1 and 2. Although EPA decided to choose an approach that incorporates field-derived BAFs, laboratory studies using cultures of phytoplankton and zooplankton, coupled with key contrasting water chemistries, would certainly aid in reducing the variability that is inherent in using field-derived data on partitioning. Results of these studies alone would avoid the ambiguity that is inherent in using the terms "seston" and "phytoplankton" interchangeably for BCFs.

The current report divides the data into two environments (lentic and lotic) but then combines BAFs to determine a national BAF in the final section of the report. I strongly encourage EPA to establish a series of National BAFs that are watershed-type based, in slightly more detail than a simple lentic/lotic division. Data from lotic systems in the report combine wetlands with flowing rivers. As a result, the lotic grouping contains high dissolved organic carbon (DOC) systems such as wetlands, with low DOC headwater streams. This type of grouping of sites with such disparate Hg-cycling environments most likely accounts for both the spread of data for directly-calculated BCFs and the lack of agreement between directly calculated and converted BCFs depicted in Figure 5-2.

While I agree that translators are appropriate in some instances, they too should be calculated on a more site-specific basis. Use of the translators to calculate the fraction (f_d) of total Hg as MeHg should be refined to address factors such as trophic state and watershed type. The grand mean of 3.2% for this translator encompasses a range from 0.2% to 13.9% in lake waters. Similarly, the grand mean from rivers of 1.4% encompasses a range from 0.2 to 5.11% in rivers. Better grouping of the data would reduce variability for this data set. For instance, Kd's for several contaminants have been shown to decrease with increasing DOC. The processes controlling methylation and particle partitioning are site-specific, and the current report attempts to define complex chemical and biological processes across gradients by the use of a simple fraction. Since this factor (the amount of inorganic Hg that is converted to the bioaccumulative methyl form) is perhaps the most critical step in developing a BCF, a simple default conversion factor is not the best approach.

Finally, development of an acceptable model is mentioned within the report as a future goal, but I feel that model development and acceptance should be fast-tracked along with development of a National MeHg BAF. Models, such as the recent revisions of the Mercury Cycling Model (MCM), that incorporate processes such as methylation, aquatic speciation, and bioenergetics are keys to validation of the BAFs among contrasting sites. Having worked specifically with the MCM Model, I am confident that is has been tested on a number of contrasting environments (northern Wisconsin lakes, Everglades, Great Lakes) and could be used to validate BAFs for differing aquatic environments.

David Krabbenhoft

Overall, I found the document to be in very good order structurally, grammatically, and was of an appropriate length for the subject matter; my compliments to the authors. A quality manuscript makes the reviewer's job much easier, and a better technical review results when he or she is not "put off" for having to do editorial service too. I heartily support the U.S. EPA's decision to pursue changes to the AWQC for mercury and have methylmercury (MeHg) be the basis for such regulations. Although this has been a long time in coming, I do recognize that the peer reviewed data for this type of proposed change has been limited to just a few study locations until the past few years. That being said, however, I have serious reservations as to whether enough high quality data has been made available by the scientific community for the EPA to make an important decision like assigning "National BAF's". The authors of this report have largely done an admirable job with what is available, but it may be slightly ahead of its time. It may be that with the very recent release of the National Academy of Sciences report on human health and mercury, and the proposed decision time line of the EPA to enact emissions

regulations in the 5-year time frame, that a well-conducted, national-synoptic study to for the proper basis for a MeHg BAF's is in order.

David Maschwitz/Edward Swain

1. An update of the mercury bioaccumulation factor (BAF) is very much needed, for the reasons cited on page 1 of Section I. The new analytical methods that can measure ambient mercury in water at sub-nanogram per liter levels, and the large number of recent studies that provide field measured BAF data make the determination of a new BAF a necessity, if EPA plans to update the human health-based mercury criterion. The BCFs/BAFs used in previous EPA mercury criteria are clearly outdated. A new mercury BAF and criterion will be a great help to states and tribes (hereinafter, state). The determination of a BAF is often the biggest road block to the calculation of a human health-based water quality standard for state regulatory agencies.

2. The following comments are on *National Bioaccumulation Factors for Methylmercury* (Section I) and *Default Chemical Translator for Mercury and Methylmercury* (Section II). We have not reviewed for comment the background document.

3. The overall organization of Sections I and II, is logical, straight forward and easy to follow.

4. The EPA search for both available published and unpublished BAF data uncovered a substantial amount of new information; and, short of carrying out an independent literature search to confirm this comment, it should be reasonably complete and current.

5. The discussion of uncertainty associated with the final recommended BAFs (beginning on page 73, Section I), including a discussion of the limitations associated with reducing highly variable BAF data to a single national BAF (for each trophic level), and the myriad of variables that can affect BAFs, is appropriate. Further, EPA's rationale that, in spite of the uncertainty (actually, because of it), the recommendation of a single default BAF for each trophic level is valid. The recommendation that states should use local BAF data is good as well, but EPA must realize that local BAF data is not likely to be available in many situations. Thus, the default BAFs will get substantial use.

6. The decision to use only the preferred, field measured, BAF data (including the converted direct BAFs) and not use the indirectly determined BAFs (BCFs or BAFs times a FCM or BFM) is appropriate given the quality and quantity of the former. This is consistent with the proposed new EPA human health criteria methodology (EPA, 1998). However, including the comparison of direct and indirect BAFs in Section I (Tables 3-10 and 4-11) is valuable information.

7. To eliminate any uncertainty about the proper application of the translators listed in Tables 5-1 and 5-2, it is suggested that EPA include in Tables 5-3 through 5-10 columns showing the translators used in the conversions, and/or a column showing the "raw" as well as the converted BAFs. An alternative to expanding these tables is to add to the summary information at the beginning of each subsection (i.e., Variable, Definition, Estimate, Distribution) a section on "Translators" or "Conversion" that shows the translator(s) and conversion calculations (this option assumes the translators used and all the conversion calculations are the same for all the individual BCFs/BAFs). A third, but less desirable alternative, is to provide example calculations in the introductory discussion of converted methylmercury BAFs, beginning on page 49 of Section I.

8. Overall, we believe the final recommended BAFs (Table 5-15) are supported and a reasonable conclusion of the data analysis.

9. The introduction to Section II (page 1) talks about EPA's policy to use dissolved analyses for trace metals to measure compliance with the standard. This policy was developed in the context of the toxicity of particulate and chemically bound, versus the toxicity of "dissolved" or ionic forms, of trace metals to aquatic life. The science behind EPA's dissolved metal policy may not be as relevant to a highly bioaccumulative metal like mercury, for which the concern is the methyl form, and the risk is to human health through fish consumption rather than to aquatic life directly. EPA should expand this section to discuss if and how mercury differs from non-bioaccumulative trace metals with regard to the need or desirability of measuring dissolved metal in water.

10. EPA discusses in the "Background" part of Section II, total to dissolved metal conversion factors. Along the lines of comment number nine, the conversion factor of 0.85 for the current mercury criteria (CMC and CCC) are applicable to toxicity-based mercury criteria, not the human health-based chronic criterion (*Federal Register* 63: 68354-68364). The conversion factor for the chronic human health-based mercury criterion is 1.0 (see also *Federal Register* 60: 15392). EPA needs to

revise their discussion of conversion factors to reflect the conversion factor for the human health criterion, and to address the points made in comment number nine.

11. Separate average translators and K_D values for lakes, rivers and estuaries as derived in Section II seem to be reasonable and supported by the data presented.

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I found the reports to be clear in their intent and in their explanation of approaches used. I especially appreciated the straightforward acknowledgment of the myriad sources of uncertainty and variability. My overall response to the entire exercise is that those sources of uncertainty and variability (geographic, water quality, water trophic status, analytical, individual organism, true trophic "level", food web complexity, etc.) make this a very difficult if not impossible proposition. I strongly support the development of tissue-based mercury criteria as the preferred mechanism for addressing mercury risk assessment and regulatory concerns throughout the huge range of aquatic systems affected. That said, if EPA has a legal charge to also develop the best predictive relationships it can as defaults, etc., the approach being used is probably as good as can be expected. It may be significantly more useful as a regional tool, though (e.g., northern midwestern lake systems, California rivers, Florida, etc). A truly applicable, nation-wide set of factors may be unattainable. I strongly concur with the suggestion that site-specific research is preferable in the event that BAFs are to be used.

ATTACHMENT B: DERIVATION AND CALCULATION OF "PSEUDO" K_DS FOR METHYLMERCURY

Derivation

$MeHg_d + TSS \rightleftharpoons Hg_p$, including $MeHg_p$

$$\text{"Pseudo"}K_D\text{MeHg / Hg} = \frac{Hg_P}{MeHg_D \bullet TSS} \quad \text{[Eqn. A.1]}$$

$$\text{Also: } K_D\text{MeHg} = \frac{MeHg_P}{MeHg_D \bullet TSS} \quad \text{[Eqn. A.2]}$$

Equating TSS and combining Eqn. A.1. and Eqn. A.2 yields:

$$\text{"Pseudo"}K_D\text{MeHg / Hg} \bullet \frac{MeHg_d}{Hg_P} = K_D\text{MeHg} \bullet \frac{MeHg_d}{MeHg_P}$$

Rearranging:

$$\text{"Pseudo"}K_D\text{MeHg / Hg} = \frac{Hg_P}{MeHg_d} \bullet \text{KMeHg} \bullet \frac{MeHg_d}{MeHg_P} \quad \text{[Eqn. A.3]}$$

Example Calculation for Lakes (see text of original draft report for source of data)

- K_DMeHg = 338,844
- When $Hg_T = 1$, $MeHg_d = 0.032$, $Hg_d = 0.60$ and therefore $Hg_p = 0.40$
  and the ratio $Hg_p/MeHg_d = 0.40/0.032 = 12.5$
- When MeHg = 1, $MeHg_d = 0.613$, and therefore $MeHg_p = 0.387$
  and the ratio $MeHg_d/MeHg_p = 0.613/0.387 = 1.58$
- Substituting the above values in Eqn. A.3 gives:
  "Pseudo" K_DMeHg / Hg = 12.5 • 338,844 • 1.58 = 6,692,169
  Log "Pseudo" K_DMeHg / Hg = 6.83

Example Calculation for Rivers (see text of draft report for source of data)

- $K_D MeHg = 64{,}565$
- When $Hg_T = 1$, $MeHg_d = 0.014$, $Hg_d = 0.37$ and therefore $Hg_p = 0.63$
  and the ratio $Hg_p/MeHg_d = 0.63/0.014 = 45.0$
- When $MeHg = 1$, $MeHg_d = 0.49$, and therefore $MeHg_p = 0.51$
  and the ratio $MeHg_d/MeHg_p = 0.49/0.51 = 0.96$
- Substituting the above values in Eqn. A.3 gives:
  "Pseudo" $K_D MeHg / Hg = 45.0 \bullet 64{,}565 \bullet 0.96 = 2{,}789{,}208$
  Log "Pseudo" $K_D MeHg / Hg = 6.44$

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Effects of tidal current phase at the junction of two straits

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Abstract

Estuaries typically have a monotonic increase in salinity from freshwater at the head of the estuary to ocean water at the mouth, creating a consistent direction for the longitudinal baroclinic pressure gradient. However, Mare Island Strait in San Francisco Bay has a local salinity minimum created by the phasing of the currents at the junction of Mare Island and Carquinez Straits. The salinity minimum creates converging baroclinic pressure gradients in Mare Island Strait. Equipment was deployed at four stations in the straits for 6 months from September 1997 to March 1998 to measure tidal variability of velocity, conductivity, temperature, depth, and suspended sediment concentration. Analysis of the measured time series shows that on a tidal time scale in Mare Island Strait, the landward and seaward baroclinic pressure gradients in the local salinity minimum interact with the barotropic gradient, creating regions of enhanced shear in the water column during the flood and reduced shear during the ebb. On a tidally averaged time scale, baroclinic pressure gradients converge on the tidally averaged salinity minimum and drive a converging near-bed and diverging surface current circulation pattern, forming a "baroclinic convergence zone" in Mare Island Strait. Historically large sedimentation rates in this area are attributed to the convergence zone.

Keywords: Salinity minimum; Convergence; Current shear; Baroclinic gradients; USA; California; San Francisco Bay

1. Introduction

The classic estuarine setting includes a longitudinal baroclinic pressure gradient heading in a consistent direction, driving a tidally averaged flow pattern of estuarine circulation (Hansen and Rattray, 1965). However, various mechanisms have been identified that alter the magnitude and direction of the longitudinal baroclinic pressure gradient, thus, modifying the residual flow pattern. For example, Largier et al. (1996) discuss the baroclinic structure of low-inflow estuaries that consist of four evaporation-created density regimes; Wolanski (1988) demonstrates a salinity maximum region that is driving a diverging near-bed flow pattern and converging surface currents; Abraham et al. (1986) discuss association of dissimilar water masses due to tidal current phasing in the Rotterdam Waterway, which alters the longitudinal density gradient; Nunes and Simpson (1985) describe axial convergence in a well mixed estuary; and Geyer et al. (1997) show sediment trapping enhanced by lateral baroclinic pressure gradients.

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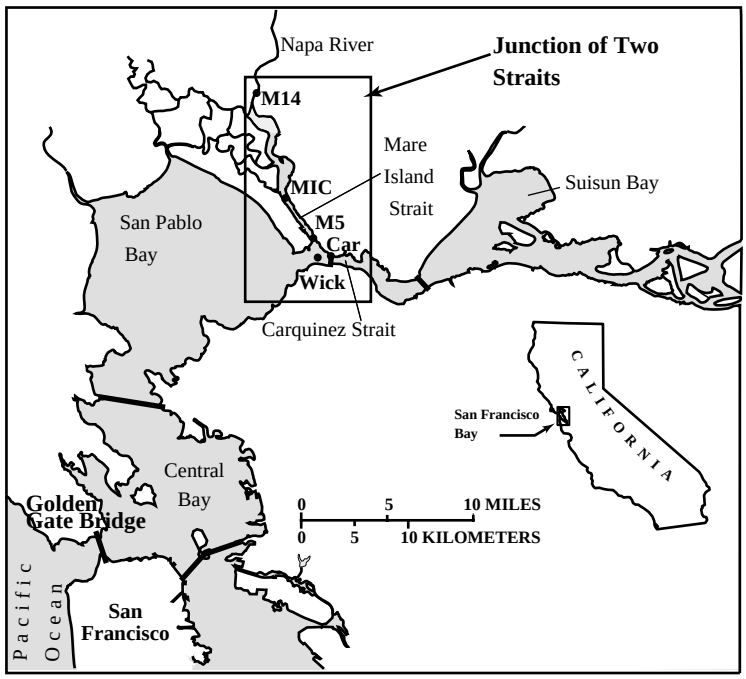

Fig. 1. Site map of San Francisco Bay, California.

In San Francisco Bay, the tide flows first through the Golden Gate into Central Bay (Fig. 1) and then northward to San Pablo and Suisun Bays before reaching the Sacramento/San Joaquin River Delta. Carquinez Strait connects the two northern bays, and the western end of the strait also serves as the junction with Mare Island Strait (the southern terminus of the Napa River). The tides are semi-diurnal with two high tides and two low tides per day. The M2, S2, O1, and K1 are the principal tidal constituents with a tidal form number of approximately 0.6 yielding a mixed tidal regime (Walters and Gartner, 1985). Unequal tidal prisms and basin geometries beyond the junction allow the behavior of the tide in Carquinez Strait to remain as a partially progressive wave and the behavior in Mare Island Strait to respond as a standing wave. These different wave forms create a phase difference of the currents at the junction.

In this paper, we use time series of measured data to illustrate the current phasing and to demonstrate the creation of a local salinity minimum in Mare Island Strait. On a tidal time scale, the local salinity minimum contains baroclinic pressure gradients in the landward and seaward directions that interact with the barotropic gradient, creating regions of enhanced and reduced shear in the water column. On a tidally averaged time scale, baroclinic pressure gradients converge on a tidally averaged local salinity minimum in Mare Island Strait, creating a circulation pattern of converging near-bed and diverging surface currents. Because the circulation pattern is created by converging baroclinic gradients, the region is termed a ''baroclinic convergence zone''. Historical increased sediment deposition rates are attributed to the zone.

2. Data collection and analysis

Data were collected at three sites along the Napa River and at one site in Carquinez Strait (Fig. 1). The sites are channel marker 14 (M14), Mare Island Causeway (MIC), channel marker 5 (M5), and Carquinez (Car). Additionally, data from a previous US Geological Survey instrument

deployment is referenced for the Wickland (Wick) site (Burau et al., 1993).

Instruments that measured velocity, conductivity, temperature, depth, and suspended sediment concentration were deployed from September 3, 1997, to March 13, 1998, at sites M14, MIC, M5, and Car (Warner et al., 1999). Due to biological fouling, equipment difficulties, and large storms, full data sets were not recovered from all the sites. To measure velocity, acoustic Doppler current profilers (ADCPs) were deployed at M14, MIC, M5, and Car (the ADCP at Car was never recovered). Conductivity-temperature-depth (CTD) sensors were deployed on taught-wire moorings at all four sites. At M14, the CTD sensor heights were 1 m above the bed. Two sensors were at MIC, M5, and Car; one near the bed and one near the surface: 1 and 7 m above the bed at MIC, 1 and 6 m above the bed at M5, and 1 and 20 m above the bed at Car. Optical backscatterance sensors (OBS) were connected to the CTDs to measure suspended sediment concentration (SSC) at all sites. The OBS sensors were calibrated with water samples taken during the deployment.

Harmonic analyses (Foreman, 1978) were performed on the measured time series of water level and velocity for time periods of low freshwater inflows. From the analysis, the M2 partial tide was selected to characterize the phasing of the water level and currents because it is the largest semi-diurnal component in the bay and the most representative tidal component (Walters et al., 1985). Tidally averaged quantities were calculated with a sixth-order low-pass Butterworth filter with a cutoff frequency of 0.025/h (period = 40 h). The parameter, hrmsf, was used as a measure of tidal energy and was calculated from the depth by removing the mean, squaring, and filtering (tidally averaging), and by taking the square root. Crests of the hrmsf time series represent increased tidal energy, and they are the spring tidal periods and the neap periods at the troughs. Finally, for analysis of baroclinic pressure gradients, only salinities are discussed because of their dominant influence on density. Daily temperature variations, on the order of 3°, and tidally averaged suspended sediment concentrations, on the order of 100 mg/l, were neglected in the density field calculation.

3. Results

3.1. Current phasing

Along the main estuary axis of San Francisco Bay, the phase difference between the M2 constituent of water level and current fluctuates between approximately 20° and 50°, representing a partially progressive wave pattern (Walters et al., 1985). For example, at site Wick in Carquinez Strait, the phase difference is approximately 20° (Fig. 2). However, in Mare Island Strait, the phase difference between the current and water level is representative of a standing wave pattern (which has a 90° phase difference). For example, site M5 has an 85° difference between the water level and velocity (Fig. 2). This behavior is caused by the almost complete reflection of the tidal signal in the Napa River, due to changes in channel geometry, increased friction, decreasing depths, and the shortness of the basin length. The standing wave in Mare Island Strait and the partially progressive wave behavior in Carquinez Strait create a 60° (2-h) phase difference for the M2 partial tide between the currents at the junction of the two straits. The effect of this difference is to cause the currents to turn 2 h earlier in Mare Island Strait than in Carquinez Strait.

3.2. Salt transport

The phase difference between the currents in Mare Island and Carquinez Straits creates a local salinity minimum that is advected up Mare Island Strait. A schematic of the junction shows Mare Island Strait as a vertical line and Carquinez Strait as a horizontal line (Fig. 3). A monotonically decreasing salinity up the estuary is assumed for Carquinez Strait, as shown by the boxes in Fig. 3 having progressively lighter colors. Two boxes are marked "1" and "2" to pronounce their original order. The box with an "X" represents the salinity level in Mare Island Strait at slack before flood (Fig. 3A), when Carquinez Strait is ebbing (flow to the left). As the Mare Island Strait current turns to flood, a decreasing salinity is advected to the left of the junction and up Mare Island Strait, pronounced with the boxes marked "1" and "2"

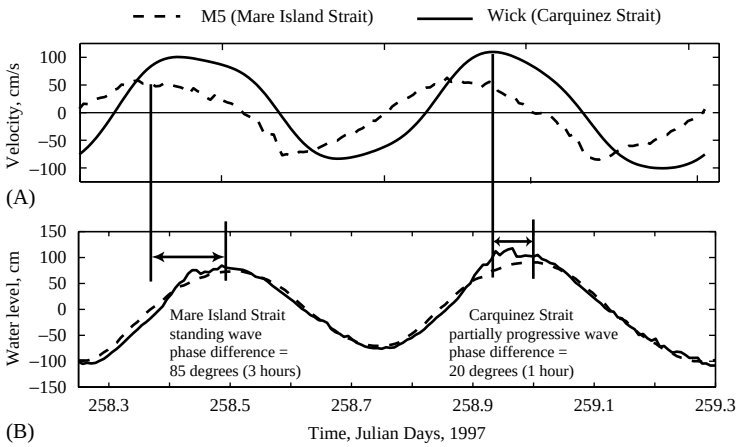

Fig. 2. Phase relation between water level and currents in Mare Island Strait (standing wave) and in Carquinez Strait (partially progressive wave). The velocity time series for site M5 displays directly measured data, whereas the time series of velocity from site Wick was harmonically reconstructed (derived from data measured several years earlier). The water level time series were calculated by removing the mean from both time series.

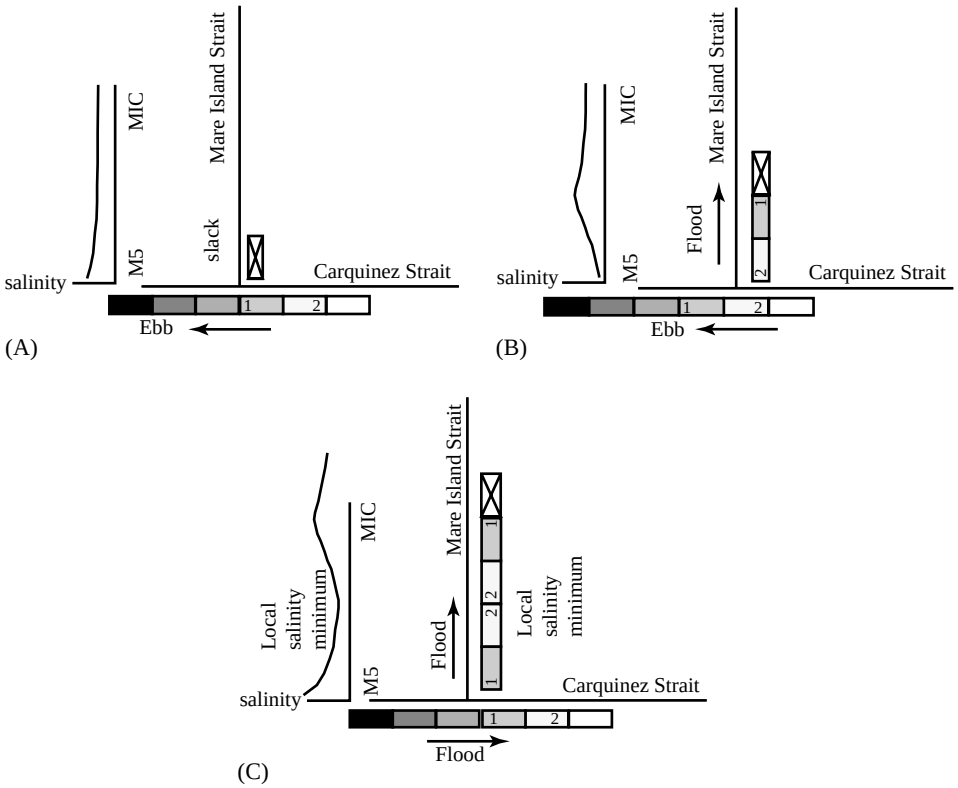

Fig. 3. Junction of Mare Island and Carquinez Straits showing the development of the local salinity minimum. Darker shading denotes saltier water.

(Fig. 3B). This creates a region of decreasing salinity in Mare Island Strait. Next, Carquinez Strait currents go to slack and then turn to flood (flow to the right, Fig. 3C). Mare Island Strait is still flooding, and increasing salinity is advected up Mare Island Strait, pronounced with the boxes marked "2" and "1". This creates a region of increasing salinity and completes the local salinity minimum in Mare Island Strait, as depicted in the axis plot on the left side. To complete the tidal cycle, the ebb current from Mare Island Strait (not shown) advects the salinity minimum into Carquinez Strait. The current in Mare Island Strait then goes to slack (Fig. 3A) and the process continues.

The current phasing yields two salinity features. First, a local salinity minimum is created and advected up Mare Island Strait, with the minimum value of salinity created when Carquinez Strait was at slack after ebb. Second, the magnitude of the salinity in Mare Island Strait (the box with the "X" in Fig. 3A) can be dissimilar to the initial magnitude of salinity advected up from Carquinez Strait. These two features are addressed below.

Field data verifies the creation of the local salinity minimum. Time-series analysis indicates that salinity was in quadrature with the velocity, implying that advection is the dominant mode for transport of salinity (Officer, 1976, p. 78). Therefore, the magnitude of the current in Mare Island Strait is utilized to demonstrate the advection of the local salinity minimum up Mare Island Strait and verify that the variability in the observed time series of salinity is predominately due to the advection of the salinity minimum. The advection is simulated by representing the salinity minimum as a parcel of water with a starting coordinate of zero at the junction of the two straits (with a positive upstream flood direction in Mare Island Strait). Parcel location is calculated by integrating the mean velocity from sites MIC and M5, with respect to time (Fig. 4D). The first parcel (Parcel 1) is released at the junction of the two straits when Carquinez Strait is at slack after ebb (Julian Day 259.35) coinciding with the midpoint of the local salinity minimum. When this parcel has traveled 1.5 km (up Mare Island Strait) the salinity minimum should be at station M5. A vertical arrow from Fig. 4D to C shows at this time that the salinity time series for site M5 has a local minimum value. Continuing in time, Fig. 4D shows that at Julian Day 259.45, Parcel 1 should be at 5.5 km (site MIC). Following the vertical arrow at this time to Fig. 4C shows a local minimum value of salinity at site MIC at this time. All the vertical arrows from Fig. 4D to C correspond to times when the parcel is at either site M5 (1.5 km, solid arrow) or MIC (5.5 km, dashed arrow). At these times local salinity minima appear at the sites, showing that the salinity structure is being advected up Mare Island Strait past sites M5 and MIC on the flood, and it returns past both sites on the ebb. These characteristics in the data affirm that the minimum value of salinity was created when Carquinez Strait was at slack after ebb. Additionally, this analysis confirms that the salinity is dominated by advection, because the parcel location matches very closely the observed salinity minimums.

The second feature is the potential dissimilarity between the salinity in Mare Island Strait (the box with the "X" in Fig. 3) and the salinity of the water that is initially advected up Mare Island Strait from Carquinez Strait. Fig. 4B shows the time series of salinity at site Car and the bold arrows denote the salinity signal corresponding to water being advected up Mare Island Strait. At Julian Day 259.35, Fig. 4B shows the water at site Car that was advected up Mare Island Strait has an initial salinity of approximately 18, reduces to a magnitude of 16, and then increases to 23. In Mare Island Strait, the magnitude of the salinity at Julian Day 259.35 was 18, as well (Fig. 4C). Therefore, the water that was advected up from Carquinez Strait at the beginning of the Mare Island Strait flood had the same salinity as that water preexisting in Mare Island Strait. Hence, the time series of salinity in Mare Island Strait first appeared as a constant and then decreased as the salinity structure appeared.

The movement of Parcel 2 (Fig. 4D) begins when Carquinez Strait is at slack after ebb on Julian Day 259.85. However, the magnitude of the salinity from Carquinez Strait that first enters Mare Island Strait is approximately 19, a salinity value greater than existed in Mare Island Strait (approximately 18). Therefore, the data show an

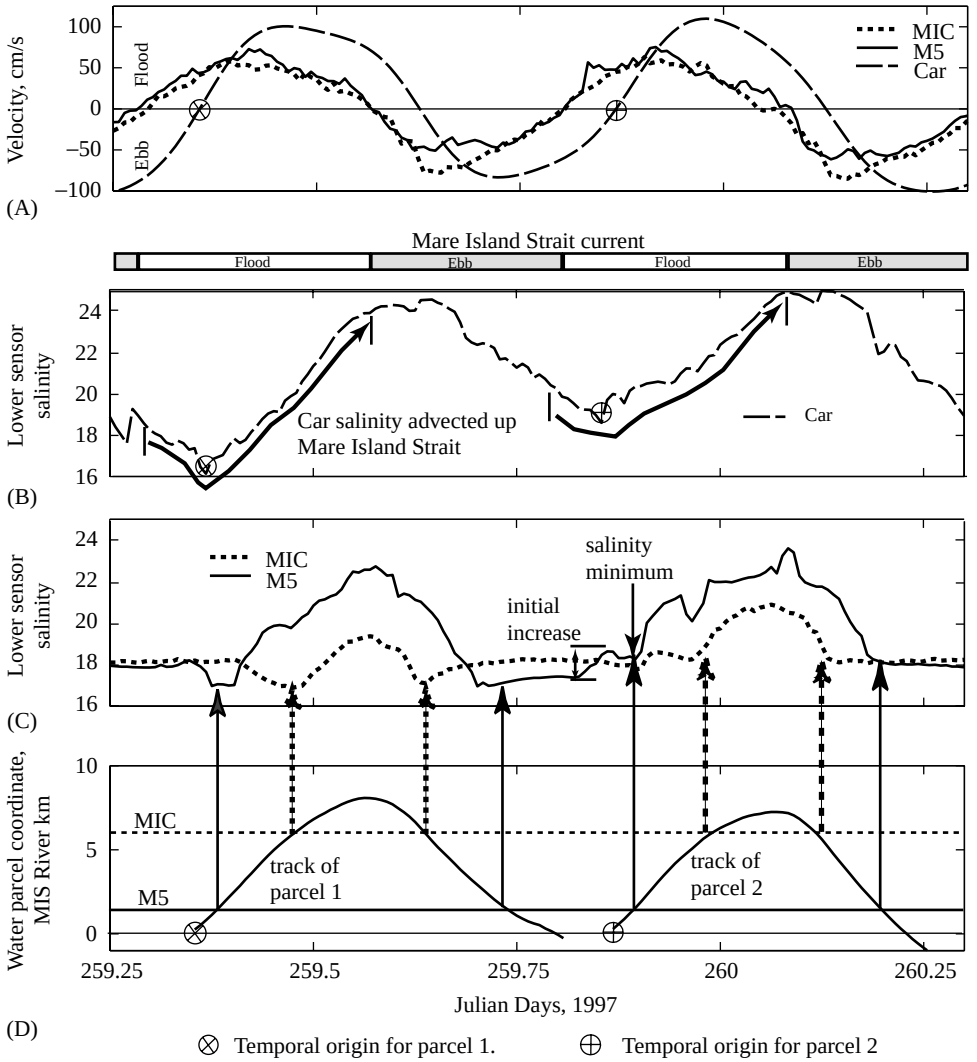

Fig. 4. Location of a water parcel tracking the local salinity minimum: (A) time series of velocity for sites MIC, M5, and Car; (B) time series of salinity from site Car; (C) time series of salinity for sites MIC and M5; and (D) the track of a parcel representing midpoint of salinity minimum. Arrows from panel d to c relate track of salinity minimum to observed time series of salinity.

initial increase in salinity in Mare Island Strait, followed by the salinity minimum. This feature is created by the diurnal inequality of the tidal regime and occurs after the higher low tide and, hence, after a shorter tidal excursion that reduces the advection of the salt field in Carquinez Strait. Larger tidal excursions occur during the tidal transition from higher high to the lower low tides and during spring tides that advect the salt field farther, enhancing the dissimilarity of salinity between the two straits.

Based on field observations, the ebb water from Mare Island Strait does not appear to influence the magnitude of salinity in Carquinez Strait. Carquinez Strait is approximately 1000 m wide and 25 m deep with surface currents that can exceed 1.5 m/s during spring tides. In contrast, Mare Island Strait is 300 m wide and 10 m deep with maximum spring

tidal currents of 0.80 m/s. The ratio of cross-sectional areas is on the order of 0.1. Salinity from site Car does not show any substantial variation that could be attributed to the ebb from Mare Island Strait. Additionally, during the first 2 h of the Mare Island Strait ebb, the salinity in the flood currents of Carquinez Strait continues to increase, contributing to the greater tidally averaged salinity in Carquinez Strait. Smith et al. (1991) show the complexity of the flow pattern at the junction due to both lateral and vertical variations in the current patterns. Therefore, the ebb water out of Mare Island Strait will be considered to fully mix with Carquinez Strait water.

4. Discussion

4.1. Tidal time scale

On a tidal time scale, the effect of the local salinity minimum is to enhance the vertical shear of the water column in Mare Island Strait. This effect is caused by the interaction of the fluctuating baroclinic gradient of the local salinity minimum with the unidirectional barotropic gradient during each phase of the tidal cycle. The influence of each of these components is best described by analyzing the vertical structure of the terms in the governing equations. The laterally averaged momentum equation in the x-direction is

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = -\frac{1}{\rho_0}\frac{\partial P}{\partial x} - \frac{1}{\rho_0}\frac{\partial \tau^{xz}}{\partial z}, \tag{1}$$

where $u(x,z,t)$ is the laterally averaged longitudinal velocity, t is time, ρ_0 is the reference density, $P(x,z,t)$ is pressure, $\tau^{xz}(x,z,t)$ is the horizontal shear stress, and z is the vertical coordinate, measured as positive upwards from the mean water surface. Because the along-channel bathymetric variations vary slowly in Mare Island Strait, the advective acceleration terms are weak and will be neglected. Vertical accelerations also are weak, so that the pressure can be reasonably assumed to be hydrostatic. The horizontal gradient of the pressure is obtained from integration of the z-momentum equation (assuming the horizontal density gradient to be invariant with depth) to obtain

$$\frac{\partial P_{z'}}{\partial x} = g(\eta - z')\frac{\partial \rho}{\partial x} + \rho_a g\frac{\partial \eta}{\partial x}, \tag{2}$$

where $\eta(x,t)$ is the displacement from the undisturbed (mean) water level at $z=0$, $\rho(x,z,t)$ is the density, and ρ_a is the water density at the surface. Combining these equations with the approximation that $\rho_0 \sim \rho_a$, and with the equation of state $\rho = \rho_0(1+\alpha s)$, where s = salinity, and α = coefficient of haline contraction (7.6×10^{-4}, Cushman-Roisin, 1994) yields

$$\frac{\partial u}{\partial t} = \underbrace{-\alpha g(\eta - z')\frac{\partial s}{\partial x}}_{\text{baroclinic}} \underbrace{- g\frac{\partial \eta}{\partial x}}_{\text{barotropic}} \underbrace{- \frac{1}{\rho_0}\frac{\partial \tau^{xz}}{\partial z}}_{\text{turbulent shear}}. \tag{3}$$

To scale the magnitude of these terms, the shear scales as ρu^{*2}, where the velocity u^* is assumed to be 0.1 times the depth-averaged mean tidal velocity $\langle u \rangle$ (Fischer et al., 1979). From sites M5 and MIC, time series of measured velocity, an estimate of $\langle u \rangle$ is 0.40 m/s, and using $\mathrm{d}z \sim 10$ m leads to a maximum size of the turbulent shear term to be on the order of $2\times10^{-4}\,\mathrm{m/s^2}$. To estimate the order of magnitude of the barotropic term, first water surface elevations were estimated from the difference between the measured depth time series and the low pass filter of the depth time series. Then the differences of water surface elevations from site M5 to MIC divided by a distance of 4 km yielded the barotropic term on the order of $2\times10^{-4}\,\mathrm{m/s^2}$. The baroclinic term has a maximum value at depth on the order of $5\times10^{-5}\,\mathrm{m/s^2}$, which is scaled by assuming a salinity gradient of $0.5\,\mathrm{km^{-1}}$, a typical value in San Francisco Bay (Jassby et al., 1995), and a depth of 10 m. This scaling shows a baroclinic-to-barotropic ratio of 0.25 on the tidal time scale, inferring the importance of the baroclinic term to the dynamic balance.

The interaction of the barotropic and baroclinic terms can create tidal asymmetry between the ebb and the flood (Jay, 1991). In an estuary, the baroclinic term typically is acting in one direction, heading landward. During the flood current, the barotropic term also is heading landward and these two terms typically will be additive and produce weaker shear throughout the water

column. During the ebb the two gradients are in opposition which enhances shear in water column. Fig. 5 is a schematic of Mare Island Strait that illustrates the longitudinal development of shear by the gradients. During the flood current, the baroclinic and barotropic gradients are negative and act together at two locations along the strait, creating a relatively weak shear in the water column (Figs. 5A, 1 and 3). However, the local salinity minimum is a region with a positive baroclinic gradient ($\partial\rho/\partial x =$ positive) that opposes the barotropic gradient, creating a relatively

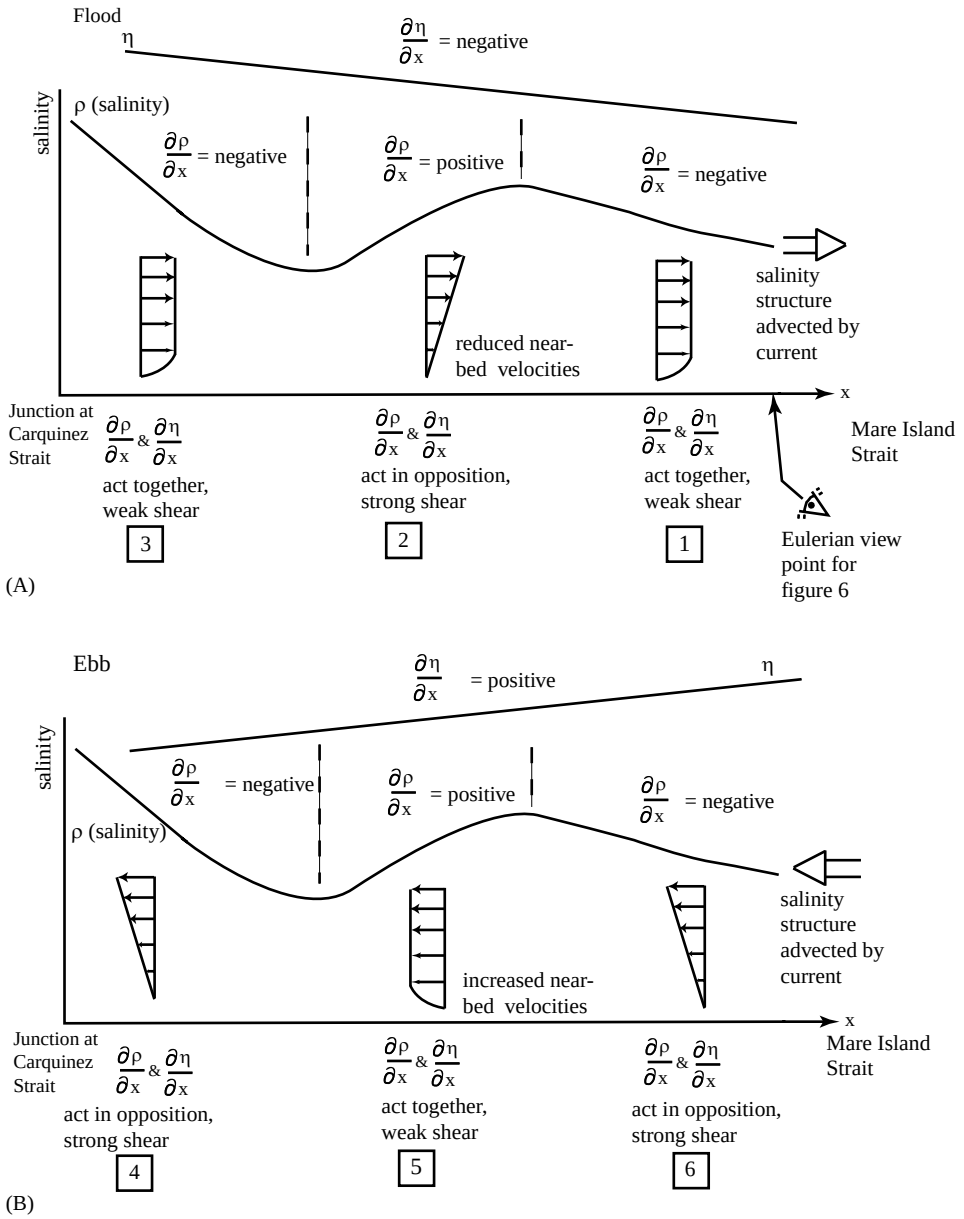

Fig. 5. Longitudinal profile of Mare Island Strait showing velocity structure created by interaction of baroclinic and barotropic pressure gradients during (A) flood, and (B), ebb current. Boxes labeled 1–6 correspond also with Fig. 6.

strong shear in the water column (Fig. 5A, 2). This region of strong shear reduces the near-bed velocities in the strait.

During the ebb current, the baroclinic gradient is negative and the barotropic gradient is positive at two locations along the strait (Fig. 5B, 4 and 6). As these gradients act in opposition, they create strong shear in the water column, as is typical in an estuary. Again, the salinity minimum structure contains a region with a positive baroclinic gradient ($\partial\rho/\partial x =$ positive), which acts together with the barotropic gradient, to create a region of weak shear (Fig. 5B, 5). This region of weak shear increases the near-bed velocities.

Using the Eulerian reference frame of the instrumentation, measured time series of velocity and salinity in Mare Island Strait from site MIC (Fig. 6) show the effects of changes in shear in the water column with the passage of the salinity minimum. A four day neap–spring transition period was selected to plot the shear in the water column (Fig. 6A) calculated as the surface minus the bottom velocity (top bin − bottom bin), with positive values for flood and negative for the ebb. The flood and ebb tides from 259.25 to 259.85 represent well the changing shear as the salinity minimum advects past the site. Times of greatest shear occur at labels 2 and 4, when the baroclinic

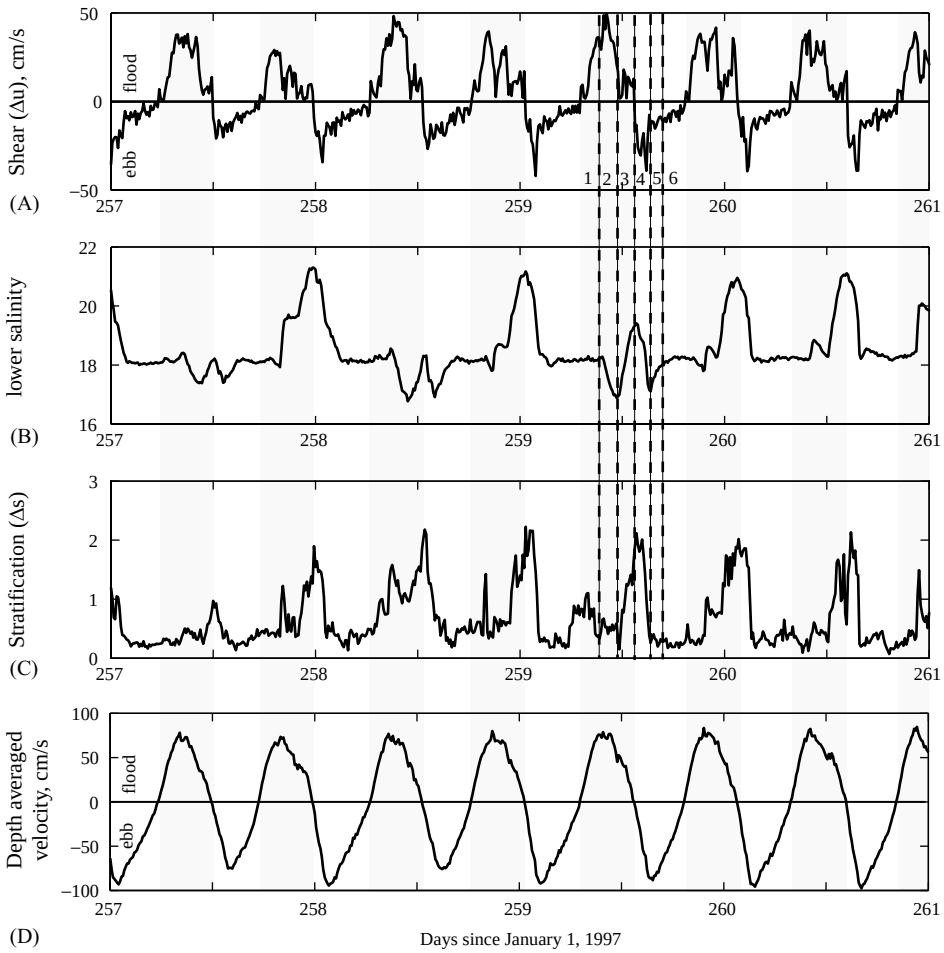

Fig. 6. Four day time series at site MIC: (A) shear in the water column calculated as top bin velocity minus lower bin velocity; (B) salinity from lower sensor; (C) stratification lower sensor minus upper sensor; and (D) depth averaged velocity.

and barotropic gradients act in opposing directions (corresponding labels in Figs. 5 and 6). Almost immediately after the baroclinic gradient changes directions (label 3 and label 5), the shear diminishes in the water column. This shows that by the time the salinity minimum advects from Carquinez Strait to site MIC, the shear stress in the water mass has adjusted to the new pressure gradient balance. Conceptually (as shown in Fig. 5) labels 1 and 3 develop similar shear, however, the actual baroclinic gradient in Mare Island Strait is near zero at the beginning of the flood and therefore label 1 shows more shear in the measured data (Fig. 6, label 1). Similarly, labels 4 and 6 conceptually have similar shear, however, the baroclinic gradient at the end of the ebb is near zero so there is less shear developed at label 6 (Fig. 6, label 6). At site MIC the reduction of the near-bed velocity during the flood and the increase in the near-bed velocity during the ebb leads to a tidally averaged near-bed velocity in the seaward direction.

Stratification at site MIC (Fig. 6C) is predominately characterized as well mixed throughout most of the tidal cycle with a period of stratification at the end of the flood. The stratification occurs when the pressure gradients act in the same direction, the shear in the water column is reduced, and turbulent mixing is weak (i.e. label 3). The shear during the initial phase of the ebb appears to create adequate mixing to remove the stratification because at the end of the ebb the water column is well mixed at both sites MIC and M5.

The strength of the shear scales with the magnitude of the salinity minimum. An initial dissimilarity between the salinity in Mare Island and Carquinez Strait (for example at day 259.85) tends to reduce the maximum shear that occurs in the water column. Additional field measurements are necessary to obtain closer spatial observations to better characterize the salt field and vertical shear dynamics in Mare Island Strait.

4.2. Tidally averaged time scale

On the tidal time scale, the local salinity minimum affects the shear in the water column that alters the tidally averaged flow pattern. Fig. 7 shows tidally averaged velocities for the upper and lower portions of the water column for sites M14, MIC, and M5 (panels B, C, and D), along with the discharge in the Napa River and hrmsf (panel A). Three representative time periods (1, 2, and 3) labeled in Fig. 7 are shown longitudinally in Fig. 8.

At time-period 1, the tidally averaged longitudinal density structure in Mare Island Strait consists of a local salinity minimum. At site M5, the tidally averaged velocity from the lower bin is directed upstream, and the tidally averaged velocity from the upper bin is directed downstream. This flow pattern is the classical structure of estuarine circulation (Figs. 7 and 8, time-period 1) that occurs because on a tidally averaged time scale, the salinity in Carquinez Strait (at the mouth of Mare Island Strait) is greater than the tidally averaged salinity in the mouth of Mare Island. However, as one travels further up Mare Island Strait, the influence of the salinity minimum structure is observed in the tidally averaged flow pattern. At site MIC, the tidally averaged, near-bed velocity is in the downstream direction with the tidally averaged, near-surface velocity fluctuating from upstream to downstream. Because site MIC near-bed velocities are tidally averaged downstream, and site M5 near-bed velocities are tidally averaged upstream, one obtains a convergence of near-bed velocities that are created by converging baroclinic pressure gradients. Thus, the location between sites M5 and MIC is termed a "baroclinic convergence zone". Site M14 is approximately 20 km upstream from the mouth of the river and this distance is beyond one tidal excursion from the mouth (approximately 10 km). Therefore, site M14 is not directly affected by the salinity minimum during each tide. Additionally, a low (approximately $1\,m^3/s$) freshwater inflow creates a weak longitudinal density gradient and site M14 exhibits a very minimal residual flow pattern. Time-period 1 represents a typical tidally averaged flow pattern from day 255 to 320.

On day 320, however, a small increase in freshwater inflow occurs in the Napa River. This buoyancy flux created a sufficiently strong

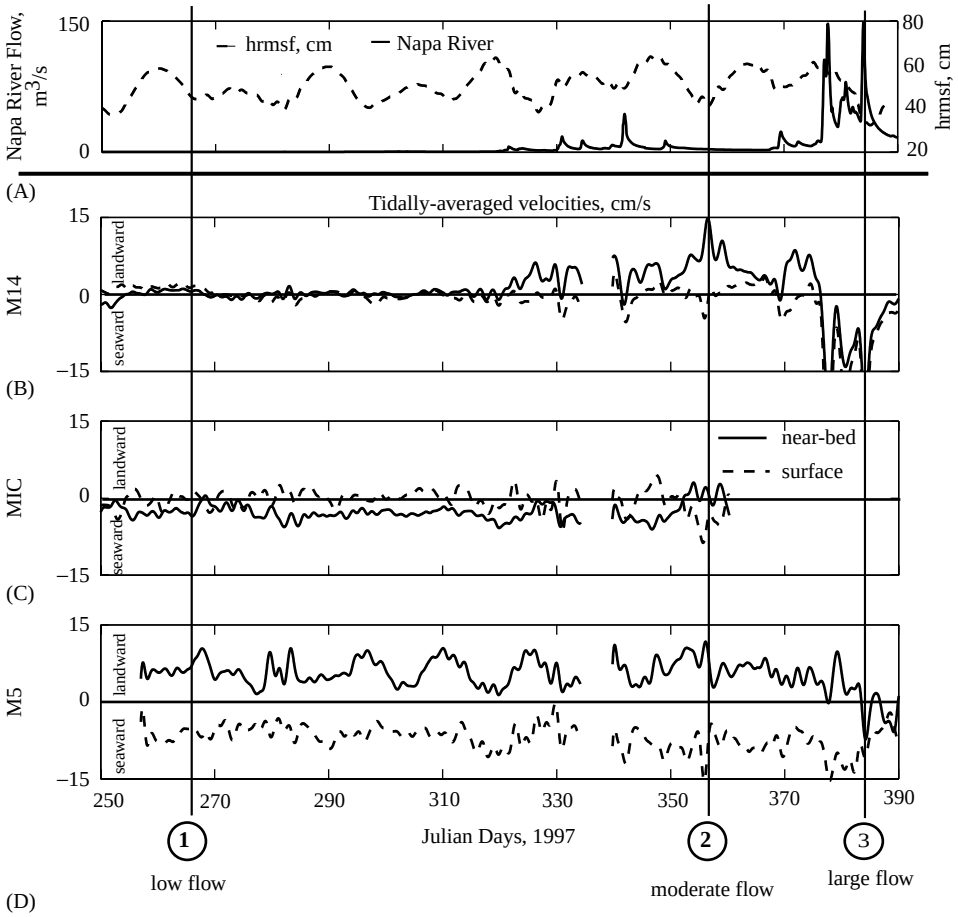

Fig. 7. Residual velocities: (A) discharge in the Napa River and hrmsf (=tidally averaged root mean square of the measured water level), and tidally averaged velocities from the top and bottom bins for sites; (B) M14; C, MIC; and D, M5. Profile lines 1, 2, and 3 refer to times of longitudinal plots in Fig. 8.

longitudinal density gradient at site M14 to produce a gravitational circulation residual current pattern (Figs. 7 and 8, time-period 2). As the freshwater inflow continued, the horizontal salinity gradient was finally pushed downstream to station MIC on day 355. This occurred during a neap tide, and a similar circulation pattern developed at MIC with upstream flow at the bottom and downstream at the surface. This circulation pattern lasted for approximately 8 days at site MIC producing a consistent flow pattern at all three sites.

Beyond Julian Day 380, the freshwater inflow increases and the salinity was temporarily washed out of Mare Island Strait (velocity record at site MIC nonrecoverable at that time). Then the residual flows throughout the strait became strictly barotropic (Figs. 7 and 8, time-period 3).

In summary, during periods of low freshwater inflow (time-period 1), a baroclinic convergence zone is created between sites M5 and MIC. However, during periods of increased freshwater inflows, an estuarine circulation pattern is established at sites M5, MIC, and M14 (time-period 2). During time periods of large, freshwater discharge, the residual velocities are downstream over the entire depth (time-period 3).

Tidally averaged suspended sediment fluxes from sites M14, MIC, and M5 are shown in Fig. 9 again with three representative time periods identified in

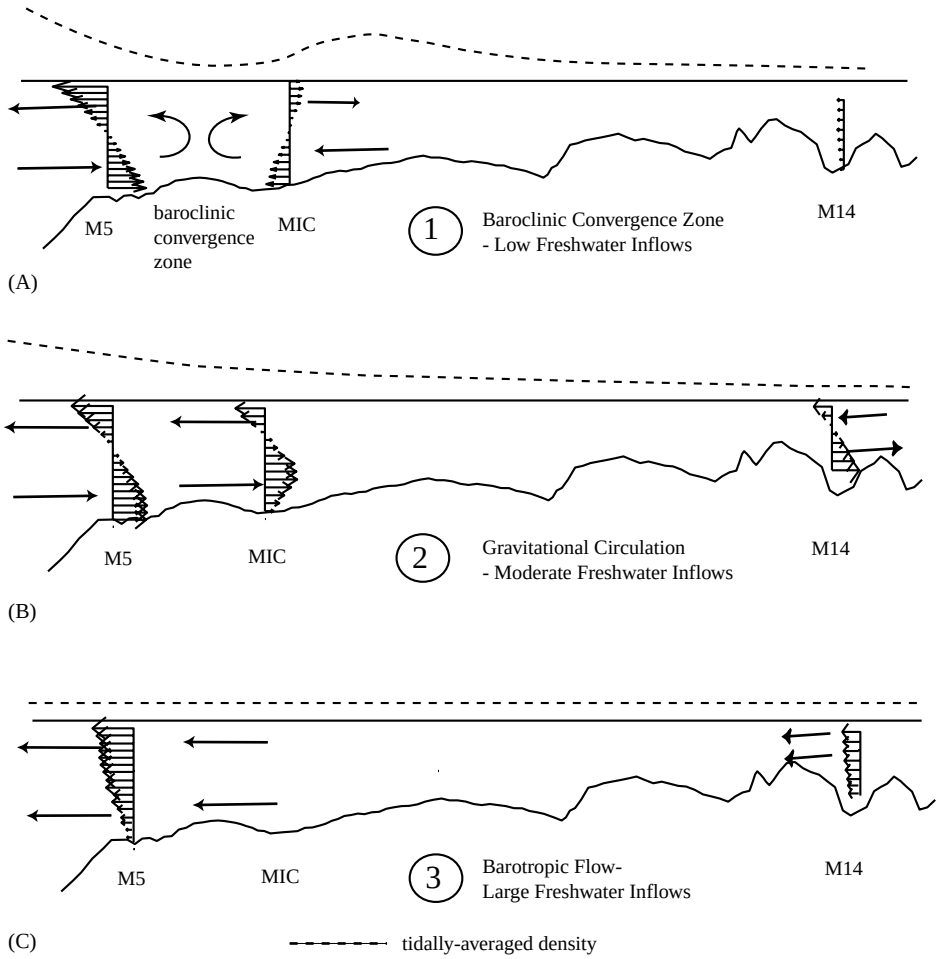

Fig. 8. Longitudinal profile of Napa River Bathymetry with vertical profiles of tidally averaged velocities and arrows showing residual circulation patterns for: (A) periods of very low freshwater inflows with baroclinic convergence zone; (B) increasing fresh water inflows with gravitational circulation; and (C) large freshwater inflows with barotropic flow. Longitudinal profiles 1, 2, and 3 refer to times in Fig. 7.

the figure. Measured time series of suspended sediment are non-continuous due to biological fouling and therefore the three representative time periods selected are different than in Fig. 7, however, the times represent similar flow magnitudes. For periods of low freshwater inflows (time-period 1) the flux of near bottom sediment is in the upstream direction at site M5 and in the downstream direction at site MIC. These converging sediment fluxes are attributed to the baroclinic convergence and will lead to enhanced deposition in Mare Island Strait. During periods of moderate freshwater discharge in the Napa River (time-period 2) the near-bed flux of sediment is upstream at all three sites responding to the estuarine circulation pattern. During high flow events (time-period 3) the sediment fluxes are downstream over the water column at all 3 sites, with peaks of sediment correlating to discharge peaks. These events occurred during barotropic flow.

5. Summary and conclusions

The monotonic increase in salinity from the head to the mouth of most estuaries creates a

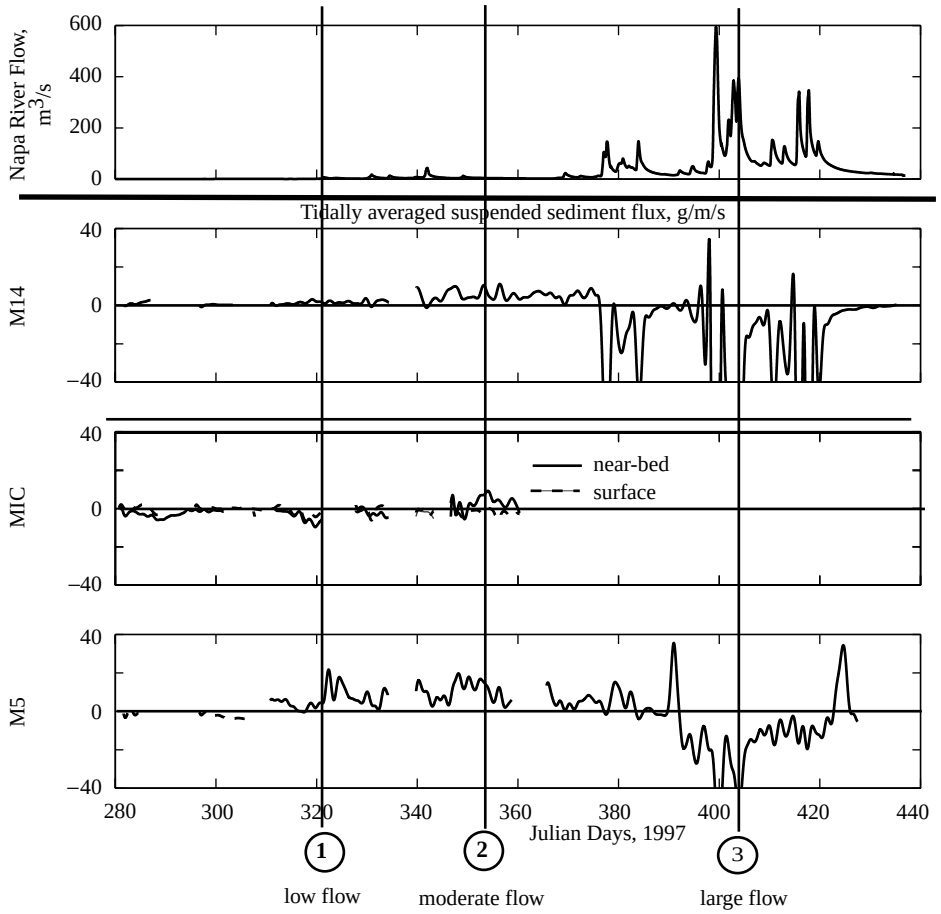

Fig. 9. Tidally averaged suspended sediment flux at sites: (A) M14; (B) MIC; and (C) M5.

residual flow pattern of estuarine circulation. However, physical processes can occur that alter the structure of the longitudinal density gradient, thus, creating different tidally averaged circulation patterns. The phasing of the currents at the junction of Mare Island and Carquinez Straits create a local salinity minimum in Mare Island Strait that alters the longitudinal density gradient. On a tidal time scale, the interaction of the baroclinic and barotropic pressure gradients affects the shear in the water column. On a tidally averaged time scale, the salinity minimum is a focus of converging baroclinic pressure gradients that drive a circulation pattern of converging near-bed velocities and diverging surface currents, termed a "baroclinic convergence zone". This convergence, together with a local supply of suspended sediment, probably account for the exceptional rates of sediment accumulation historically observed in Mare Island Strait.

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MODELING METAL BIOACCUMULATION AND TISSUE DISTRIBUTION IN KILLIFISH (*FUNDULUS HETEROCLITUS*) IN THREE CONTAMINATED ESTUARIES

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(Submitted 22 May 2013; Returned for Revision 23 June 2013; Accepted 8 September 2013)

Abstract: The present study experimentally assessed the uptake, loss, and resulting tissue distribution of As(V), Cd, Cr(III), Hg(II), and methylmercury (MeHg) in killifish (*Fundulus heteroclitus*) following aqueous exposure in water collected from 3 contaminated field sites—Baltimore Harbor and Elizabeth River (Chesapeake Bay), and Mare Island (San Francisco Bay)—using a radiotracer technique. Uptake rate constants ($L\,g^{-1}\,d^{-1}$) were highest for MeHg (0.370–0.781) and lowest for As (0.00028–0.00065). Loss rate constants (d^{-1}) were highest for As (0.046–0.096) and lowest for MeHg (0.006–0.009). Tissue distribution data showed that MeHg was redistributed around the body throughout the 9-d depuration period, and drinking may be an uptake mechanism for Cd from the aqueous phase in higher-salinity water. The kinetic parameters calculated in the present study were entered into a bioaccumulation model to calculate the predicted body burden of each metal at steady state and the percentage body burden attributable to dietary exposure on a site-specific basis. Calculated body burdens varied between field sites for all metals except Cr. The predicted values for Cd, Hg(II), and MeHg matched independent field data from contaminated estuaries, indicating that the model can account for the major processes governing metal concentration in killifish. The diet accounted for >97% of the body burden of Cd and MeHg and was the predominant exposure route for As and Cr. *Environ Toxicol Chem* 2014;33:89–101. © 2013 SETAC

Keywords: Metal uptake Bioavailability Metal accumulation Tissue distribution Biokinetic modeling

INTRODUCTION

Industrialized coastal estuaries have elevated levels of metals in sediment and water caused by anthropogenic activities, resulting in increased metal body burdens in estuarine organisms [1]. Methylmercury is of particular concern because it is highly toxic, can be biomagnified in aquatic food chains, and is found at elevated concentrations in a broad spectrum of marine and estuarine fish and shellfish that are regularly consumed as seafood [2], potentially posing a risk to human health.

Fish are exposed to metals through dietary and aqueous pathways, although studies have shown that diet is the dominant uptake route for most metals [3–5]. Various factors including prey choice and ingestion rate influence the assimilation efficiency (defined as the percentage of ingested metal that crosses the gut lining) and therefore dietary uptake of metal in fish; but the importance of the aqueous uptake pathway should not be overlooked. If the ingestion rate of the fish is low, the assimilation efficiency of ingested prey is low; or if the concentration of metal in the prey is low, then the aqueous phase could become an important uptake route. The bioavailability of aqueous metals to fish is predominantly influenced by the salinity and dissolved organic matter (DOM) concentration in the water. Salinity influences metal bioavailability as a result of chloro-complexation of the metal ion [6], whereas DOM can either decrease or enhance metal uptake into fish, depending on the composition of the DOM and the metal [7].

The distribution of metals in fish tissues following dietary and aqueous exposure remains poorly understood. Previous studies have attempted to characterize the tissue distribution of metals following uptake or after a depuration period [3,5–7], and these distributions are normally non–tissue-specific (e.g., head, viscera, and body). To provide a better understanding of the dynamics of metal redistribution between fish tissues, dissections need to be tissue-specific and carried out throughout the depuration period to enable calculations of metal efflux or influx rates for different tissues.

Killifish (*Fundulus heteroclitus*), a ubiquitous, small forage fish found in estuaries, bays, and salt marshes along the eastern seaboard of the United States from the Gulf of St. Lawrence to northeastern Florida [8], can be used as a model organism to investigate metal accumulation and tissue distribution. Killifish are a useful regional bioindicator of heavy metal contamination because they are euryhaline, have a limited swimming range, and show varying susceptibilities to aquatic contaminants [8].

To further understand the influence of salinity and dissolved organic carbon (DOC) on metal uptake and loss from the aqueous phase in natural waters and model metal bioaccumulation, we exposed killifish to 3 metals—Cd, Cr(III), and Hg (as Hg[II] and methylmercury [MeHg])—and 1 metalloid, As(V), in water collected from 3 contaminated field sites with varying salinity and DOC concentration: 2 in the Chesapeake Bay (Baltimore Harbor and Elizabeth River) and 1 in San Francisco Bay (Mare Island). The uptake and loss of each metal were monitored using gamma-emitting radioisotopes, and uptake rate constants (k_us) and loss rate constants (k_{ew}s) were calculated for each metal on a site-specific basis. The tissue distribution of each metal was determined at the end of depuration for all 3 field sites; however, to investigate how each metal is redistributed around the body over a 9-d period following aqueous exposure, fish in Baltimore Harbor were dissected regularly throughout depuration to calculate the efflux or influx rate constant for each tissue compartment and the corresponding biological half-life of each metal. Calculated kinetic parameters describing metal accumulation from water (k_u, k_{ew}; the present study) were entered into a bioaccumulation model [9], with the assimilation efficiency and loss rate constant after dietary

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exposure (k_{ef}) calculated in a prior study [10], to determine the steady-state metal concentration in killifish and the primary uptake route for each metal at each field site.

All metals were chosen because they are on the list of US Environmental Protection Agency priority pollutants and are found at elevated concentrations in coastal waters, particularly those near large population centers and industrial activity. All of these metals are of environmental interest because of their potential impact on the health of aquatic ecosystems and the associated risk to humans from consuming contaminated seafood. Cadmium and Hg are known to chloro-complex, whereas As and Cr do not [11]. Cadmium and Hg are present as cations in solution, whereas As and Cr are present as oxyanions.

MATERIALS AND METHODS

Water and experimental conditions

Experiments were conducted using 0.2 μm sterile-filtered (Millipak 200; Millipore) water collected from 3 contaminated field sites: Baltimore Harbor (Baltimore, MD, USA; 39°12′25″N, 76°31′41″W), Elizabeth River (Norfolk, VA, USA; 36°12′32″N, 76°20′09″W), and Mare Island (Vallejo, CA, USA; 38°04′23″N, 122°14′91″W). Water was collected from a 2-m depth using a trace metal clean pump. Water parameters (salinity, chloride ion concentration, DOC concentration, and pH) are shown in Table 1. The chloride ion concentration was measured using a Dionex DX-500 ion chromatograph with an IonPac AS4A-SC anion-exchange column and sodium carbonate/bicarbonate eluent, and the DOC concentration was measured using a Shimadzu TOC-5000 total organic carbon analyzer. Filtered water from each field site was analyzed for background metal levels (concentration of metal in the water before addition of the radioisotope) by the Trace Element Analysis Core Laboratory at Dartmouth College (total Hg) and the Inorganic Analytical Core Laboratory at Rutgers University (As, Cd, and Cr) using inductively coupled plasma mass spectrometry (ICP-MS), and the results are shown in Table 1. All experiments were held at 18 ± 0.5 °C on a 14:10-h light:dark cycle.

Fish

Field-collected killifish, *F. heteroclitus* (Taylor River, Hampton, NH, USA; salinity = 25–30 ppt, mean wet wt = 1.95 g ± 0.35 standard deviation [SD]), purchased from Aquatic Research Organisms, were used in the present study. Fish were acclimated to experimental conditions for at least 2 wk prior to the start of experiments and fed a daily diet of bloodworms or brine shrimp and TetraCichlid cichlid flakes (TetraHolding). Prior to the start of experiments, fish were starved for 36 h to purge their gut of any remaining food, and the fish were not fed during the metal-uptake portion of the experiment; therefore, metal uptake was from only the aqueous phase.

Metal uptake, depuration, and tissue distribution from the aqueous phase

Radiolabeled water (250 mL) from each field site was poured into individual containers and left to equilibrate for several hours. Per 250 mL, each fish was exposed to 23 kBq to 38 kBq ^{73}As, 10 kBq to 14 kBq ^{109}Cd, 33 kBq to 38 kBq ^{51}Cr, 1.9 kBq to 9.6 kBq ^{203}Hg(II), and 1.1 kBq to 1.3 kBq MeHg. This equates to the addition of the following metal concentrations: 0.27 nM to 1.06 nM ^{73}As (Baltimore Harbor = 0.27 nM, Elizabeth River = 1.06 nM, Mare Island = 0.34 nM), 0.45 nM ^{109}Cd, 0.27 nM to 0.85 nM ^{51}Cr (Baltimore Harbor = 0.27 nM, Elizabeth River = 0.43 nM, Mare Island = 0.85 nM), 0.01 nM to 0.03 nM ^{203}Hg(II) (Baltimore Harbor and Elizabeth River = 0.01 nM, Mare Island = 0.03 nM), and 0.13 nM MeHg. Concentrations for each metal varied between field sites because of the radioactive decay of the radioisotopes between experiments. Methylmercury, ^{109}Cd, and ^{203}Hg(II) were single-labeled, whereas ^{73}As and ^{51}Cr were added together because the gamma emissions of these isotopes did not interfere with each other.

After radioisotope equilibration, 1 fish was added per container and uptake was monitored at regular intervals for 36 h to 37 h ($n = 8$ for Elizabeth River and Mare Island, $n = 25$ for Baltimore Harbor). This time period was chosen to allow sufficient time to radiolabel the fish while minimizing the risk of excessive metal loss from the fish throughout the uptake period. At each sample time throughout the uptake period, fish were removed from their container, rinsed twice with unlabeled site water to remove excess radioisotope adhering to the body surface, and radioassayed. A 1-mL water sample was also collected at each sample time and radioassayed to allow for calculations of concentration factors and uptake rate constants in the fish for each metal and field location. No fish showed adverse health effects (death, abnormal swimming behavior, excess mucus production, or not feeding during depuration) from the experimental procedure.

At the end of metal uptake, fish were radioassayed and returned to individual containers with 600 mL unlabeled water from the same field site, fed unlabeled bloodworms, and allowed to depurate for 9 d. To monitor metal loss, fish were regularly radioassayed for the first 2 d of depuration and then once a day for the remaining 7 d. Water was changed after 1 d and then every other day. At the end of the 9-d depuration period fish in Elizabeth River and Mare Island water were killed using tricaine methanesulfonate (MS-222); dissected into the head, gill, viscera, and body (skeleton, axial musculature [muscle], and skin); radioassayed; and dried at 60 °C for 48 h to calculate dry tissue weights. To investigate how the body distribution of each metal changed over 9 d following exposure to aqueous metals, 5 fish in Baltimore Harbor water were killed at the end of uptake and after 1 d, 3 d, 6 d, and 9 d of depuration. The head,

Table 1. Salinity, chloride ion concentration, dissolved organic carbon concentration, pH, and background metal concentrations for Baltimore Harbor, Elizabeth River, and Mare Island water[a]

					C_w				
Site	Salinity (ppt)	Chloride (mM)	DOC (mg L)	pH	As (μg L^{-1})	Cd (μg L^{-1})	Cr (μg L^{-1})	Hg(II) (ng L^{-1})	MeHg (ng L^{-1})
BH	7.6	161 ± 0.2	2.6 ± 0.3	7.56	0.97	0.24	0.19	2.81	0.09
ER	19.5	415 ± 0.5	4.6 ± 0.04	7.45	1.38	0.21	0.25	3.30	0.10
MI	22	447 ± 0.6	2.0 ± 0.1	7.76	2.20	0.19	0.20	2.62	0.08

[a] For chloride ion concentration and DOC concentration, values represent means ± 1 standard deviation, $n = 3$.
BH = Baltimore Harbor; ER = Elizabeth River; MI = Mare Island; DOC = dissolved organic carbon; C_w = background metal concentration; MeHg = methylmercury.

gills, brain, eyes, viscera (excluding liver), liver, skeleton (including fins), muscle, and skin were dissected, radioassayed, and dried to obtain dry weights. Efflux or influx rates of metals in individual fish tissues were calculated by converting the mean radioactivity concentration in each fish tissue between day 1 and day 9 of depuration into percentage retained and conducting a linear regression analysis; the resulting slope was the efflux or influx rate.

One-way analysis of variance and Tukey post hoc tests were used to determine significant differences ($p < 0.05$ or $p < 0.01$) between kinetic parameters (k_u, k_{ew}) and field site. All statistical analyses were conducted using IBM SPSS statistics software (Ver 21).

Radioisotopes and radioanalyses

Microliter quantities of high–specific activity radioisotopes (1221–7844 kBq μg^{-1} ^{73}As, 814–1110 kBq μg^{-1} ^{109}Cd, 3071–6808 kBq μg^{-1} ^{51}Cr, 1369–15,318 kBq μg^{-1} ^{203}Hg[II], and 163–196 kBq μg^{-1} MeHg) were used in the present study. ^{73}Arsenic ($t_{½} = 80.3$ d, as As[V]) and ^{109}Cd ($t_{½} = 462.6$ d), both dissolved in 0.1 M HCl, were purchased from Los Alamos National Laboratory; ^{51}Cr ($t_{½} = 27.7$ d, as Cr[III], dissolved in 0.5 M HCl) was purchased from PerkinElmer; and ^{203}Hg ($t_{½} = 46.6$ d, as Hg[II], dissolved in 1 M HCl) was obtained from Georgia State University. Methylmercury ($CH_3{}^{203}Hg[II]$) was synthesized in our laboratory using a procedure described elsewhere [12] and held in deionized water. After adding the radioisotopes to experimental water, an equimolar concentration of sodium hydroxide was added to neutralize the acid, after which the pH was checked; it remained unchanged.

Killifish were radioassayed noninvasively in 30 mL non-radiolabeled site water using a Canberra deep-well NaI(Tl) gamma-detector for no longer than 5 min to reduce stress on the fish; this allows the same fish to be monitored throughout metal uptake and depuration, therefore reducing biological variability. The propagated counting errors were ≤5%, except for As and Cr where propagated counting errors could reach 25% because of low uptake of the radioisotopes. Water and dissected fish tissue were radioassayed for 5 min using an intercalibrated LKB Pharmacia-Wallac 1282-CompuGamma CS gamma-counter. All sample counts were corrected for background radioactivity and radioactive decay. The gamma-emissions of ^{109}Cd, ^{73}As, ^{203}Hg, and ^{51}Cr were detected at 22 keV, 53 keV, 279 keV, and 320 keV, respectively.

Modeling metal bioaccumulation in killifish

Metal bioaccumulation in killifish can be evaluated using a biokinetic model [9], which takes into account metal uptake and loss from aqueous and dietary sources and has been successfully tested using fish [3–5]. Under steady-state conditions

$$C_{ss} = [(k_u \times C_w)/(g + k_{ew})] + [(AE \times IR \times C_f)/(g + k_{ef})] \quad (1)$$

where C_{ss} is the steady-state concentration of metal in killifish ($\mu g\, g^{-1}$ dry wt), k_u is the uptake rate constant of metal from the dissolved phase ($L\, g^{-1}\, d^{-1}$), C_w is the background metal concentration in water ($\mu g\, L^{-1}$), g is the growth rate constant (d^{-1}), k_{ew} is the metal efflux rate constant after aqueous exposure (d^{-1}), AE is the assimilation efficiency of ingested metal in killifish (percentage as fraction), IR is the killifish ingestion rate ($g\, g^{-1}\, d^{-1}$), C_f is the metal concentration in prey ($\mu g\, g^{-1}$), and k_{ef} is the metal efflux rate constant after dietary exposure (d^{-1}).

Concentration factors were calculated by dividing the disintegrations per minute (dpm) per gram dry weight in fish by the dpm in 1 mL of water. Dry weight concentration factors can be converted to wet weight concentration factors by dividing by 4 (dry weight is approximately 25% of wet wt). Uptake rate constants of metal from the dissolved phase (k_u) were calculated as the slope of regressions for each metal and field site relating dpm per gram dry weight in fish divided by dpm in 1 L of water against time. For the model, k_u values were calculated between the 1-h and 13-h uptake time points for As, the 1-h and 25-h points for Cr, the 10.5-h and 37-h points for Hg(II), and the 1-h and 37-h points for Cd and MeHg. Efflux rate constants following aqueous exposure (k_{ew}) were calculated by fitting an exponential regression between the 2-d and 9-d depuration time points; the k_{ew} was the slope of the curve. For Baltimore Harbor, k_{ew}s were calculated only for fish that were killed at the end of 9 d.

In our model calculations, metal assimilation efficiency and k_{ef} values for killifish after feeding on amphipods in Baltimore Harbor water were taken from a prior study [10] and are as follows: assimilation efficiency, As = 9.4%, Cd = 4.5%, Cr = 0.2%, Hg(II) = 14%, MeHg = 92%; and k_{ef}, As = 0.287 d^{-1}, Cd = 0.064 d^{-1}, Hg(II) = 0.131 d^{-1}, MeHg = 0.008 d^{-1}. The Cr k_{ef} after feeding on amphipods was not determined because of near complete elimination of the radioisotope, so we applied a k_{ef} value for Cr in killifish after feeding on worms (0.064 d^{-1}) [10]. We applied an ingestion rate of 0.1 $g\, g^{-1}\, d^{-1}$ (dry wt) [13] and a growth rate of 0.005 d^{-1} [14].

Background metal concentrations in experimental waters (C_w) are shown in Table 1. The total Hg background values were 2.9 ng L^{-1} for Baltimore Harbor, 3.4 ng L^{-1} for Elizabeth River, and 2.7 ng L^{-1} for Mare Island; speciation of total Hg into Hg(II) and MeHg was determined assuming that 3% of Hg in marine waters is present as MeHg [15]. The C_f values for crustacean zooplankton prey (dry wt) were calculated by multiplying the C_w by the concentration factor of each metal in zooplankton; for Cr, the concentration factor was 6670 (assuming zooplankton dry wt is 15% of wet wt) [16]; and for As and Cd, the concentration factor was calculated by dividing the body burden of As and Cd in *Leptocheirus plumulosus* (0.85 $\mu g\, g^{-1}$ and 6.74 $\mu g\, g^{-1}$ dry wt, respectively) [17] by the C_w for Elizabeth River water, resulting in concentration factors of 615 for As and 32 000 for Cd. Inorganic Hg and MeHg zooplankton concentration factors (3820 and 366 700, respectively) were calculated using water and organism values from a prior study [15], assuming that 75% of Hg in crustacean zooplankton is present as MeHg [18].

To understand the relative importance of dietary and dissolved exposure routes, Equation 1 can be rearranged to calculate the percentage of C_{ss} that is attributed to dietary exposure (R)

$$R = ([(AE \times IR \times C_f)/(g + k_{ef})]/C_{ss}) \times 100 \quad (2)$$

To understand how long it takes for each metal to be excreted from the whole fish or individual tissue compartments after exposure to aqueous metal, the biological half-life ($tb_{½}$) can be calculated

$$tb_{1/2} = \ln 2/k_e \quad (3)$$

Assuming it takes 7 half-lives for >99% of the metal to be released from the whole fish or individual tissue compartments, the biological residence time for each metal can be calculated.

RESULTS

Metal uptake from the aqueous phase

Figure 1 shows the accumulation of As, Cd, Cr, Hg(II), and MeHg in killifish throughout the 37-h uptake period in experimental waters. To facilitate comparisons among metals, uptake over time is expressed as a dry weight concentration factor. For all metals and field sites, metal uptake was greatest during the first hour of exposure and then slowed throughout the remaining uptake period, except for Hg(II) in Mare Island water, which experienced the greatest uptake between 13 h and 37 h of exposure. While metal uptake slowed through the exposure period for most metals, concentration factors for Cd, Hg(II), and MeHg continued to slowly increase throughout the exposure period, whereas those for As and Cr began to approach steady state (except As in Mare Island water and Cr in Baltimore Harbor water). Cadmium, Cr, and MeHg accumulation was highest in Baltimore Harbor water, whereas As accumulation was highest in Elizabeth River water and Hg(II) accumulation was highest in Mare Island water at the end of the 37-h exposure period. When comparing the 2 Hg species, killifish in all 3 field-collected waters accumulated more MeHg than Hg(II) at the end of 37 h (Baltimore Harbor = 21.5 times, Elizabeth River = 15.4 times, and Mare Island = 2.5 times). Less than 1% of dissolved As, Cd, and Cr was removed from the water by the fish at the end of the 37-h exposure, whereas <28% of Hg(II) and 36% to 83% of MeHg was removed.

Throughout the uptake period concentration factors were highest for MeHg, followed by Hg(II), Cd, and Cr, with the lowest for As (Figure 1). Inorganic Hg and MeHg concentration factors were >1 throughout the uptake period, indicating that fish were more enriched in the metal than the experimental water, whereas As concentration factors were <1 for all field-collected waters. Figure 2 shows that Cd and MeHg accumulation had an inverse relationship with salinity, As accumulation increased with increasing salinity, and Cr accumulation showed no relationship with salinity. Inorganic Hg concentration factors were similar at 7.6 ppt (Baltimore Harbor) and 19.5 ppt

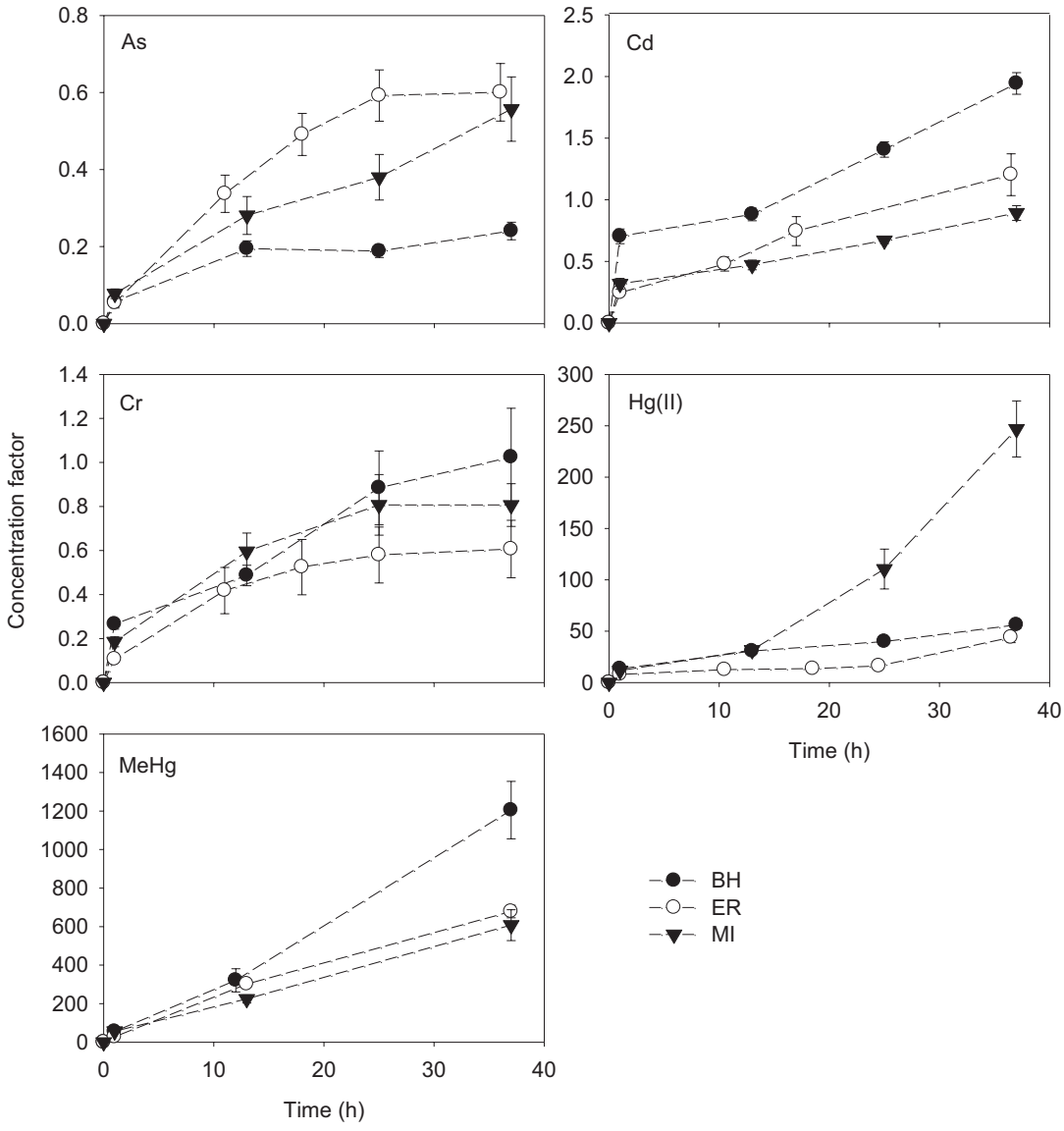

Figure 1. Accumulation of aqueous As, Cd, Cr, Hg(II), and methylmercury (MeHg) (as dry wt concentration factor) over a 37-h uptake period in killifish (*Fundulus heteroclitus*) in Baltimore Harbor (BH), Elizabeth River (ER), and Mare Island (MI) water. Values represent mean ± 1 standard error; $n = 8$ for Elizabeth River and Mare Island, $n = 25$ for Baltimore Harbor.

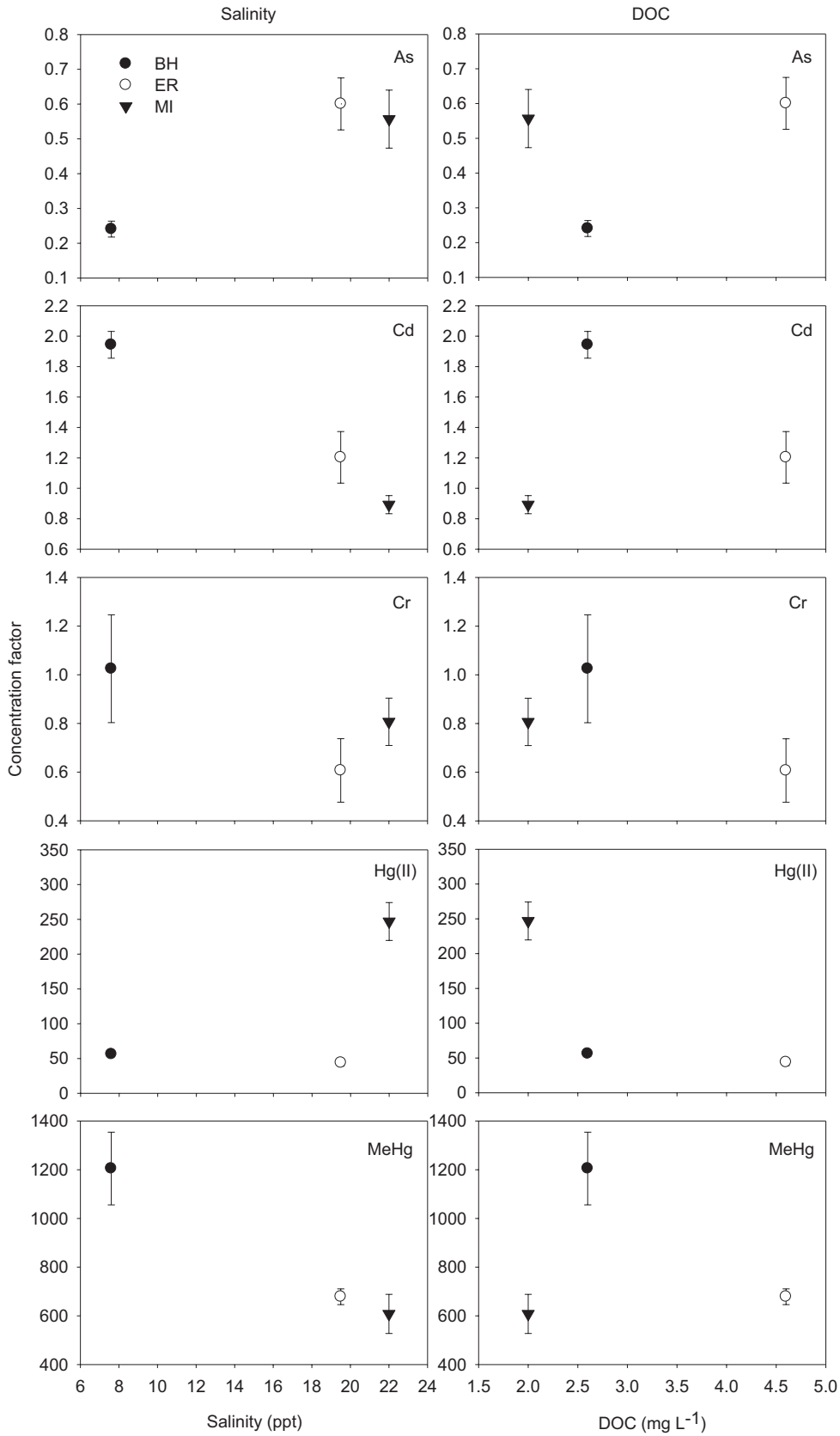

Figure 2. Metal concentration factors as a function of salinity and dissolved organic carbon (DOC) concentration in killifish (*Fundulus heteroclitus*) after 37-h exposure in Baltimore Harbor, Elizabeth River, and Mare Island water. Salinity and DOC concentration values are found in Table 1. Values represent mean ± 1 standard error; $n = 8$ for Elizabeth River and Mare Island, $n = 25$ for Baltimore Harbor. MeHg = methylmercury.

(Elizabeth River) (concentration factors = 40–44) and increased to 247 at 22 ppt. Of all the investigated metals, Hg(II) was the only one to show a relationship between metal accumulation and DOC concentration: as DOC concentration increased, Hg(II) accumulation decreased (Figure 2).

Table 2 shows the k_u ($L\,g^{-1}\,d^{-1}$) for each metal and field-collected water. Uptake rate constants were highest for MeHg (0.370–0.781), followed by Hg(II) (0.026–0.215), and lowest but comparable for Cd, Cr, and As (0.00039–0.00085, 0.00047–0.00063, and 0.00028–0.00065, respectively). The k_us did not vary significantly between field sites for Cr ($p > 0.05$) but did vary for As ($p < 0.01$; Baltimore Harbor vs Elizabeth River), Cd ($p < 0.01$; Baltimore Harbor vs Mare Island), Hg(II) ($p < 0.01$; Baltimore Harbor vs Mare Island, Elizabeth River vs Mare Island), and MeHg ($p < 0.05$; Baltimore Harbor vs Mare Island).

Metal retention and elimination after aqueous exposure

Figure 3 shows the loss of metals from killifish over 9 d following aqueous exposure in water collected from the 3 field sites. All metals in all field-collected waters showed the most rapid elimination of metal within the first several hours of depuration and a slower physiological turnover throughout the remaining 8 d. Efflux rate constants (d^{-1}) were highest for As and Cr (0.046–0.096 and 0.045–0.075, respectively) and lowest for MeHg (0.006–0.009) (Table 2). The k_{ew}s did not vary significantly between field sites for Cd and Cr ($p > 0.05$) but did vary for As ($p < 0.01$; Baltimore Harbor vs Elizabeth River), Hg(II) ($p < 0.01$, Baltimore Harbor vs Elizabeth River; $p < 0.05$, Baltimore Harbor vs Mare Island), and MeHg ($p < 0.05$; Baltimore Harbor vs Elizabeth River).

The biological half-lives ($tb_{½}$; d) of metals in whole fish following aqueous exposure were highest for MeHg (77–116) and lowest for Cr (9.2–15) and As (7.2–15) (Table 2). Assuming it takes 7 half-lives for all metal to be excreted from the killifish, the residence times are as follows: 539 d to 809 d for MeHg, 194 d to 323 d for Cd, 105 d to 211 d for Hg(II), 65 d to 108 d for Cr, and 51 d to 105 d for As.

Tissue distribution and radioactivity concentrations after aqueous exposure

Table 3 shows the tissue distribution, as a percentage of total body burden, at the end of 9-d depuration for each field location. Cadmium was predominantly associated with the gills (45%–60%); As, Hg(II), and MeHg were predominantly associated with the body (44–66%, 40–47%, and 57–58%, respectively); and Cr was split between the head (22–54%) and body (30–45%). Inorganic Hg and MeHg showed similar tissue distribution between the 3 field sites, whereas As, Cd, and Cr did not. In higher-salinity waters (Elizabeth River, Mare Island) the percentage of Cd associated with the gills was lower and the percentage of Cd associated with the viscera was higher than in lower-salinity water (Baltimore Harbor). The percentage of Cr associated with the head decreased and that associated with the viscera and body increased as the DOC concentration in the water increased (Elizabeth River > Baltimore Harbor > Mare Island). The percentage of As associated with the gills was greatest in the highest-DOC water (Elizabeth River) and that associated with the body decreased as DOC concentration increased. Radioactivity concentrations of each metal in fish were not calculated at the end of 9-d depuration for each field site because fish were exposed to varying radioactivity concentrations throughout uptake and therefore cannot be compared.

Table 4 shows the movement of metals between tissue compartments, as a percentage of total body burden, throughout the 9-d depuration period after exposure to aqueous metals in Baltimore Harbor water. Throughout depuration, Cr and Hg(II)

Table 2. Uptake rate constants, efflux rate constants, and corresponding biological half-lives in killifish after aqueous exposure to metals in Baltimore Harbor, Elizabeth River, and Mare Island water[a]

		k_u ($L\,g^{-1}\,d^{-1}$)			k_{ew} (d^{-1})			
Metal	Site	Mean	SE	Range	Mean	SE	Range	$tb_{½}$ (d)
As								
	BH	0.00028**	0.00003	0.000034–0.00085	0.096**	0.022	0.037–0.147	7.2
	ER	0.00065**	0.00007	0.00027–0.00093	0.046**	0.003	0.032–0.057	15
	MI	0.00041	0.00010	0.00012–0.0010	0.062	0.005	0.031–0.079	11
Cd								
	BH	0.00085**	0.00005	0.00037–0.0015	0.025	0.009	0.007–0.056	28
	ER	0.00065	0.00011	0.00038–0.0013	0.015	0.002	0.007–0.027	46
	MI	0.00039**	0.00004	0.00019–0.00052	0.016	0.001	0.011–0.020	43
Cr								
	BH	0.00062	0.00016	0.00016–0.0041	0.075	0.008	0.055–0.096	9.2
	ER	0.00047	0.00013	0.00021–0.0013	0.046	0.011	0.007–0.085	15
	MI	0.00063	0.00014	0.00038–0.0016	0.045	0.009	0.015–0.096	15
Hg(II)								
	BH	0.026[b]	0.002	0.010–0.052	0.046[c]	0.002	0.040–0.052	15
	ER	0.030[b]	0.003	0.019–0.043	0.023[c]	0.001	0.019–0.028	30
	MI	0.215[b]	0.026	0.073–0.307	0.037[c]	0.002	0.025–0.046	19
MeHg								
	BH	0.781*	0.096	0.268–2.025	0.006*	0.001	0.003–0.009	116
	ER	0.426	0.023	0.338–0.547	0.009*	0.001	0.005–0.013	77
	MI	0.370*	0.056	0.201–0.643	0.009	0.001	0.007–0.012	77

[a] Values represent means ± 1 standard error, $n = 8$ for Elizabeth River and Mare Island k_u and k_{ew}, $n = 25$ for Baltimore Harbor k_u, and $n = 5$ for Baltimore Harbor k_{ew}.

[b] $p < 0.01$ Baltimore Harbor versus Mare Island and Elizabeth River versus Mare Island.

[c] $p < 0.01$ Baltimore Harbor versus Elizabeth River and $p < 0.05$ Baltimore Harbor versus Mare Island.

* Statistically significant differences between field and kinetic parameters (k_u, k_{ew}) ($p < 0.05$).

** Statistically significant differences between field and kinetic parameters (k_u, k_{ew}) ($p < 0.01$).

k_u = uptake rate constant; k_{ew} = efflux rate constant; $tb_{½}$ = biological half-life; SE = standard error; BH = Baltimore Harbor; ER = Elizabeth River; MI = Mare Island; MeHg = methylmercury.

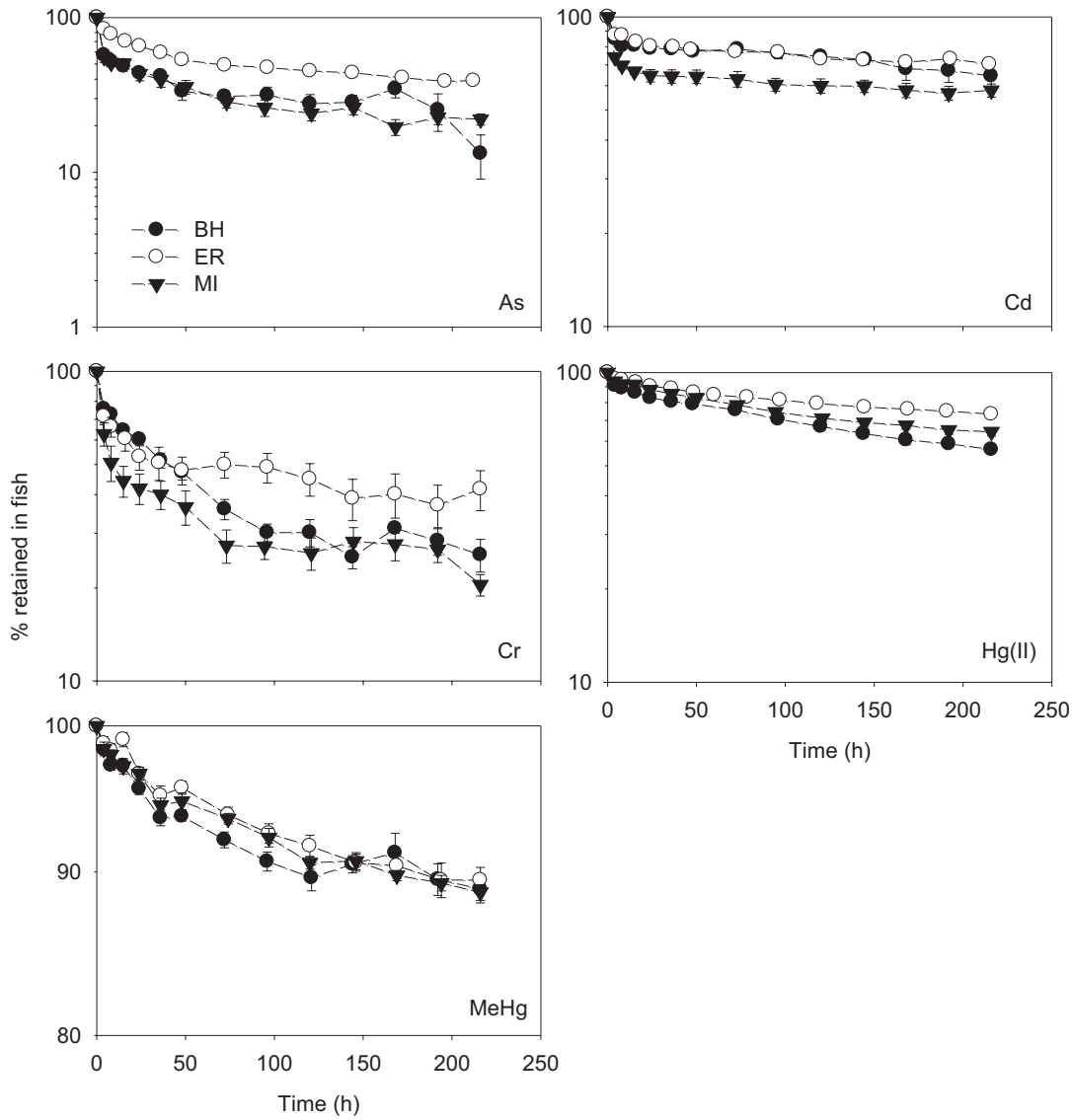

Figure 3. Loss of As, Cd, Cr, Hg(II), and methylmercury (MeHg) from killifish (*Fundulus heteroclitus*) over 9 d after aqueous exposure in Baltimore Harbor (BH), Elizabeth River (ER), and Mare Island (MI) water. Retention is shown as a percent of initial body burden after exposure. Values represent mean ± 1 standard error; $n = 8$ for Elizabeth River and Mare Island, $n = 5$ to 20 for Baltimore Harbor.

were predominantly associated with the head, Cd with the gills, and As with the muscle. The tissue distribution of MeHg changed throughout depuration; the percentage of MeHg associated with the head and gills decreased (25–19% and 23–4%, respectively), and that associated with the muscle increased (10–33%). Table 5 shows the radioactivity concentration on a weight-normalized basis in individual tissue compartments throughout depuration after exposure to aqueous metals in Baltimore Harbor water. Throughout depuration the highest concentration of Cd and Hg(II) was in the gills, whereas the highest concentration of Cr was in the gills and brain. The concentration of MeHg was highest in the gills, viscera, and liver, whereas As had a varied tissue distribution throughout depuration, which showed no consistent trends. Table 6 shows the rates of metal uptake or loss in each tissue compartment and the corresponding biological half-life. Arsenic had a high efflux rate and therefore a short biological half-life in the liver, whereas Cd, Cr, and Hg(II) were transferred into the liver over time. The gills and liver had the highest loss rate of MeHg, whereas MeHg was taken up over time into the brain, eyes, and muscle.

Modeling metal bioaccumulation in killifish

Model-predicted metal body burdens at steady-state (C_{ss}; ng g^{-1}; Table 7) were highest for Cd (396–508) and lowest for Cr (5.2–7.2) and Hg(II) (2.6–15.1). Chromium C_{ss} values did not vary between the 3 field sites, whereas the As, Cd, Hg(II), and MeHg values varied. The diet was the dominant source of Cd and MeHg to killifish at all field sites, accounting for >97% of accumulated metal, whereas a portion of As and Cr accumulation was attributed to aqueous exposure (13%–40% and 29%–40%, respectively). The importance of Hg(II) aqueous and dietary sources varied between field sites; the diet accounted for 43% of the Hg(II) C_{ss} for Baltimore Harbor but only 7% for Mare Island (Table 7).

DISCUSSION

Metal uptake from the aqueous phase

For all 3 field sites, the greatest accumulation of each metal was observed during the first hour of exposure as a result of the bioavailable metal binding to the most reactive site on the fish,

Table 3. Tissue distribution (as percentage of total body burden) of As, Cd, Cr, Hg(II), and MeHg in killifish after 9-d depuration following aqueous exposure in Baltimore Harbor, Elizabeth River, and Mare Island water[a]

Metal	Site	Head	Gills	Viscera	Body
As					
	BH	23 ± 4	5 ± 3	20 ± 7	52 ± 11
	ER	23 ± 3	17 ± 2	16 ± 2	44 ± 4
	MI	21 ± 3	3 ± 1	10 ± 2	66 ± 5
Cd					
	BH	26 ± 1	60 ± 2	8 ± 1	6 ± 1
	ER	17 ± 2	46 ± 4	27 ± 2	10 ± 1
	MI	23 ± 2	45 ± 3	25 ± 7	7 ± 1
Cr					
	BH	41 ± 5	8 ± 3	18 ± 5	33 ± 4
	ER	22 ± 3	12 ± 2	21 ± 3	45 ± 6
	MI	54 ± 13	12 ± 7	4 ± 3	30 ± 12
Hg(II)					
	BH	31 ± 1	15 ± 0.1	10 ± 0.7	44 ± 2
	ER	26 ± 0.9	16 ± 0.7	11 ± 0.5	47 ± 1
	MI	31 ± 1	16 ± 1	13 ± 0.6	40 ± 1
MeHg					
	BH	21 ± 0.6	4 ± 0.3	17 ± 1	58 ± 1
	ER	21 ± 0.6	4 ± 0.3	17 ± 0.3	58 ± 0.9
	MI	23 ± 1	4 ± 0.1	16 ± 0.5	57 ± 1

[a] Values (means ± 1 standard error) represent the percentage of total body burden associated with each tissue compartment (head, gills, viscera, and body); $n = 5$ for Baltimore Harbor and $n = 8$ for Elizabeth River and Mare Island.
BH = Baltimore Harbor; ER = Elizabeth River; MI = Mare Island; MeHg = methylmercury.

presumably the gills. It is presumed that after the initial rapid uptake, the rate of metal accumulation decreased because of either saturation of the most reactive binding sites on the gill or possible internal regulation of the metal in the fish, as observed for As in Baltimore Harbor and Elizabeth River water and for Cr in Elizabeth River and Mare Island water. The difference in salinity between the 3 field sites most likely accounted for the difference in the concentration factor and k_u values calculated in the present study for most metals, whereas DOC concentration had less influence. Dissolved organic carbon can reduce metal bioavailability for fish, but the 3 field sites do not differ markedly in their DOC concentration range (2.0–4.6 mg L^{-1}), which could account for why no clear trend was observed between metal uptake and DOC concentration. The DOC concentration in each site water falls within the range of concentrations typically observed in estuarine waters [1]. It should be noted that the composition of the DOM presumably varies between field sites, but this was not characterized in the present study.

The experiments conducted in the present study were carried out in natural waters, and therefore, the interaction between salinity and DOC concentration could not be adequately assessed to understand the effect of each variable. While prior studies have investigated the influence of salinity and DOC concentration on metal uptake in killifish as separate variables [6,7], future experiments should include a full factorial design controlling for both salinity and DOC concentration to understand the effect of salinity on metal uptake at different DOC concentrations and vice versa.

Table 4. Metal partitioning (as percentage of total body burden) in killifish at the end of aqueous uptake (day 0) and after 1 d, 3 d, 6 d, and 9 d of depuration in Baltimore Harbor water[a]

Metal	Day	Head	Gills	Brain	Eyes	Viscera	Liver	Skeleton	Muscle	Skin
As										
	0	17 ± 3	5 ± 1	0 ± 0	1 ± 0.5	9 ± 3	5 ± 0.5	10 ± 3	41 ± 4	12 ± 4
	1	16 ± 2	7 ± 2	5 ± 4	5 ± 2	6 ± 2	4 ± 2	6 ± 2	45 ± 4	6 ± 2
	3	13 ± 3	5 ± 0.4	4 ± 2	7 ± 2	6 ± 2	7 ± 1	17 ± 7	29 ± 3	12 ± 1
	6	25 ± 3	5 ± 2	0 ± 0	2 ± 2	4 ± 2	0 ± 0	4 ± 3	56 ± 9	4 ± 2
	9	13 ± 4	5 ± 3	2 ± 2	9 ± 2	18 ± 6	1 ± 1	16 ± 7	30 ± 7	6 ± 4
Cd										
	0	31 ± 2	56 ± 3	0.5 ± 0.1	0.5 ± 0.04	6 ± 1	1 ± 0.1	2 ± 0.2	1 ± 0.2	2 ± 0.1
	1	24 ± 1	65 ± 2	0.5 ± 0.1	0.5 ± 0.1	4 ± 0.8	1 ± 0.1	2 ± 0.2	1 ± 0.1	2 ± 0.1
	3	23 ± 2	66 ± 2	0.5 ± 0.1	0.5 ± 0.04	3 ± 0.5	1 ± 0.1	2 ± 0.3	1 ± 0.1	3 ± 0.4
	6	27 ± 0.6	58 ± 2	0.5 ± 0.1	0.5 ± 0.04	6 ± 0.9	3 ± 0.7	2 ± 0.6	1 ± 0.2	2 ± 0.4
	9	25 ± 1	60 ± 2	0.5 ± 0.1	0.5 ± 0.04	4 ± 0.5	4 ± 0.9	3 ± 0.9	1 ± 0.2	2 ± 0.3
Cr										
	0	30 ± 2	15 ± 1	3 ± 0.8	3 ± 0.4	13 ± 2	4 ± 0.9	11 ± 2	12 ± 0.8	9 ± 1
	1	37 ± 4	20 ± 2	4 ± 1	2 ± 2	19 ± 4	2 ± 1	5 ± 1	4 ± 2	7 ± 1
	3	39 ± 9	17 ± 5	0 ± 0[b]	2 ± 2	9 ± 4	0 ± 0	31 ± 15	0 ± 0[b]	2 ± 2
	6	38 ± 5	9 ± 4	3 ± 2	3 ± 2	15 ± 5	4 ± 1	13 ± 6	6 ± 2	9 ± 3
	9	31 ± 3	7 ± 3	3 ± 1	7 ± 3	12 ± 6	6 ± 2	13 ± 5	13 ± 2	8 ± 0.5
Hg(II)										
	0	29 ± 3	21 ± 3	1 ± 0.8	2 ± 0.3	5 ± 0.4	1 ± 0.2	14 ± 1	10 ± 0.9	17 ± 1
	1	26 ± 1	21 ± 2	3 ± 0.1	1 ± 0.1	5 ± 0.3	2 ± 0.3	11 ± 0.9	12 ± 0.8	19 ± 0.8
	3	30 ± 1	17 ± 0.5	1 ± 0.3	2 ± 0.1	5 ± 0.4	3 ± 0.4	14 ± 0.5	13 ± 1	15 ± 1
	6	31 ± 1	17 ± 1	1 ± 0.04	2 ± 0.3	6 ± 0.4	3 ± 0.4	14 ± 0.5	12 ± 1	14 ± 0.4
	9	29 ± 1	15 ± 0.1	1 ± 0.1	1 ± 0.08	6 ± 0.5	4 ± 0.3	13 ± 0.7	15 ± 1	16 ± 0.7
MeHg										
	0	25 ± 1	23 ± 1	2 ± 0.1	2 ± 0.1	7 ± 0.3	3 ± 0.3	14 ± 1	10 ± 0.5	14 ± 0.5
	1	24 ± 1	10 ± 1	1 ± 0.1	1 ± 0.1	12 ± 1	4 ± 0.4	14 ± 0.6	17 ± 0.7	17 ± 0.7
	3	20 ± 1	6 ± 0.3	1 ± 0.1	1 ± 0.04	13 ± 0.8	5 ± 0.2	12 ± 0.8	25 ± 0.7	17 ± 0.5
	6	21 ± 0.8	4 ± 0.3	1 ± 0.1	1 ± 0.04	12 ± 0.7	6 ± 0.8	10 ± 0.4	32 ± 2.2	13 ± 1
	9	19 ± 0.8	4 ± 0.3	1 ± 0.2	1 ± 0.04	11 ± 0.4	6 ± 0.7	8 ± 0.6	33 ± 0.7	17 ± 1

[a] Values (means ± 1 standard error) represent the percentage of total body burden of each metal associated with each tissue compartment, $n = 5$.
[b] Values <0.1%.
MeHg = methylmercury.

Table 5. Radioactivity concentrations (means ± 1 standard error) of metals in individual tissue compartments at the end of aqueous uptake (day 0) and after 1 d, 3 d, 6 d, and 9 d of depuration in Baltimore Harbor water ($n = 5$)

Metal	Day	Head	Gills	Brain	Eyes	Viscera	Liver	Skeleton	Muscle	Skin
As[a]										
	0	20 ± 7	64 ± 31	0 ± 0	28 ± 28	24 ± 9	27 ± 7	30 ± 10	32 ± 16	23 ± 8
	1	11 ± 5	41 ± 11	106 ± 85	43 ± 14	12 ± 4	8 ± 4	13 ± 7	17 ± 5	9 ± 3
	3	9 ± 2	36 ± 7	104 ± 45	71 ± 21	12 ± 2	25 ± 6	36 ± 16	13 ± 1	17 ± 3
	6	9 ± 4	18 ± 8	0 ± 0	17 ± 12	3 ± 1	0 ± 0	7 ± 6	11 ± 5	3 ± 3
	9	7 ± 3	25 ± 12	14 ± 14	60 ± 14	29 ± 8	2 ± 2	16 ± 6	10 ± 4	7 ± 4
Cd[a]										
	0	121 ± 15	2617 ± 248	25 ± 6	22 ± 4	79 ± 18	31 ± 5	18 ± 2	3 ± 0.3	11 ± 1
	1	122 ± 9	2523 ± 979	96 ± 74	32 ± 7	58 ± 16	33 ± 4	21 ± 3	2 ± 0.3	21 ± 2
	3	107 ± 10	2467 ± 261	26 ± 22	36 ± 6	43 ± 8	54 ± 9	20 ± 4	3 ± 0.3	23 ± 3
	6	113 ± 14	1934 ± 320	20 ± 5	26 ± 3	72 ± 15	68 ± 22	22 ± 7	3 ± 0.5	18 ± 3
	9	63 ± 7	1336 ± 387	13 ± 5	15 ± 2	52 ± 11	63 ± 20	18 ± 6	2 ± 0.3	10 ± 0.8
Cr[a]										
	0	122 ± 7	622 ± 81	401 ± 119	199 ± 34	135 ± 25	107 ± 46	116 ± 24	27 ± 3	69 ± 10
	1	68 ± 10	396 ± 32	275 ± 99	50 ± 40	102 ± 23	26 ± 17	24 ± 7	5 ± 2	26 ± 2
	3	53 ± 7	159 ± 30	17 ± 17	46 ± 31	29 ± 12	0 ± 0	857 ± 803	1 ± 1	64 ± 64
	6	40 ± 7	103 ± 45	101 ± 62	55 ± 26	55 ± 26	55 ± 15	20 ± 8	3 ± 1	15 ± 3
	9	46 ± 2	120 ± 46	137 ± 45	167 ± 51	62 ± 39	48 ± 18	47 ± 20	11 ± 1	23 ± 4
Hg(II)[a]										
	0	168 ± 10	1308 ± 297	129 ± 75	96 ± 18	134 ± 57	43 ± 11	221 ± 25	50 ± 6	186 ± 57
	1	144 ± 12	917 ± 287	217 ± 63	67 ± 6	75 ± 6	56 ± 9	199 ± 69	43 ± 4	142 ± 15
	3	158 ± 23	436 ± 78	105 ± 20	166 ± 25	186 ± 60	119 ± 39	196 ± 14	46 ± 6	135 ± 20
	6	120 ± 15	557 ± 103	41 ± 11	98 ± 10	101 ± 47	67 ± 15	125 ± 19	33 ± 6	86 ± 14
	9	83 ± 12	298 ± 49	60 ± 14	58 ± 9	73 ± 13	77 ± 8	94 ± 13	28 ± 3	71 ± 12
MeHg[b]										
	0	1.7 ± 0.3	10 ± 1.1	0.7 ± 0.1	1.1 ± 0.2	2.8 ± 0.8	3.6 ± 0.7	2.0 ± 0.2	0.7 ± 0.2	1.5 ± 0.2
	1	1.7 ± 0.1	6.1 ± 0.8	1.1 ± 0.2	1.2 ± 0.1	3.8 ± 0.6	7.9 ± 0.7	2.2 ± 0.2	1.1 ± 0.1	2.0 ± 0.2
	3	1.5 ± 0.2	3.3 ± 0.3	1.5 ± 0.2	1.2 ± 0.1	4.4 ± 0.5	7.7 ± 1.1	2.1 ± 0.1	2.0 ± 0.2	1.9 ± 0.1
	6	1.2 ± 0.1	1.9 ± 0.2	1.2 ± 0.1	0.9 ± 0.1	2.8 ± 0.4	4.1 ± 1.0	1.3 ± 0.1	1.4 ± 0.3	1.4 ± 0.2
	9	1.2 ± 0.3	1.8 ± 0.3	1.8 ± 0.4	1.8 ± 0.9	2.5 ± 0.4	3.0 ± 0.4	1.3 ± 0.2	1.6 ± 0.3	1.5 ± 0.3

MeHg = methylmercury.
[a] Units are Bq g^{-1} dry wt.
[b] Units are kBq g^{-1} dry wt.

The low uptake of As in all 3 field-collected waters resulted in concentration factors <1, indicating the water was more enriched in As than the fish, consistent with earlier findings [6,7]. This could be attributed to both As(V) and the fish body surface being negatively charged and, therefore, repelling each other. Arsenic uptake appeared to reach steady state in killifish in Baltimore Harbor and Elizabeth River water by the end of the 36-h exposure. The high efflux rate (23% d^{-1}) of As from the liver calculated for killifish in Baltimore Harbor water (Table 6) indicates that As may be internally regulated, and therefore, part of the reason that steady-state conditions were reached was the rapid physiological turnover of As in the liver. Arsenic accumulation in killifish increased with increasing salinity; fish in Mare Island water (22 ppt) accumulated 2.3 times more As than fish in Baltimore Harbor water (7.6 ppt) by the end of the exposure period. Marine fish drink to osmoregulate, and drinking could be a possible uptake route for As; but this was not supported by the tissue-distribution data. The same relationship was observed in another laboratory study [6] and in a field study where fish collected from higher-salinity water had a higher body burden of As [19]. The k_u values calculated in the present study are comparable to those calculated in other laboratory studies [6,7].

Table 6. Rates of metal uptake (positive values) and loss (negative values) in individual tissue compartments (days) and the corresponding biological half-lives following aqueous exposure in Baltimore Harbor water

Metal		Head	Gills	Brain	Eyes	Viscera	Liver	Skeleton	Muscle	Skin
As										
	Uptake or loss	−0.050	−0.079	−0.272	−0.017	0.055	−0.230	−0.046	−0.063	−0.097
	$tb_{½}$	13.9	8.8	2.5	40.8	nd	3.0	15.1	11.0	7.1
Cd										
	Uptake or loss	−0.073	−0.081[a]	−0.222	−0.100	0.009	0.076	−0.014	−0.006	−0.095
	$tb_{½}$	9.5	8.6	3.1	6.9	nd	nd	49.5	115.5	7.3
Cr										
	Uptake or loss	−0.051	−0.140	0.018	0.147	−0.019	0.084	−0.099	0.150	−0.076
	$tb_{½}$	13.6	5.0	nd	nd	36.5	nd	7.0	nd	9.1
Hg(II)										
	Uptake or loss	−0.074	−0.112	−0.171	−0.047	−0.036	0.007	−0.102[a]	−0.062	−0.095[a]
	$tb_{½}$	9.4	6.2	4.1	14.7	19.3	nd	6.8	11.2	7.3
MeHg										
	Uptake or loss	−0.047	−0.153	0.044	0.037	−0.067	−0.135[a]	−0.077	0.020	−0.040
	$tb_{½}$	14.7	4.5	nd	nd	10.3	5.1	9.0	nd	17.3

[a] Rates of metal loss significantly different from 0 ($p < 0.05$).
$tb_{½}$ = biological half-life; MeHg = methylmercury; nd = not determined.

Table 7. Model-predicted body burden of metals in killifish at steady state and the percentage of body burden attributed to dietary exposure for each metal and field site

Metal	Location	C_{ss} (ng g^{-1})[a]	Percentage of body burden from diet
As(V)			
	BH	21.9	87
	ER	45.6	60
	MI	57.4	76
Cd			
	BH	508	99
	ER	435	98
	MI	396	99
Cr(III)			
	BH	5.2	71
	ER	7.2	67
	MI	6.4	60
Hg(II)			
	BH	2.6	43
	ER	5.1	25
	MI	15.1	7
MeHg			
	BH	241	97
	ER	263	99
	MI	210	99

[a] The C_{ss} values were calculated using background metal concentration values in Table 1, uptake rate constant and efflux rate constant values in Table 2, and assimilation efficiency, metal efflux rate constant, metal concentration in prey, ingestion rate, and growth rate constant values in *Materials and Methods*.
C_{ss} = steady-state concentration, dry weight; BH = Baltimore Harbor; ER = Elizabeth River; MI = Mare Island; MeHg = methylmercury.

Chromium was the only metal for which salinity and DOC concentration did not influence metal accumulation, as shown by the overlapping error bars in Figure 2. Like As, Cr also binds to oxygen and does not chloro-complex in seawater [11]. By the end of uptake, concentration factors were <1 in killifish in Elizabeth River and Mare Island water, indicating that the water was more enriched in Cr than the fish at those 2 field sites. Chromium(III) is particle-reactive and has low cell membrane permeability, which may account for the observed low uptake in all 3 field-collected waters. In comparison, Cr(VI) is much less particle-reactive than Cr(III) but has greater cell membrane permeability and therefore accumulates in aquatic organisms, as observed in mussels [20]. Chromium accumulation appeared to reach steady state in Elizabeth River and Mare Island water within the 37-h exposure period; unlike for As, there was not a high efflux rate of Cr from the liver; instead, the concentration of Cr in the liver increased over time. Another laboratory study also concluded that salinity had no influence on the uptake of Cr in fish [6]. Chromium accumulation was lowest in Elizabeth River water, which had the highest DOC concentration; although the 3 field sites have a narrow DOC concentration range, this finding conforms to another study which concluded that as DOM concentration increased from 0 mg L^{-1} to 5 mg L^{-1}, the uptake of Cr decreased [7].

Cadmium uptake showed an inverse relationship with salinity, similar to the findings of other studies [6,21]; concentration factors in killifish in Baltimore Harbor water were 2.2 times higher than those in killifish in Mare Island water. As salinity increases, Cd^{2+} binds to chloride, forming $CdCl_2$ and other chloro-complexes, which are less chemically reactive and therefore less bioavailable for uptake by killifish. The concentration of DOC did not influence Cd accumulation in killifish, supporting the finding of another study [7]. This could possibly be attributed to Cd having a lower binding affinity for DOC ($\log K_{Cd\text{-}DOC} = 7.4$) than for fish gills ($\log K_{Cd\text{-}gill} = 8.6$) [22]. The concentration factor and k_u values calculated in the present study are comparable to those from another study where Cd uptake was investigated as a function of salinity at 6 ppt, 12 ppt, and 25 ppt [6].

Like Cd, Hg(II) and MeHg chloro-complex in seawater. In freshwater, Hg binds to hydroxide (Hg is speciated as $Hg[OH]_2$ and MeHg as CH_3HgOH), whereas in seawater Hg(II) and MeHg bind to chloride, forming mercuric–chloride complexes ($HgCl_2$ and CH_3HgCl_2, respectively) [23]. As salinity increased, Hg(II) and MeHg behaved differently; at the end of uptake, the Hg(II) concentration factor was 5.6 times higher and the k_u value 7.2 times higher in Mare Island water than in Elizabeth River water, even though there was only a 2.5 ppt salinity difference between the 2 site waters. The reason for the sudden increase in Hg(II) uptake in Mare Island water after 12-h exposure is not apparent to us. This Hg(II)-uptake pattern was also observed in another study where Hg(II) accumulation in killifish was investigated as a function of humic acid concentration; in that study, the greatest rate of Hg(II) uptake was observed between 24 h and 47.5 h of exposure [7]. Furthermore, another laboratory-based study [6] showed a positive relationship between salinity and Hg(II) accumulation, whereas no clear trend was observed in the present study. The inverse relationship between Hg(II) uptake in killifish and DOC concentration was also observed in a prior study [6]. The Hg(II) k_u values in Baltimore Harbor and Elizabeth River water calculated in the present study are within the range of values calculated for freshwater, estuarine, and marine fish [3,5–7], although the k_u of Hg(II) in Mare Island water is higher than most values in other studies.

Methylmercury uptake showed an inverse relationship with salinity; killifish accumulated 2.0 times more MeHg in Baltimore Harbor water than in Mare Island water. In another study where MeHg accumulation in killifish was investigated as a function of salinity, a positive relationship was observed [6]. It should be noted that the prior study was strictly controlled, so salinity was the only variable, whereas the present study was conducted in natural waters. A field study investigating the concentration of Hg in largemouth bass (*Micropterus salmoides*) also found an inverse relationship with salinity [24]. Octanol–water partition coefficients (K_{OW}) calculated for Hg(II) and MeHg favor $HgCl_2$ and CH_3HgCl_2 as the most bioavailable species for uptake because of their greater lipophilicity and therefore cell membrane permeability [23]; as a result, Hg(II) and MeHg should be more readily taken up at higher salinities based on their K_{OW} values.

Metal retention and elimination after aqueous exposure

The rate of metal uptake in killifish and the resulting body burden from aqueous exposure are influenced by water chemistry and therefore varied between the 3 field sites. However, the loss of metals from killifish could be attributed to the physiological turnover rate of each metal within the fish. Apart from the higher As and Cr k_{ew} values in Baltimore Harbor water, there was little variability in the k_{ew} and therefore physiological turnover rate between the 3 field sites for each metal. This could possibly be attributed to the experiments being temperature-controlled; therefore, the killifish used in each experiment would have had the same routine metabolic rate.

Arsenic and Cr had the highest k_{ew} in all 3 field-collected waters, possibly accounting for As and Cr reaching steady state throughout uptake in Baltimore Harbor and Elizabeth River water and in Elizabeth River and Mare Island water, respectively. To our knowledge, this is the first study to calculate k_{ew} values

for fish after aqueous exposure to As, whereas our Cd, Cr, Hg(II), and MeHg k_{ew} values are within the range calculated in prior studies [3,5,25–27].

Tissue distribution of aqueous metals

Although the Cd k_u value decreased as salinity increased, there was an increase in the percentage of Cd associated with the viscera (presumably the intestine) in higher-salinity water (Elizabeth River, Mare Island). This can be attributed to marine fish drinking to osmoregulate, and drinking therefore is an uptake mechanism for Cd from the aqueous phase, as observed in prior studies where the tissue distribution of Cd was investigated as a function of salinity [6,21]. This finding indicates that the calculated Cd k_u value in Elizabeth River and Mare Island water is a result of aqueous uptake across the gut as well as the gill, whereas the calculated Cd k_u value in lower-salinity Baltimore Harbor water is predominantly a result of Cd uptake at the gill. A prior study has shown that Cd shares the same uptake pathway in the gill and gut as Ca^{2+} in fish [28]. The tissue distribution of As and Cr appeared to be influenced by DOC concentration, for reasons not apparent to us. Arsenic(V) is known to compete with PO_4 for uptake into cells, and the PO_4 transporter was recently identified in zebrafish [29]. It could be that Cr(III) is complexed to organic compounds, which are selected for by killifish and therefore taken up across the gills as observed in bivalves [30,31]; but to our knowledge, this is not known to be an uptake mechanism in fish. It should be noted, however, that very low radioactivity counts of As and Cr were detected in each tissue compartment, and this may account for some of the larger calculated standard error values. The similar tissue distribution of Hg(II) and MeHg between field sites indicates that once inside the body, Hg(II) and MeHg are redistributed around the body in the same way and are not influenced by salinity or DOC concentration. Both Hg species were predominantly associated with the body, presumably the muscle, because of their high binding affinity for sulfur.

To our knowledge, this is the first study to assess the body distribution of metals in fish throughout a several-day depuration period following aqueous exposure and the first study in which metal efflux and influx rates for individual tissue compartments were determined. Prior studies have focused on factors that influence the assimilation efficiency and k_u values of metals in fish, and the k_{ew} and k_{ef} values have received less attention. It is easier to understand what influences the calculated k_u and assimilation efficiency values because they result from uptake at essentially 1 site (gill and gut, respectively), although the calculated k_u value may be a result of aqueous uptake across the gut as well as the gill if drinking is an uptake mechanism. In comparison, the whole-fish k_{ew} and k_{ef} is essentially an integration of the efflux rate constants from different tissue compartments in fish, each with its own turnover rate. To date, efflux and influx rate constants in different tissue compartments have not been well described in animals, partially because it is difficult to do, but some exceptions exist [32]. A radiotracer technique can be used to overcome this issue and provide further insight into what determines whole k_{ew} and k_{ef} values, as determined in a prior study using fish following dietary exposure to MeHg [33]. However, it should be noted that between the metals examined, only 4 tissue compartments had calculated efflux rate constants that were significantly different from 0 ($p < 0.05$; Table 6); this can be attributed to the mean radioactivity concentration values being used in the regression analysis, so for each tissue compartment and metal only 4 data points were used. Furthermore, efflux rates from different tissue compartments may be a result of the transport of metal between individual tissue compartments and may not be responsible for the k_{ew} value calculated for the whole fish.

Cadmium and Hg(II) were not redistributed around the body throughout the 9-d depuration period. The large decrease in Cd and Hg(II) radioactivity concentrations in individual tissue compartments, especially the head, gills, and brain (48%, 47%, and 86% for Cd and 42%, 68%, and 72% for Hg[II], respectively) accounted for most of the metal loss observed from the whole fish and the resulting k_{ew} values. The high k_{ew} (7.5% d^{-1}) for Cr in killifish in Baltimore Harbor water is attributed to the 70% decrease in radioactivity concentration in the gills and the 39% decrease in the viscera. The lack of apparent trend in the tissue partitioning of As throughout depuration could be a result of low radioactivity counts in each tissue compartment. The loss of As from each tissue compartment, particularly the brain and liver, accounts for the highest k_{ew} value (9.6% d^{-1}) and shortest $tb_{½}$ of any metal in the whole fish. In comparison, MeHg was effectively redistributed around the body throughout depuration, presumably via the blood, instead of being released from the fish (except the liver), resulting in the low calculated k_{ew} value (0.6% d^{-1}).

For all metals the liver had an important role in the processing and excretion of metals, presumably via a biliary excretion route. We attempted to dissect the kidney in the present study to investigate renal excretion; however, the kidney is very small, and an accurate dry weight could not be determined. The influx rate of MeHg into the brain, eyes, and muscle indicated that MeHg accumulates in the sulfur-rich portion of the body (muscle) and can readily cross the blood–brain barrier in fish. A prior study also found that MeHg accumulates in the brain following dietary exposure [33], supporting the findings of the present study. For each metal, the calculated efflux rates for the skin (4.0–9.7% d^{-1}) were surprisingly high; although care was taken when dissecting the fish, a small portion of muscle tissue may have remained attached to the skin. However, the body surface of killifish is covered in scales, which can accumulate metals to high concentrations [34]; as a result, the calculated efflux rate constant may be a result of metals detaching from the scales.

Modeling metal bioaccumulation in killifish

When the aqueous kinetic parameters calculated in the present study were entered into the biokinetic model with the dietary kinetic parameters calculated in a previous study [10], the predicted body burden (C_{ss}) did not vary between the 3 field sites for Cr but did vary for As, Cd, Hg(II), and MeHg. Cadmium C_{ss} values were influenced by the salinity of the experimental waters; killifish exposed to Cd in Mare Island water had the lowest C_{ss} because of the low k_u compared to the other 2 field sites. The lower As C_{ss} calculated for killifish in Baltimore Harbor water is a result of fish in Baltimore Harbor water having a 1.5 to 2 times higher k_{ew} and therefore a faster physiological turnover of aqueous metal and a lower C_w compared with the other 2 field sites. Killifish in Mare Island water had a 3.5 to 5 times higher Hg(II) body burden because of the k_u value being 7.7 times higher in Mare Island fish compared with Baltimore Harbor and Elizabeth River fish. The MeHg C_{ss} value varied between field sites, with the lowest C_{ss} value found in the highest-salinity water (Mare Island) as a result of Mare Island having the lowest C_w and k_u values. To our knowledge, this is the first study to predict the concentration of As and Cr in fish at steady state.

No literature values could be found to compare our predicted values to field-collected fish at any of the 3 field sites. The

predicted Cd, Hg(II), and MeHg values calculated for killifish in the present study matched independent field data from other contaminated estuaries and partially enclosed bays, indicating that the model accounts for the major processes governing metal concentration in killifish and that metal parameters (k_u, assimilation efficiency, k_{ew}, k_{ef}) measured in laboratory experiments are applicable to natural waters. Our model-predicted Cd values are higher than those observed for field-collected killifish (*Fundulus parvipinnis*) in contaminated areas in southern California (200–300 ng g^{-1} dry wt) [35] but fall within the range of values observed for fish worldwide (0.04–15 840 ng g^{-1} dry weight) [1]. Our calculated MeHg values are within the range observed for field-collected killifish in a contaminated estuary in the Gulf of Maine (50–240 ng g^{-1} dry wt) [36] but higher than the total Hg value observed for killifish in contaminated bays on the south shore of Long Island, NY, USA (58–184 ng g^{-1} dry wt; J. Dutton and M.J. Record, Adelphi University, unpublished data). No As and Cr levels in field-collected killifish or other small forage fish were found in the literature. The killifish used in the present study were collected from a noncontaminated river; the background concentrations of metals in killifish, measured by ICP-MS (mean ± 1 SD, n =5) are as follows: As = 1332 ± 623 ng g^{-1}, Cd = 9.5 ± 1.6 ng g^{-1}, Cr = 1368 ± 715 ng g^{-1}, total Hg = 84 ± 15 ng g^{-1}. Our model-calculated Cd and Hg values for killifish in contaminated estuaries are much higher than those for pristine waters; however, our calculated As and Cr values are much lower. The latter can be attributed to ICP-MS analysis calculating total As and Cr concentrations in killifish, whereas the present study predicted the body burden of As(V) and Cr(III). Hexavalent Cr (Cr[VI]) is the dominant form of Cr in seawater [11], and although As is found as As(V) in seawater [1,11], in fish it is predominantly found as organic arsenobetaine, which is accumulated via the diet [37].

For Cd and MeHg dietary sources accounted for >97% of the metal body burden, as shown in other studies when fish were fed zooplankton prey [3–5,27]. The present study indicates that aqueous exposure can account for a significant portion of the Hg(II) body burden in killifish, especially in Mare Island water where aqueous accumulation of Hg(II) accounted for 93% of the C_{ss} value because of the higher k_u value. Our calculated Hg(II) values are lower than the findings of other studies using freshwater redear sunfish (46–60%) [3] and Atlantic silversides (>96%) [5]. Interspecific differences are presumably attributable to physiological differences between these fish. To our knowledge, this is the first study to calculate the relative importance of dietary and aqueous exposure routes on the body burden of As and Cr in fish, and for both metals the diet was the predominant exposure pathway.

Studies measuring the levels of metals in small field-caught fish are limited and in need of further pursuit because small forage fish, including killifish, are a conduit for the transfer of metals from lower trophic levels to their predators, including blue crab (*Callinectes sapidus*), bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and dogfish (*Mustelus canis*) [38–40], which, if consumed, potentially provide a source of metals to humans. The present study and previous studies [3–5], provide important information to regulatory agencies that determine water-quality standards based on the ambient concentration of metals in the water and largely overlook the importance of the diet as a source of metals to fish. Although the diet is considered to be the dominant exposure pathway of most metals, our data combined with other literature values stress the importance of not ignoring the aqueous phase as a source of metals to fish.

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A National Pilot Study of Mercury Contamination of Aquatic Ecosystems along Multiple Gradients

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ABSTRACT

Mercury (Hg) contamination of aquatic ecosystems is a global problem. However, databases for Hg in environmental samples at regional-to-national scales are few, especially for multi-media sampling that include determination of methylmercury (MeHg). A national scale pilot study to examine relations of total Hg (Hg_T) and MeHg in water, sediment and fish was conducted in the summer and fall of 1998. Samples were collected at 106 sites from 21 basins across the United States, including Alaska and Hawaii. The data showed wide ranges in concentrations, which were expected given the diverse array of environmental settings, water chemistry, and Hg loading represented by these sites. Wetland density was the single most important basin-scale factor controlling MeHg production. At low concentrations, total Hg in sediment may also influence MeHg production, but at high total Hg concentrations (>1,000 nanograms per gram; ng/g) in sediment there was little evidence of increasing MeHg production with increasing total Hg. An atmospheric Hg accumulation index was developed for differentiating areas where atmospheric Hg deposition was the dominant Hg source from areas with significant on-site sources. Four study basins along the east coast of the United States had the greatest methylation efficiency, as reflected by the MeHg/HgT ratio in sediments. Nationwide, sub-basins characterized as mixed agriculture and forest cover types had the highest methylation efficiency, whereas areas affected by mining had the lowest efficiency. This study represents a first step toward a national assessment of Hg contamination of aquatic ecosystems in the United States, however, additional data are needed to improve our resolution of the factors controlling MeHg production and bioaccumulation.

INTRODUCTION

Methylmercury is the most toxic and widespread contaminant affecting our Nation's aquatic ecosystems. Methylmercury contamination has prompted steadily increasing numbers of fish-consumption advisories in 40 states, now accounting for more than eighty percent of all such advisories in the Nation (1,782 advisories for mercury of 2,196 total advisories nationwide; U.S. Environmental Protection Agency, 1998). Eleven states have statewide advisories for Hg in fish from lakes and/or rivers, and five have statewide advisories for coastal waters. In addition, some tribal representatives report that adherence to fish-consumption advisories has adversely affected the social, economic, and cultural well being of certain Native American tribes (for example, Wheatley and others, 1997; Wheatley, 1997). Methylmercury readily crosses biological membranes, can accumulate to harmful concentrations in exposed organisms, and biomagnifies to concentrations of toxicological concern in aquatic food webs, posing a threat to humans (Grandjean and others, 1997) and an increasing, potentially severe threat to fish-eating wildlife (Heinz and Hoffman, 1998).

For most aquatic ecosystems, atmospheric deposition of inorganic Hg (about 0.3 to 30 micrograms per square meter per year; U.S. Environmental Protection Agency, 1997) is the primary source of contamination. Generally only a small fraction of this atmospheric Hg load to aquatic ecosystems exists as MeHg (Rudd, 1995). In addition, the masses of MeHg found in sedimentary and biological compartments of most

aquatic ecosystems cannot be accounted for by direct inputs of MeHg (Branfireun and others, 1998), and mass effluxes of MeHg from watersheds generally far exceed total inputs (Hurley and others, 1995). The bridge between the seemingly incongruent observations that inorganic Hg is the dominant form released to the environment, and MeHg is the dominant form of Hg found in edible fish (Bloom, 1992; Wiener and Spry, 1996) is the process of methylation. It is generally accepted that in natural settings mercury methylation is mediated through microbial sulfate reduction (Gilmour, 1991). Over the past 10 years, a great deal of scientific attention has been placed on trying to better understand mercury methylation. Yet, a complete understanding of the factors controlling methylation has remained elusive.

Management and regulatory responses to the growing mercury problem have been greatly impeded by a lack of information from a wide range of locations and environmental settings on the sources, transport, biogeochemical transformations, biological exposure, and toxicological consequences of mercury in the environment. Although there is a growing body of literature on mercury in the environment, to date there has not been a coordinated effort using consistent sampling and analytical methods conducted at the national scale. This paper presents the initial results of a pilot study to evaluate whether trends in Hg accumulation and MeHg production can be identified at national or regional scales across the United States. The study was designed so that a range of factors known to affect contamination levels, such as Hg loading rates, Hg source types, water chemistry, and land use and cover, could be evaluated.

THE USGS NATIONAL MERCURY PILOT STUDY

The National Mercury Pilot Study was conducted though the collaborative efforts of the Toxic Substances Hydrology program and the National Water Quality Assessment (NAWQA) program of the U.S. Geological Survey (USGS). The overall objective of this study is to identify ecosystem characteristics that favor the production and bioaccumulation of MeHg. Ultimately, we would like to be able to construct predictive models indicating environments of most concern for MeHg contamination, such as that depicted in figure 1. Ecosystems that have low methylation efficiency may exhibit low or moderate bioaccumulation even under high Hg loads, such as the Poplar Creek watershed, near Oak Ridge, Tennessee (Turner and others, 1993). On the other hand, significant bioaccumulation of methylmercury can result even when very low Hg loading rates exist if methylation efficiency is high, such as low-pH lakes in northern Wisconsin (Wiener and others, 1990; Lamborg, and others, 1995). Other ecosystems, such as newly constructed reservoirs, may experience a

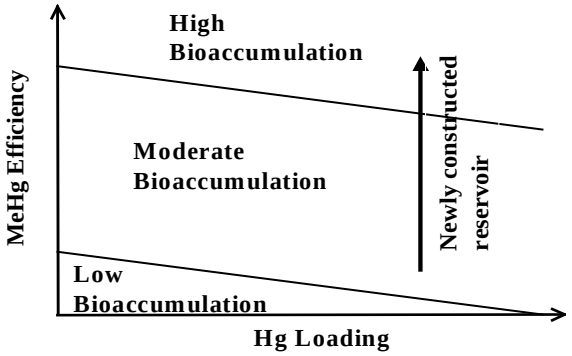

Figure 1. Hypothetical model for the relations between Hg loading, methylation efficiency and boaccumulation.

perturbation that increases methylation efficiency without increasing the mercury load (Bodaly and others, 1997). In this case, after flooding, the methylation efficiency of the reservoir would be expected to show a vertically upward trend across this conceptual model.

Regional and national scale fish surveys have been done in the past for mercury and other bioaccumulative contaminants. This is the only known study, however, in which national-scale, multi-media sampling (water, sediment, and fish) was conducted in concert with low-level Hg speciation analysis. Recent studies in Wisconsin have shown that several basin-scale factors influence the relative sensitivity of ecosystems to MeHg production (Hurley and others, 1995). These basin-scale factors include the relative abundance of wetlands (a site known to favor Hg methylation), soil types, and land use and cover. In Wisconsin, these factors serve as good

predictors of mercury methylation efficiency, Hg and MeHg yields, and levels of MeHg in water. We caution that when viewed from a national perspective, however, the variation in atmospheric Hg-deposition rates across Wisconsin are small (U.S. Environmental Protection Agency, 1997), point-source contributions were presumably few and moderate in strength, geologic sources were negligible, and the range of ecosystem types were limited. Thus, we can not reliably transfer these results to a national scale.

Study Design

The major characteristics of this study were its (1) national scope, (2) emphasis on multi-media sample collection (water, sediment, and predator fish), (3) consistent use of trace metal clean sampling methods, and (4) low-level Hg and MeHg analytical procedures. By collecting and analyzing all three media, much more can be ascertained about controls of Hg and MeHg partitioning, accumulation, bioconcentration, and methylation efficiency across the vast diversity of sites that comprise our Nation's freshwater ecosystems.

The NAWQA program has scientists located throughout the United States who are trained in the procedures for the collection of water, sediment and biological samples; this greatly facilitated field efforts for this study. An additional benefit of conducting the pilot study at NAWQA study basins is the substantial amount of ancillary information available to strengthen the interpretations of the data generated via this study.

Sampling was conducted from June to October, 1998 at multiple locations (3 to 8) in each of 21 NAWQA study basins (figure 2, table 1) for a total of 106 sampling sites. Nationally, these basins spanned the dominant east-to-west mercury deposition gradient (figure 3) and represented a wide range of environmental settings. Individual study basin teams were asked to choose sites spanning gradients of wetland density, surface water pH, sulfate (SO_4), total organic carbon (TOC), and suspected or known Hg loading. In most cases, the sites sampled were streams, and every attempt was made to sample during baseflow conditions. Several of the chosen basins had known point sources of mercury from mining activity, and were representative of very high mercury loading conditions.

Table 1. NAWQA study basins from which samples were collected for this study.

Abbrev.	Study Basin Name
ACAD	Acadian-Pontchartrain
ALMN	Allegheny and Monongahela Basins
COOK	Cook Inlet Basin
DELR	Delaware River Basin
GRSL	Great Salt Lake Basins
LINJ	Long Island and N. J. Coastal Drainages
LTEN	Lower Tennessee River Basin
MIAM	Great and Little Miami River Basins
MOBL	Mobile River and Tributaries
NECB	New England Coastal Basins
NROK	Northern Rockies Intermontane Basins
NVBR	Nevada Basin and Range
OAHU	Oahu Island
SACR	Sacramento Basin
SANA	Santa Ana Basin
SANT	Santee Basin and Coastal Drainages
SOFL	Southern Florida
TRIN	Trinity River Basin
UCOL	Upper Colorado River Basin
UIRB	Upper Illinois River Basin
YELL	Yellowstone Basin

Sampling Methods for Water, Sediment, and Fish

Aqueous Hg and MeHg samples were collected with trace-metal clean methods (Fitzgerald and Watras, 1989). All sample containers were Teflon (any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government), which had been rigorously cleaned in hot acid, partially filled with one percent HCl for storage, and then double bagged in Ziploc bags. Sampling crews wore plastic gloves, and executed clean-hands, dirty-hands techniques (Olson and DeWild, 1999) to remove the sample bottle from the two bags. Almost all of the sampling locations were streams, whereby grab samples were taken from the centroid of flow by submersing the bottle while wearing arm-length

gloves. Total-Hg (Hg_T) samples were acidified to one percent HCl by volume, while MeHg samples were immediately placed in a darkened cooler until they could be frozen.

Bed sediment samples were collected using the NAWQA program's trace-element sampling protocols (Shelton and Capel, 1994). Briefly, field personnel wore plastic gloves and used a clean Teflon or plastic scoop to collect the top few centimeters of sediment. Generally, samples were taken from multiple points (about 5 to 10) at each site, which were then pooled, homogenized, and then subsampled. A Teflon vial was used for the total Hg and MeHg subsample, while a second subsample was taken in a polypropylene vial and used for other analyses. Sediment samples were frozen as soon as possible.

Fish were collected by the most efficient means available, provided it did not jeopardize the specimen with regard to mercury contamination. Up to five individuals of a single, top-predator species were collected from each site. Field crews were asked to focus sampling efforts on largemouth bass of age 2-3 years, but in the absence of these fish to collect the most common predator species inhabiting the basin. If at all possible, the same species was collected from each sampling site within a study basin. Each fish was rinsed in stream water, measured for length and weight, placed in Ziploc bags, and frozen as soon as possible.

Anaytical Methods for Sediment and Water and Wetland Delineation

Details of the analytical procedures for Hg_T and MeHg in sediment and water are given in Olson and DeWild (1999) and Olson and others (1997). Samples collected for this study were shipped to the USGS Mercury Research Laboratory in Middleton, Wisconsin. Total mercury in aqueous samples was determined by cold vapor atomic fluorescence spectroscopy (CVAFS) following oxidation with BrCl at 50°C, reduction by $SnCl_2$, and purge and trap of the evolved Hg^0 onto gold-coated glass bead columns. Total mercury in sediments was determined with the same procedure, but samples were pre-digested with nitric and sulfuric acids in sealed Teflon bombs at 125°C. Methylmercury in sediment and water was analyzed with the distillation and aqueous phase ethylation method of Horvat et al. (1993), and detection by CVAFS. Analytical results for fish tissue samples were not available at the time of this paper, so the procedures are not given. Ancillary chemical parameters were determined by the following methods: pH was measured in the field with a calibrated probe; SO_4 by ion chromatography; DOC by a carbon analyzer that employs acidification and persulfate/UV oxidation; dry weight percent by drying wet sediment at 105°C; and loss on ignition (LOI) by heating dried sediment samples to 550°C.

A Geographic Information System (GIS) was used to quantify wetland areas within the study basins. Sampling locations for each study basin were plotted, and the sub-basin areas upstream of each point were delineated. Percent wetland area for each of the sub-basins was determined by overlaying a GIS coverage of the National Wetlands Inventory (Greg Allord, USGS, unpub. data, 1999).

RESULTS AND DISCUSSION

The study results are presented in three ways: across individual sites, among basins, and among site types.

All analytically determined parameters varied considerably within and among sites (table 2). This was expected given the extreme ranges in environmental settings (climate, geology, land use, and land cover), water chemistry, and Hg loading represented by this array of sampling sites. Generally, the Hg_T and MeHg concentrations in water and sediment were similar to the range of values from other recent freshwater studies that employed clean sampling and low-level Hg analysis. Very high concentrations of Hg_T and MeHg in water and sediment observed at the mining affected sites created a highly skewed distribution of concentration data. As a result, the mean values were much larger than their respective median values (table 2).

Overall, stronger correlations were observed between sediment MeHg and the

ancillary data (wetland density, pH, DOC and SO_4) than for aqueous MeHg results. This was likely due to the more transient nature of surface water samples compared to sediment, which tends to integrate site conditions over longer periods of time. Of the ancillary measurements, the strongest correlation was between sediment MeHg and percent wetland in the sub-basin (figure 4). Previous studies of MeHg production in boreal ecosystems also concluded that wetland density greatly influenced MeHg production (St. Louis and others, 1994; Hurley and others, 1995).

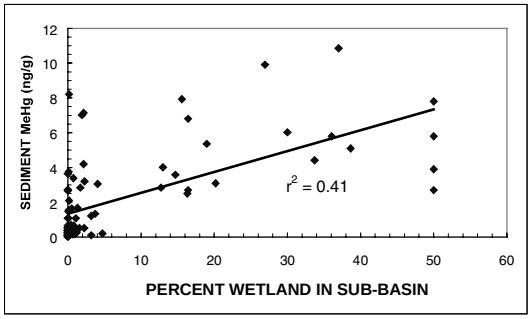

Figure 4. Sediment MeHg versus percent wetland in the sub-basins sampled during this study.

Similar positive correlations observed here suggest that these conclusions are valid over much broader geographical scales and ecosystem types. Sediment MeHg concentration also correlated positvely with LOI ($r^2 = 0.26$), which was used as a surrogate for organic carbon content of sediment. A subset of fifteen samples collected for this study and analyzed for organic carbon concentration showed a strong correlation with LOI ($r^2 = 0.97$). Negative correlations were observed between sediment MeHg and percent dry weight and surface water pH ($r^2 = 0.29$ and 0.15, respectively). The correlation results between MeHg and TOC was lower than expected ($r^2 = 0.18$), given that other studies have observed much stronger relations between these variables (Hurley and others, 1998). A more detailed analyses of the TOC quality from these various study basins may help to unravel the complexities of Hg-carbon interactions. Our observations suggest that mercury methylation is greatest for sub-basins with significant wetland density, organic sediments, and with low surface water pH.

One of the difficulties in analyzing Hg data from such differing ecosystems is the considerable variation in the measurable factors controlling important processes, such as methylation. For example, when we excluded the sites with mining impacts, a strong, positive correlation was observed between sediment MeHg and SO_4. When we included the data from the sulfate-rich mining sites, a weak, negative correlation was observed. At very high sulfate levels, methylation of mercury may not be limited by the availability of sulfate, or methylation can be inhibited by the abundance of sulfide (a by product of sulfate reduction) (Gilmour and others, 1998).

One important question concerning Hg bioaccumulation in aquatic ecosystems is whether Hg load drives methylation. The averaged, LOI-adjusted Hg_T and MeHg data for the 21 study basins suggest that Hg load (as reflected by Hg_T accumulation in sediment) has a logarithmic effect on methylation (figure 5). Methymercury production appears proporational to Hg_T concentrations at low sediment Hg_T levels; but at high Hg_T levels little additional MeHg is produced with additional Hg_T.

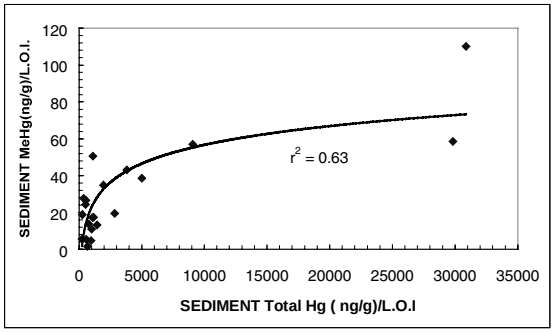

Figure 5. Average normalized (to LOI) sediment MeHg versus Hg_T for the 21 basins sampled for this study.

This finding is consistent with mercury methylation experiments on sediments, where a reduced methylation response to loading was observed when concentrations of $Hg_T > 1{,}000$ ng/g were used (Rudd and others, 1983). The two data points on the high end of the curve in figure 5 had Hg_T concentrations of about 1,000 ng/g (before normalizing to LOI).

The importance of atmospheric deposition relative other Hg sources within each

study basin was assessed by normalizing sediment Hg_T concentrations to estimated current atmospheric deposition rates for each study basin and LOI. In essence, this calculation produces an index of atmospheric Hg accumulation (AHA). High AHA values would be diagnostic of study basins having Hg sources other than atmospheric deposition, and low index values would suggest the atmosphere is the dominant Hg source for the basin. The AHA values for all 21 study basins are shown in table 3. Those study basins with the six highest AHA indices were heavily contaminated with metals from mining. Interestingly, the next highest AHA index value is for the Oahu study basin, which has no known mining contamination sites. One likely Hg source for Hawaii is the Kilauea volcano. Volcanoes are known to emit gaseous Hg vapors; however, quantitative estimates of Hg emissions and their impacts are scarce. Although not a precise estimate, this analysis suggests Hg from Kilauea is depositing on Oahu Island at a rate similar to loading from areas where mining activity is pervasive. After the Oahu study basin, the next highest AHA value was for the Yellowstone study basin. One likely Hg source for this study basin is the numerous hot springs that are known to have high mercury concentrations (Rytuba, 1997). The remaining study basins all had AHA values that were notably lower. Many of these study basins were heavily urbanized, yet the AHA values suggested that the atmosphere was the dominant Hg source for these areas. It should be noted that several of these areas have relatively high Hg_T concentrations in sediment, such as the New England Coastal Basins, but that apparently most of this mercury can be accounted for by high atmospheric deposition rates. Ecosystem effects from pending legislation to reduce atmospheric mercury emissions would likely be most effective in such areas. The Southern Florida study basin, which had the lowest AHA value, provides a calibration point for this index, given that recent studies have demonstrated that atmospheric deposition is the dominant source of mercury to the Everglades (Guentzel and others, 1995).

Methylation efficiency is a critical factor affecting the susceptibility of ecosystems to bioaccumulation. Actual methylation rate estimates would be expensive to perform on a national basis, but the $MeHg/Hg_T$ ratio in sediments and water provides a reasonable predictor of methylation efficiency (Gilmour and others, 1998). Table 3 lists the average MeHg concentration in sediments and the average $MeHg/Hg_T$ ratio for sediment and water for each study basin. Both of these measures identify the New England Coastal Basins, Santee Basin, Long Island and N. J. Coastal Drainages, and Southern Florida as systems having enhanced methylation efficiency. All of these areas have widespread advisories for high Hg concentrations in game fish.

Table 3. Summary data for the 21 study basins.

Site Abbrev.	Hg Atm. Dep. Rate ($\mu/m^2/y$)[1]	AHA Index[2]	Sed. MeHg (ng/g)	$MeHg/Hg_T$ Ratio[3]
ACAD	4	170	0.17	0.05
ALMN	18	80	0.48	0.02
COOK	1	3,828	1.24	0.03
DELR	25	31	0.77	0.03
GRSL	2	4,533	2.45	0.01
LINJ	27.5	19	6.23	0.06
LTEN	7.5	146	0.65	0.01
MIAM	17	114	0.51	0.03
MOBL	8	126	0.24	0.02
NECB	27.5	182	7.28	0.09
NROK	1.5	20,584	3.52	0.02
NVBR	1	29,817	2.00	0.02
OAHU	1	963	1.10	0.01
SACR	1.5	1,891	0.91	0.01
SANA	2	188	2.30	0.05
SANT	7.5	35	3.60	0.11
SOFL	25	9	5.05	0.10
TRIN	5	114	0.28	0.01
UCOL	1	1,153	1.03	0.04
UIRB	10	110	0.99	0.06
YELL	1	545	1.04	0.04

[1]Estimated from USEPA, 1997.
[2]Average Hg_T concentration observed for each study basin normalized to the atmospheric deposition rate and the average loss on ignition percentage of sediment.
[3]Average value for the $MeHg/Hg_T$ ratio for sediment and water.

All of the study basins were heterogeneous with respect to land cover and use. For the purposes of this analysis, the sub-basins above each of the sampling sites were categorized into one of the five following broad classes: agriculture dominant (Ag); mixed agriculture and forest (A/F); background or reference site for the

study basin (Bkg); current or abandoned mining activity near sampling site (Mine); and urban or industrial activity near sampling site (Urb) (table 2). Total and methyl mercury concentrations in sediment and water differ significantly among these broad categories (table 4).

Table 4. Summary data for Hg_T and MeHg by land use/cover category.

Land use/cover (N)[1]	MeHg (ng/L)	Hg_T (ng/L)	MeHg (ng/g)	Hg_T (ng/g)
A/F (11)	0.48	5.59	2.73	34.07
Ag. (30)	0.15	10.76	1.20	73.34
Bkg (21)	0.13	3.43	2.10	104.9
Mine (14)	0.10	84.43	1.89	788.2
Urb. (30)	0.09	3.34	2.07	218.6

[1]Land use/cover definitions are found in table 2, N is the number of sampling sites falling each categories.

Sub-basins with mining operations present had the highest Hg_T concentrations in sediment and water, but MeHg levels were relatively low. Interestingly, sub-basins described as mixed agriculture and forest had the lowest average Hg_T concentration in sediment, yet the highest MeHg levels in sediment and water. Thus, the mixed agriculture and forest land type had the highest methylation efficiency, whereas mining and urban areas had the lowest (figure 6).

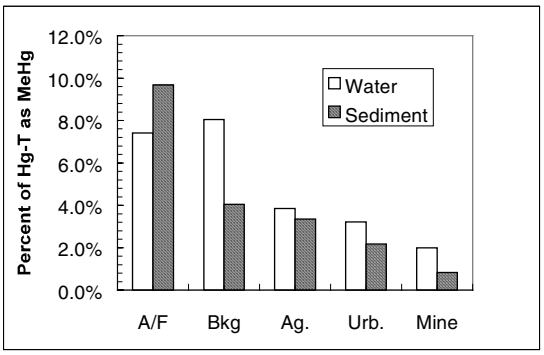

Figure 6. Average, normalized (to LOI) sediment MeHg versus Hg_T for the 21sub-basins sampled for this study.

SUMMARY

The concentrations of Hg_T and MeHg in sediment and water collected at 106 sites from 21 basins across the United States ranged widely. Variability in these data were expected, given the wide array of environmental settings, water chemistry, and Hg loading represented. Wetland density was found to be the most important basin-scale factor controlling MeHg production. By normalizing the sediment Hg_T and MeHg data to LOI, a logarithmic relation between Hg_T and MeHg was revealed. Methylmercury production appears proportional to Hg_T concentrations at low sediment Hg_T levels. At high Hg_T levels (<1,000 ng/g), however, little additional MeHg was evidently produced with increasing Hg_T. By normalizing the sediment Hg_T concentrations to LOI and the estimated atmospheric deposition rate for each study basin, a useful index (AHA) for assessing areas where atmospheric deposition is the dominant Hg source was obtained. Surprisingly, this index indicated that a significant Hg source other than atmospheric deposition exists for the Oahu study basin. Volcanic activity was a likely source of mercury in this basin. The New England Coastal Basins, Santee Basin, Long Island and N.J. Coastal Drainage, and Southern Florida showed the greatest methylation efficiency as reflected by the $MeHg/Hg_T$ ratio in sediments. That all of these sites had low AHA indices suggests that pending emission reductions might be especially effective in these areas. Sub-basins characterized as mixed agriculture and forested had the highest methylation efficiency, whereas areas affected by mining were the lowest. This study was designed as a "pilot" effort to test whether multi-media sampling for low-level Hg determinations could be effectively conducted. While the spatial coverage of sampling was good, the site density (106 sites nationally) is probably not adequate for making final conclusions about mercury contamination of aquatic ecosystems across the United States. More detailed sampling, including sampling for seasonal differences, across this same series of study basins is needed to provide a more thorough analysis of what controls Hg methylation, partitioning, and bioaccumulation at national scales.

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Table 2. Study basin names, type, percent wetland area of sub-basin, and analytical results from the sediment (dry weight) and water samples.[-- indicate no data, ng/L (nanograms per liter); ng/g (nanograms per gram); mg/L (milligrams per liter)]

Study Basin	Site Name	Site[1] type	% Wet-Land[2]	Water					Sediment		
				MeHg (ng/L)	Hg_T (ng/L)	TOC (mg/L)	pH	SO_4 (mg/L)	MeHg (ng/g)	Hg_T (ng/g)	LOI[3] (%)
ACAD	Mermentau R. @ Mermentau	Urb.	--	0.09	1.11	8.9	7.5	3.6	0.06	157.0	7.87
ACAD	Calcasieu River @ Kinder	A/F	--	0.15	3.68	5.2	6.8	3.7	0.05	1.9	0.26
ACAD	Bayou Boeuf	Urb.	--	0.05	1.66	8.6	8.9	21.06	0.10	53.5	5.93
ACAD	Turtle Bayou nr B. Penchant	Bkg.	--	0.03	1.03	8.6	7.4	29.07	0.41	83.6	32.46
ACAD	Bayou Lacassine	Ag.	--	0.46	1.61	11.1	6.7	3.03	0.26	88.1	10.06
ALMN	Youghiogheny R.	Mine	2	0.02	1.16	2.1	7.6	94	0.52	96.78	4.01
ALMN	Allegheny R. @ New Kensing.	Urb.	1	0.01	0.85	1.8	7.8	86	0.27	56.51	4.10
ALMN	Dunkard Crk. @ Shann.	Mine	0	0.04	0.64	2.6	7.5	195	0.15	12.8	4.26
ALMN	Tenmile Crk @ Amity	Bkg.	0	0.10	2.48	3.9	7.7	31	0.38	20.7	3.04
ALMN	Clarion River	Mine	1	0.09	8.09	4.2	7.4	39	1.08	76.5	2.81
COOK	Chester Creek	Urb.	0	0.02	2.96	3.8	8	28	0.38	109.9	3.24
COOK	SF Campbell Creek	Bkg.	0	0.02	2.50	1.6	7.8	9.3	0.67	200.0	2.83
COOK	Deshka River	Bkg.	39	--	--	8.4	6.8	0.2	5.10	21.0	4.07
COOK	Johnson R. abv Lateral Glacier	Bkg.	0	0.02	9.78	0.7	7.7	6.1	0.01	50.4	0.79
COOK	Costello Creek	Bkg.	0	0.02	4.97	0.7	8.1	41	0.04	169.1	3.45
DELR	Little Neshaminy Ck.	Ag.	0	0.10	4.08	4.9	7.8	39	0.38	40.1	3.04
DELR	Tulpehocken Creek	Ag.	1	0.09	2.14	2.7	7.9	28	0.57	45.8	6.46
DELR	Hay Creek nr Birdsboro, PA	Ag.	1	0.04	0.77	1.4	7.8	24	1.64	36.4	5.45
DELR	Manataway Creek	Urb.	0	0.06	1.37	3.3	8.7	17	1.08	62.8	8.85
DELR	Raccoon Ck. @ Swedesboro	Ag	5	0.05	1.11	2.9	7.3	21	0.20	33.9	4.49
GRSL	Cub River nr. Richmond, UT	Ag.	0	0.03	2.60	2.1	8.5	9.9	0.14	11.3	1.80
GRSL	Weber River nr. Coalville, UT	Mine	13	0.10	21.76	3.1	8.5	14.0	4.02	1041	7.13
GRSL	Jordan River @ Salt L. City, UT	Urb.	2	0.03	4.80	3.3	7.5	217.6	3.20	116.3	3.97
LINJ	Passaic River, Millington, NJ	Urb..	37	0.24	2.72	5.5	6.9	15	2.67	89.8	15.20
LINJ	Swan River	Urb..	0	0.06	2.13	2.4	6	11	10.85	161.4	34.69
LINJ	Muddy Run	Ag.	30	0.06	2.25	3.9	7.3	10	6.03	252.3	43.48
LINJ	Great Egg @ Sicklerville	A/F	19	0.35	12.26	3.4	5.8	8.4	5.36	31.8	8.96
LTEN	Seqwatchie R. @ Whitnell, TN	A/F	--	0.01	1.38	1.4	7.6	6.7	0.18	10.4	2.32
LTEN	Buffalo River, Flatwoods, TN	Bkg.	--	0.01	1.45	0.9	7.2	6.1	0.64	47.7	2.88
LTEN	Indian Creek nr Madison, AL	Urb..	--	0.03	3.40	1.6	7.2	7.2	1.14	66.4	6.18

Table 2. Site names, type and analytical results from the sediment and water samples—Continued

[-- indicate no data]

Study Basin	Site Name	Site[1] type	% Wet-Land[2]	Water					Sediment		
				MeHg (ng/L)	Hg_T (ng/L)	TOC (mg/L)	pH	SO_4 (mg/L)	MeHg (ng/g)	Hg_T (ng/g)	LOI[2] (%)
MIAM	Stillwater R. on Springfield Rd	Ag.	1	0.05	2.10	3.3	7.6	56.87	0.17	34.0	1.04
MIAM	Great Miami R.	Ag.	1	0.05	2.52	3.4	7.9	64.2	0.34	31.4	1.41
MIAM	Mad R., Hwy 41, Springfield	Ag.	0	0.08	0.79	2.1	8.0	61.5	1.54	30.8	2.27
MIAM	Holes Creek	Urb..	0	0.05	1.10	2.5	7.8	37.23	0.26	10.5	1.02
MIAM	Great Miami R., Hamilton, OH	Urb..	1	0.19	3.00	5.0	8.4	73.5	0.67	87.2	2.36
MIAM	Whitewater R. @ Nulltown, IN	Ag.	0	0.03	0.81	1.9	7.7	33.67	0.43	11.7	1.51
MIAM	Little Miami R. @ Milford, OH	Urb.	0	0.05	1.57	3.5	8.3	49.3	0.45	9.2	1.12
MIAM	EF L. Miami R., @ Williamsburg	Ag.	0	0.07	2.09	4.4	8.3	44.9	0.24	13.3	1.03
MOBL	Shades Ck. @ Homewood, AL	Urb..	--	0.04	1.31	2.6	8.2	--	0.17	15.2	1.42
MOBL	Cahaba Valley Creek	Urb..	--	0.02	0.97	1.7	6.7	--	0.31	34.8	3.54
MOBL	Satilpa Ck.nr Coffeeville, AL	A/F	--	0.07	2.09	3.8	7.5	--	0.18	11.8	1.06
MOBL	Chickasaw Creek	A/F	--	0.21	2.27	5.5	6.3	--	0.65	11.1	2.11
MOBL	Alabama River @ Clairborne	Ag.	--	0.04	1.78	4.4	7.8	--	0.15	19.5	2.38
MOBL	Coosa River @ Rome	Ag.	--	0.04	4.68	2.4	7.5	--	0.15	33.2	1.74
MOBL	Tombigbee R. @ Coffeeville	Urb..	--	0.04	2.74	4.3	7.9	--	0.06	26.3	2.81
NECB	Stillwater River, Sterling, MA	Bkg.	2	0.25	0.53	2.1	6.6	10.9	7.02	72.9	17.45
NECB	Neponset R. @ Norwood, MA	Urb..	16	0.28	4.40	6.6	6.6	7.9	7.93	2477	20.23
NECB	Ipswich R. nr S. Middleton, MA	Urb..	27	0.44	2.72	7.0	6.6	15.6	9.91	380.0	22.54
NECB	Saugus R. @ Saugus Iron.	Urb..	34	0.11	2.79	4.4	7	19.5	4.41	309.2	16.70
NECB	Aberjona River	Urb..	2	0.08	9.11	4.0	6.5	24.4	7.14	1488	17.36
UCOL	Red Mountain Creek	Mine	0	0.02	1.68	0.4	3.3	484	0.13	107.2	6.40
UCOL	Dry Creek @ Begonia Road	Ag.	1	0.15	6.05	3.9	8.2	467	1.68	37.4	3.82
UCOL	Snake River @ Peru Creek	Mine	0	0.02	0.48	1.3	6.7	46	0.28	56.2	7.45
UCOL	French Gulch nr Breckenridge	Mine	0	0.02	0.64	1.4	7.8	63	0.21	113.2	5.76
UCOL	Colorado River @ Baker Gulch	Bkg.	13	0.05	0.57	1.3	7.8	6.2	2.84	27.4	6.18
NROK	Flathead River @ Perma, MT	Ag.	1	0.01	1.14	1.7	8.1	2.7	0.18	19.2	1.62
NROK	Clark Fork @ Turah Bridge	Mine	0	0.09	5.57	2.0	8.6	39.6	3.75	337.7	3.27
NROK	Clark Fork@ St. Regis, MT	Ag.	1	0.02	1.53	1.5	8.1	12.8	3.39	41.4	1.85
NROK	MF Flathead R. nr W. Glacier.	Bkg.	0	0.01	1.63	0.7	8.5	4.5	2.10	24.0	3.53
NROK	S. Fork Coeur d'Alene	Mine	0	0.01	8.91	0.6	7.0	61	8.21	4517	5.73
NVBR	Carson @ Dresslerville	Mine	0	0.16	3.42	1.5	8.3	24	2.73	66.2	5.53

Table 2. Site names, type and analytical results from the sediment and water samples—Continued
[-- indicate no data]

Study Basin	Site Name	Site[2] type	% Wet-Land[2]	Water					Sediment		
				MeHg (ng/L)	Hg_T (ng/L)	TOC (mg/L)	pH	SO_4 (mg/L)	MeHg (ng/g)	Hg_T (ng/g)	LOI[2] (%)
NVBR	Carson @ Markleeville	Bkg.	0	0.08	4.74	1.3	8.31	--	0.55	45.3	5.69
NVBR	Carson @ Deer Run Rd.	Ag.	3	0.68	31.08	6.9	8.1	52	1.21	78.4	1.73
NVBR	Carson @ Fort Churchill	Mine	2	5.12	1106	4.7	8.2	77	4.20	4130	3.33
NVBR	Carson @ Tarzan Rd.	Ag.	4	1.34	204.57	5.5	8.4	145	1.34	778.3	0.82
OAHU	S. Fork Lake Wilson	Urb..	--	0.12	1.93	3.3	6.8	--	1.18	300.2	17.02
OAHU	Kawainui Canal	Bkg.	--	0.02	1.00	3.1	7.0	--	0.64	106.2	41.79
OAHU	Ala Wai Canal	Urb..	--	0.01	1.17	0.6	8	--	0.34	255.7	21.62
OAHU	Nuuanu Reservoir	Ref	--	0.10	24.27	2.5	7.8	--	0.46	291.2	23.97
OAHU	Waikele Stream	Ag.	--	0.01	1.27	0.8	7.2	--	3.55	186.0	15.95
SACR	Bear River @ Hwy 70	Mine	0	0.24	17.82	3.5	7.4	5.6	0.55	176.8	2.89
SACR	Putah Creek @ Davis	Mine	0	0.05	4.10	2.3	8	28	0.27	275.6	3.86
SACR	Cottonwood Creek	Mine	0	0.03	1.02	1.5	8.5	10.8	0.36	26.3	2.61
SACR	Sacramento Slough	Ag.	2	0.15	10.19	3.2	7.9	7.9	2.84	128.5	7.07
SACR	Colusa Basin Drain	Ag.	2	0.08	6.90	5.9	7.9	55.3	0.52	53.3	6.85
SANA	Santa Ana R. blw Prado Dam	Urb..	0	0.14	14.67	4.8	7.8	105	1.47	45.6	5.77
SANA	Mill Ck. @ Chino-Cor. Rd.	Urb..	--	0.08	2.99	6.9	10.0	53.8	1.29	30.3	7.75
SANA	Santa Ana R. @ Hamner Rd.	Urb..	--	0.03	3.71	3.0	8.2	94.4	1.70	24.3	5.02
SANA	Santa Ana R. @ MWD Cross.	Urb..	--	0.05	2.28	2.3	8.1	87.6	3.42	27.3	5.81
SANA	S. Fork, Santa Ana River	Bkg.	0	0.02	0.61	0.6	7.7	1.4	3.65	28.8	17.22
SANT	NF Edisto R. nr Fairview Cross	A/F	16	0.32	3.77	4.8	6.1	1.1	6.80	86.6	12.04
SANT	NF Edisto River nr Branchville	A/F	16	1.48	9.41	3.8	6.4	2.9	2.50	6.1	15.46
SANT	SF Edisto River @ Springfield	A/F	16	0.41		3.0	6.3	--	2.70	41.5	28.09
SANT	SF Edisto River, Canaan	A/F	20	0.40	7.27	5.9	6.4	2.1	3.10	69.4	31.03
SANT	Edisto River, Givhans	A/F	36	1.36	8.18	4.6	6.6	4	5.80	70.1	21.31
SANT	Saluda River, Silverstreet, SC	Bkg.	0	0.09	1.05	2.9	7.1	5.5	0.70	23.9	6.67
SOFL	WCA 2, site U3	Bkg.	50	0.61	3.50	24.0	7.5	25.6	2.70	194.0	91.00
SOFL	WCA 2, site 2BS	Bkg.	50	0.45	2.10	18.0	6.9	10.2	3.90	234.0	90.00
SOFL	WCA 3, site 3A15	Bkg.	50	0.50	1.90	16.0	7.1	0.5	7.80	288.0	92.00
SOFL	Everglds. Natl. Pk., site TS7	Bkg.	50	0.20	2.38	12.0	6.8	0.5	5.80	145.0	90.00
TRIN	Trinity River nr Crockett, TX	Urb.	0	0.02	6.50	5.8	7.5	--	0.28	30.6	4.42
TRIN	Lake Livingston	Urb.	1	0.02	1.34	6.0	--		0.20	45.2	7.59
TRIN	White Rock Ck. Dallas, TX	Urb.	0	0.04	1.65	4.9	--	--	0.14	8.6	
TRIN	White Rock Lake, Dallas	Urb.	0	0.02	1.24	5.6	7.9	--	0.52	55.4	6.24

Table 2. Site names, type and analytical results from the sediment and water samples—Continued
[-- indicate no data]

Study Basin	Site Name	Site[1] type	% Wet-Land[2]	Water					Sediment		
				MeHg (ng/L)	Hg_T (ng/L)	TOC (mg/L)	pH	SO_4 (mg/L)	MeHg (ng/g)	Hg_T (ng/g)	LOI[2] (%)
TRIN	Clear Crk. @ Sanger	Bkg.	0	--	--		8.0	55	0.23	5.9	2.18
UIRB	Des Plaines River	Ag.	15	0.10	4.18	11.4	7.5	94	3.58	11.6	1.40
UIRB	Nippersink Ck. bv Wonder L.	Ag.	0	0.04	1.42	3.5	7.8	64	0.08	8.7	2.30
UIRB	Salt Creek @ W. Springs, IL	Urb..	0	0.13	9.26	6.3	7.3	89	1.10	46.8	3.29
UIRB	Pitner Ditch nr LaCrosse, IN	Ag.	0	0.03	0.27	3.1	7.8	89	0.09	9.1	1.66
UIRB	Mukwanago R. @ Mukwanago	Ref	3	0.06	1.48	6.9	8.0	--	0.11	31.6	1.15
YELL	Bighorn River nr. Kane	Ag.	1	0.13	3.89	3.7	8.4	170	0.60	16.3	2.09
YELL	Bighorn Lake @ Hwy14A	Ag.	1	0.10	2.48	3.8	8.3	190	0.59	33.0	5.31
YELL	Shoshone River	Ag.	0	0.13	5.31	4.2	8.1	240	0.53	11.1	1.83
YELL	Tongue River	Ag.	4	0.06	1.87	3.4	8.5	94	3.05	27.7	8.23
YELL	Yellowstone R. near Sidney	Ag.	1	0.15	4.07	2.9	8.6	110	0.45	18.7	2.14
Summary Statistics											
Mean				0.15	16.6	4.15	5.3	55.5	1.87	211	11
Median				0.06	2.28	3.4	7.7	28	0.62	46.3	4
Std. Dev.				0.26	110.4	3.57		83.7	2.39	648	18
Coeff. of Variation				1.73	6.63	0.86		1.51	1.27	3.06	1.64
Minimum				0.01	0.27	0.4	3.3	0.2	0.01	1.85	0.0
Maximum				1.481	1106.7	24	10.09	484	10.851	4517	92
N				104	103	105	104	84	106	106	105

[1]General site categories for the sampling locations within each study basin:

Ag. = agriculture dominant.
A/F = agriculture and forested mix.
Bkg. = Background or reference site.
Mine = Current or abandon mining activity near sampling site.
Urb. = Urban or industrial activity near sampling site.

[2]Percent of each sub-basin classified as wetland areas.

[3]Percent of dry sediment mass lost on ignition (LOI) after firing to 550°C for two hours.

DEVELOPMENT OF FISH CONTAMINANT GOALS AND ADVISORY TISSUE LEVELS FOR COMMON CONTAMINANTS IN CALIFORNIA SPORT FISH:

CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

June 2008

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FOREWORD

This report describes the process of developing Fish Contaminant Goals and Advisory Tissue Levels for evaluating methylmercury, chlordane, DDTs, dieldrin, PCBs, selenium, and toxaphene, common contaminants in California sport fish. Fish provide unique nutritional benefits while also serving as a significant exposure pathway for several chemicals of concern. Fish Contaminant Goals (FCGs) are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs prevent consumers from being exposed to more than the daily RfD for non-carcinogens or to a risk level greater than $1x10^{-6}$ for carcinogens (not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime). FCGs are based solely on public health considerations without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption.

Advisory Tissue Levels (ATLs), while still conferring no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, were developed with the recognition that there are unique health benefits associated with fish consumption and that the advisory process should be expanded beyond a simple risk paradigm in order to best promote the overall health of the fish consumer. ATLs provide a number of recommended fish servings that correspond to the range of contaminant concentrations found in fish and are used to provide consumption advice to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). ATLs are designed to encourage consumption of fish that can be eaten in quantities likely to provide significant health benefits, while discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be eaten in amounts recommended for improving overall health (eight ounces total, prior to cooking, per week). ATLs are one of the criteria that will be used by OEHHA for issuing fish consumption guidelines.

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EXECUTIVE SUMMARY

Chemical contamination of fish is a global problem that has resulted in the issuance of fish consumption advisories in most states, including California. Although mercury contamination is a frequent basis for these advisories, polychlorinated biphenyls (PCBs) and chlorinated pesticides such as chlordane and dichlorodiphenyltrichloroethane (DDT) are also often implicated. In California, the Office of Environmental Health Hazard Assessment (OEHHA) is the agency solely responsible for evaluating the potential public health risks of chemical contaminants in sport fish and issuing state advisories, when appropriate. OEHHA is also consulted by other agencies interested in assessing the health risks of fish consumption during the process of developing water quality or clean-up "criteria." There are key differences between fish consumption advisories and other environmental risk criteria; advisories consider the significant benefits of fish consumption, while criteria may be strictly risk-based and may not take into account other factors.

In order to develop water quality criteria or fish consumption advisories, appropriate toxicity values for a chemical must be established. In this document, cancer and non-cancer health effects were evaluated for seven common contaminants found in California sport fish: chlordane, DDT and its metabolites (DDTs), dieldrin, mercury (as methylmercury), PCBs, selenium, and toxaphene. For each chemical, the toxicological literature was reviewed to establish an acceptable non-cancer reference dose (RfD; an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime) and/or a cancer slope factor (an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen).

Fish Contaminant Goals (FCGs) were then developed for these seven contaminants. FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs prevent consumers from being exposed to more than the daily RfD for non-carcinogens or to a risk level greater than $1x10^{-6}$ for carcinogens (not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime). FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption. FCGs were developed using an 8-ounce (227 g) serving size (prior to cooking; approximately six ounces after cooking) for adults who weigh 70 kg.

As a prelude to developing tissue-based values to be used for advisories, OEHHA reviewed the scientific literature on the benefits of fish and fish oil consumption. Although decreased incidence of coronary heart disease is perhaps the most recognized benefit of fish consumption, there is considerable evidence that other, particularly

inflammatory, disorders may also be mitigated or prevented by inclusion of fish in the diet. Additionally, maternal fish consumption is likely to provide cognitive benefits to the fetus. Following this review, OEHHA determined that there is a compelling body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality. With the recognition that there are unique health benefits associated with fish consumption, it was concluded that the advisory process should be expanded beyond a simple risk paradigm, as is used in criteria development, in order to best promote the overall health of the fish consumer.

The first step in the advisory process, then, was to develop Advisory Tissue Levels (ATLs). ATLs were calculated using the same general formulas as those used to calculate FCGs, with some adjustments in order to incorporate the benefits of fish consumption. ATLs provide a number of recommended fish servings that correspond to the range of contaminant concentrations found in fish and are designed to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). The use of ATLs still confers no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, while encouraging consumption of fish that can be eaten in quantities likely to provide significant health benefits and discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be recommended in amounts suggested for improving overall health (i.e., eight ounces total, prior to cooking, per week).

ATLs are used as part of the process to develop traditional health advisories (which focus on fish whose consumption should be avoided) as well as the newer "safe eating guidelines," which inform consumers of fish with low contaminant levels considered safe to eat frequently. ATLs should not be misinterpreted as static "bright lines" that others can use to duplicate state fish consumption advisories. ATLs are but one component of a complex process of data evaluation and interpretation used by OEHHA in the assessment and communication of fish consumption risks. The nature of the contaminant data or omega-3 fatty acid concentrations in a given species in a water body, as well as risk communication needs, may alter strict application of ATLs when developing site-specific advisories. OEHHA will use the guidelines set forth in this report as a framework, along with best professional judgment, to provide fish consumption guidance on an *ad hoc* basis that best combines the need for health protection and ease of communication for each site.

This document represents current knowledge of the toxicity of seven common fish contaminants and the overall benefits of fish consumption; FCGs and ATLs for individual chemicals may be revised, if necessary, as information becomes available. FCGs and ATLs may also be developed in the future for additional contaminants, as appropriate, using the same methodology.

INTRODUCTION

Fish consumption advisories have been issued in most states and cover approximately 35 percent and 24 percent of the country's total lake acreage and river miles, respectively (U.S. EPA, 2004a). Mercury contamination of fish, in particular, is a national problem that resulted in the issuance of 222 new advisories in 2003 alone (U.S. EPA, 2004a). Polychlorinated biphenyls (PCBs) and chlorinated pesticides such as chlordane and dichlorodiphenyltrichloroethane (DDT) are also a frequent basis for fish consumption advisories throughout the United States (U.S. EPA, 2004a). In California, the Office of Environmental Health Hazard Assessment (OEHHA) is the agency responsible for evaluating potential public health risks from chemical contamination of sport fish. This includes issuing state advisories, when appropriate, based on mandates in the California Health and Safety Code, Section 59009, to protect public health, and Section 59011, to advise local health authorities, and the California Water Code, Section 13177.5, to issue health advisories. OEHHA is also consulted by other agencies interested in assessing the health risks of fish consumption during the process of developing water quality or clean-up "criteria." There are key differences between fish consumption advisories and other environmental risk criteria; advisories consider the significant benefits of fish consumption, while criteria may be strictly risk-based and may not take into account other factors.

In order to develop advisories or criteria, appropriate toxicity values for a chemical must be established. In this document, cancer and non-cancer health effects were evaluated for seven common contaminants found in California sport fish: chlordane, DDT and its metabolites (DDTs), dieldrin, mercury (as methylmercury), PCBs, selenium, and toxaphene. For each chemical, the toxicological literature was reviewed to establish an acceptable non-cancer reference dose (RfD; an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime) and/or a cancer slope factor (an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen). Limited background information on the chemistry, environmental fate, metabolism, and typical exposure routes for each chemical is also provided.

Fish Contaminant Goals (FCGs) were then developed for these seven contaminants. FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption.

FCGs for non-cancer risk for non-nutrients were derived from the following basic equation:

$$\text{Tissue concentration} = \frac{(\text{Reference dose})(\text{Body weight})}{\text{Daily consumption rate}}$$

FCGs for cancer risk for non-nutrients were derived from the following basic equation:

$$\text{Tissue concentration} = \frac{(\text{Risk level})(\text{Body weight})}{(\text{Cancer slope factor})(\text{Daily consumption rate})}$$

Additional discussion and examples of FCG development can be found in the section "Equations used to calculate Fish Contaminant Goals."

As a prelude to developing tissue-based values to be used for advisories, OEHHA reviewed the scientific literature on the benefits of fish and fish oil consumption to determine to what degree the advisory process should be expanded beyond a simple risk paradigm, as is used in criteria development, in order to best promote the overall health of the fish consumer. Advisory Tissue Levels (ATLs), while still conferring no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, use the same general equations as those used to develop FCGs, with some adjustments to take into account benefits that are provided by fish consumption. ATLs were designed to encourage consumption of fish that can be eaten in quantities likely to provide significant health benefits, while discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be recommended in amounts suggested for improving overall health (i.e., eight ounces total, prior to cooking, per week).

This report provides critical toxicity values, FCGs and ATLs for seven common contaminants in California sport fish. Most fish advisories in the United States are issued for mercury, PCBs, chlordane, dioxins, and DDTs (U.S. EPA, 2005). OEHHA also included toxaphene and selenium in this document because of historic use in the state and natural occurrence, respectively. At this time, limited available analytical data for dioxins in fish throughout the state do not show widespread or high dioxin contamination. Several former point sources have been eliminated and subsequent concentrations in fish at associated sites were below a level of concern (Fan, 1994). Consequently, OEHHA did not develop an FCG or ATLs for dioxins at this time. However, FCGs and ATLs may be developed in the future for dioxins or other contaminants, as resources permit, using the same methodology. OEHHA staff is available for consultation on any fish contaminant of concern.

TOXICOLOGY AND CRITICAL TOXICITY VALUES FOR COMMON CONTAMINANTS IN CALIFORNIA SPORT FISH

CHLORDANE

CHLORDANE TOXICOLOGY

Chlordane is a chlorinated cyclodiene insecticide that was used in the United States beginning in 1948 for a variety of agricultural and structural pest control purposes (ATSDR, 1994; Ecobichon, 1991; Matsumura, 1985; U.S. EPA, 1997). Technical chlordane, the commercial mixture, is comprised of approximately 60 percent *cis* and *trans* chlordane isomers and about 40 percent other related compounds (e.g., *cis*-nonachlor, *trans*-nonachlor and oxychlordane) (U.S. EPA, 1997). As a result of their lipophilicity, low volatility and slow degradation rates, chlordane and other organochlorine pesticides are exceptionally persistent in the environment and are able to bioconcentrate and biomagnify throughout the food chain (Ecobichon, 1991). Bioconcentration factors (the quotient of the concentration of a chemical in an organism divided by the concentration of the chemical in the ambient water) for chlordane in various marine and freshwater fish, for example, have been reported as high as 3,000 to 37,800 (ATSDR, 1994; Fisher, 1999). Because of this, as well as concerns over human cancer risk and hazards to wildlife, the use of chlordane was severely restricted in the United States in 1978 and ultimately banned in 1988 (ATSDR, 1994; U.S. EPA, 2000). Chlordane remains a contaminant in many soils and waterways, however, with the most frequent source of human exposure being consumption of contaminated foods, especially fish (ATSDR, 1994). Saltwater and fresh water fish and shellfish, combined, account for approximately 95 percent of the total dietary exposure to chlordane (Dougherty et al., 2000).

Chlordane is readily absorbed by all exposure routes (ATSDR, 1994). Once absorbed, chlordane is rapidly distributed to the liver and kidneys, whereupon it undergoes transformation to a number of metabolites. Chlordane excretion is mainly through bile and breast milk (ATSDR, 1994). Chlordane that is not excreted is deposited in adipose tissue, primarily as the metabolites oxychlordane and heptachlor epoxide (ATSDR, 1994; U.S. EPA, 1997). The elimination half-life of chlordane in humans reported in different studies has ranged from 21to 88 days (Aldrich and Holmes, 1969; ATSDR, 1994; Curley and Garrettson, 1969; Olanoff et al., 1983).

The Agency for Toxic Substances and Disease Registry (ATSDR, 1994), U.S. Environmental Protection Agency (U.S. EPA, 1997), and OEHHA (1997) have extensively reviewed the toxicity of chlordane. Following acute oral exposures (14 days or less), chlordane is considered moderately to highly toxic to humans (U.S. EPA, 2000). The World Health Organization (WHO, 1984) estimated the acute human lethal dose to be between 25 and 50 mg/kg body weight. Acute poisoning symptoms include vomiting, diarrhea, seizures, anuria, ataxia, tremors, coma, and respiratory failure (ATSDR, 1994;

Curley and Garrettson, 1969; NIOSH, 1981, 2003; Olanoff et al., 1983), and can occur within 45 minutes of exposure (Grutsch and Khasawinah, 1991). The difference between the no-effect and the fatal serum levels in humans is small (approximately 3 to 5 times), indicating a steep dose-response curve (Grutsch and Khasawinah, 1991). Death is rare following acute oral poisoning, however, because the individual generally vomits, reducing the available dose (Grutsch and Khasawinah, 1991). Apparent recovery in non-fatal cases is rapid (Aldrich and Holmes, 1969; Curley and Garrettson, 1969; Grutsch and Khasawinah, 1991), although chemical hepatitis may develop subsequent to the acute phase (Olanoff et al., 1983). Acute chlordane toxicity in animals also results in neurotoxicity signs such as hyper-excitability, tremors, convulsions, hind limb paralysis and hypothermia (ATSDR, 1994; Grutsch and Khasawinah, 1991). Like other cyclodiene insecticides, the mechanism of neurotoxic action is believed to be inhibition of chloride transport, causing incomplete repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999).

Subchronic or chronic chlordane toxicity in humans has been difficult to quantify because of problems with dose determination and confounding exposures. Some humans living in chlordane-treated homes have developed hepatic and neurological signs such as jaundice and grand-mal seizures, respectively. The exact dose-response relationship has not been determined, however (ATSDR, 1994). In their review of the literature, Grutsch and Khasawinah (1991) reported that chronic, low-level chlordane exposure via inhalation, oral, or dermal routes has not been found to elicit signs or symptoms indicative of chlordane toxicity. ATSDR (1994) also noted that adverse health effects resulting from chlordane exposures have not been confirmed in studies of workers engaged in the manufacture of chlordane. More recent epidemiological studies, though, have indicated that chlordane may cause neurotoxicity following chronic exposures in humans (IRIS, 1998). In a cross-sectional study, Kilburn and Thornton (1995) found that neurobehavioral functions such as reaction times, verbal recall, and trail-making were impaired in 216 adults exposed to chlordane via inhalation compared to an unexposed referent population matched by age and educational level. However, effect levels could not be assigned because data on exposure, dose-response or potential co-exposure to other neurotoxicants were not available (U.S. EPA, 1997). In a subsequent study of nine chlordane-exposed patients seen consecutively for effects of chemical exposure, Kilburn (1997) noted that neurobehavioral functions such as balance, reaction times, verbal recall, and color discrimination were also diminished in the exposed group compared to a control population. Exposure dose was unknown and exposure duration ranged from 50 minutes to 18 years. Potential limitations associated with experimental design, including selection bias and an inadequately matched control population, severely limit interpretation of this study.

In rodent studies, the liver is clearly the target organ of chronic chlordane toxicity and hepatic necrosis has been deemed the critical effect (U.S. EPA, 1997). Khasawinah and Grutsch (1989a, 1989b) conducted the most extensive rat and mice toxicity studies available for chlordane, at similar dose-rates, which indicated that the mouse is more susceptible to the hepatotoxic effects of chlordane than is the rat (U.S. EPA, 1997).

Additional hepatic toxicity signs in mice included increased liver weights and elevated serum aspartate transferase (AST) and alanine transferase (ALT) levels (Khasawinah and Grutsch, 1989b).

Reproductive toxicity has been shown to occur following oral exposure to relatively high levels of chlordane in male mice. Balash et al. (1987) found that mature male mice orally gavaged with chlordane for 30 days had dose-related histological changes in seminiferous tubules. Similarly, Al-Omar et al. (2000) determined that mice gavaged with approximately 20 or 70 percent of the median lethal dose of chlordane suffered damage to testicular tissues, including decreased seminiferous tubule diameter, and reduced numbers of spermatogonia, spermatocytes and spermatids.

Developmental effects have also been reported in response to chlordane exposure in mice and rats (ATSDR, 1994). A series of neurobehavioral tests given to mice offspring following third-trimester fetal exposure to chlordane found depressed avoidance response acquisition and increased seizure threshold and exploratory activity, suggesting an effect on fetal brain (ATSDR, 1994; Al-Hachim and Al-Baken, 1973). Cassidy et al. (1994) showed that male and female rats exposed to low levels of chlordane *in utero* and during the early postnatal period (Day 4 of gestation through Day 21 of lactation) had gender-dependent alterations of sexually dimorphic functions and behaviors such as spatial abilities and auditory startle-evoked responses. Based on these results, the authors suggested that chlordane mimics and/or alters sex steroid concentrations and, thus, has a masculinizing effect on fetal and/or neonatal rats. In their review of the paper, however, U.S. EPA (1997) noted that dose-response relationships were inconsistent, as effects in high-dose animals were often similar to controls. Additionally, testosterone levels in males and females were not systematically related to the observed behavioral changes. U.S. EPA thus questioned the authors' interpretation of the study results and indicated that further research was necessary to confirm a relationship between these behavioral effects and low-dose chlordane exposure.

Immunological studies in mice indicated that *in utero* and neonatal treatment with chlordane suppressed cell-mediated immunity (Barnett et al., 1985a, 1985b; 1990a, 1990b; Blaylock et al., 1990; IRIS, 1998; Menna et al., 1985). Reported effects following such chlordane exposures included decreased fetal hematopoietic activity, delayed-type hypersensitivity-mediated pathology, and mixed lymphocyte reactivity. However, in some experiments, this suppression led to increased survival following influenza virus infection during young adulthood (Barnett et al., 1985a; Blaylock et al., 1990; Menna et al., 1985). More recent research has shown a variety of immunotoxic responses of rats following 28-day oral gavage of *cis*-nonachlor, *trans*-nonachlor and technical chlordane (Tryphonas et al., 2003). In those studies, *cis*- and *trans*-nonachlor were more likely to cause immunotoxic effects than technical chlordane, with these results more pronounced in females.

Oxychlordane, one of the principal metabolites of chlordane, is the second most common chlordane-related residue found in food, following *trans*-nonachlor (Bondy et al., 2003).

A series of twenty-eight-day feeding studies in female rats showed that oxychlordane caused weight loss and histopathological changes in the liver, thymus, and thyroid and produced signs of toxicity at doses approximately eight times lower than *cis*- or *trans*-nonachlor (Bondy et al., 2003). The authors suggested that exposure to oxychlordane may prove to be a more significant human health hazard than exposure to other chlordane compounds found in foods.

Information regarding the potential carcinogenicity of chlordane in humans is conflicting. A few studies have shown an association between chronic chlordane inhalation exposure in humans and the development of various blood dyscrasias, such as leukemia (reported in ATSDR, 1994; U.S. EPA, 1997). In contrast, Brown et al. (1990; 1993) failed to find a relationship between leukemia or multiple myeloma and chlordane inhalation exposure in adult men (U.S. EPA, 1997). A retrospective mortality study of workers in the chlordane manufacturing industry (Brown, 1992) indicated that workers exposed to chlordane and other organochlorines had lower than expected mortality from all causes as well as from all malignant neoplasms (ATSDR, 1994). Yet, in two case-control studies, Cantor et al. (1992) and Woods and Polissar (1989) found that non-Hodgkin's lymphoma patients were more likely to have had previous inhalation exposure to chlordane than healthy controls, although this association was only significant in the Cantor et al. study. U.S.EPA (1997) notes that there is no evidence to support the conclusion that oral exposure to chlordane from food or drinking water causes human carcinogenicity; however, the weight of evidence following high-level, long-term dermal or inhalation exposures does suggest that chlordane is likely a human carcinogen.

The International Agency for Research on Cancer (IARC) has listed chlordane as a possible human carcinogen, based on inadequate evidence in humans and sufficient evidence in experimental animals (IARC, 2001). U.S. EPA has classified chlordane as a likely human carcinogen, based on limited epidemiological evidence in humans, development of hepatocellular carcinomas in multiple strains of mice and liver toxicity in rats, and the structural resemblance of chlordane to other rodent hepatic carcinogens (IRIS, 1998; U.S. EPA, 1997). Chlordane is on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR CHLORDANE

A chronic reference dose (RfD) is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), expressed in units of mg/kg-day (IRIS, 1995). This estimate includes a factor to account for data uncertainty. The underlying assumption of an RfD is that, unlike most carcinogens, there is a threshold dose below which certain toxic effects will not occur. The RfD for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals and/or humans. These studies are used to determine a No-Observed-Adverse-Effect-Level (NOAEL; the highest dose at which no adverse effect is seen), a Lowest-Observed-Adverse-Effect-Level

(LOAEL; the lowest dose at which any adverse effect is seen), or a benchmark dose level (BMDL; a statistical lower confidence limit of a dose that produces a certain percent change in the risk of an adverse effect) (IRIS, 1995). Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, an RfD is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the probability of adverse effects occurring has increased (IRIS, 1993).

Because chlordane dose-response data in humans are inadequate, the U.S. EPA RfD for this chemical was derived from animal data based on hepatic necrosis as the critical effect (IRIS, 1998; U.S. EPA, 1997). Although several studies have indicated that chronic chlordane exposure may also result in neurobehavioral or other neurotoxic effects, reliable dose-response information as well as data to support a plausible mode-of-action are not available for these endpoints (U.S. EPA, 1997). U.S. EPA thus chose Khasawinah and Grutsch (1989b) as the principal study for the RfD because of the clear dose-related incidence of hepatic effects, overall strength of the study, and comparatively low adverse effect level (IRIS, 1998; U.S. EPA, 1997). Newer chlordane toxicity studies published since the RfD was developed do not have sufficient data to determine acceptable exposure values and/or have not shown a lower adverse effect level.

Khasawinah and Grutsch (1989b) fed 80 ICR mice per sex per group 0, 1, 5, or 12.5 parts per million (ppm) dietary chlordane (estimated to be 0, 0.15, 0.75, and 1.875 mg/kg-day, respectively) for 104 weeks. Hepatocellular swelling was seen in both male and female mice at doses of 5 and 12.5 ppm dietary chlordane; incidence of hepatic necrosis was also significantly elevated at those dose levels, but only in male mice. Other hepatic effects, such as increased relative liver weights and alanine transferase activity, were seen at varying dose levels. The NOAEL and LOAEL values for this study were considered to be 1 and 5 ppm, respectively. To the NOAEL, U.S. EPA applied a 300-fold uncertainty factor (10 for interspecies extrapolation, 10 for intraspecies variation, and 3 for lack of a multigenerational reproductive study), leading to an RfD of $5x10^{-4}$ mg/kg-day (IRIS, 1998; U.S. EPA, 1997).

As required under Health and Safety Code Section 901(g), OEHHA developed a child-specific reference dose (chRD) for chlordane for the purpose of assessing risk at proposed or existing California school sites (OEHHA, 2005). The Cassidy et al. (1994) paper was selected as the most useful study for determination of a chRD, based on endocrine disruption in the developing offspring. Pregnant Sprague-Dawley rats were fed doses of 100, 500, or 5,000 ng/g technical chlordane from day 4 of gestation until day 21 of lactation. Offspring were dosed from postnatal day (PND) 22 to PND 80 and began behavioral testing on PND 76; serum testosterone was measured on PND 85. Body weights were significantly increased in the 500 ng/g dose group compared to controls for females only. Serum testosterone levels were significantly reduced in female offspring dosed with 500 and 5,000 ng/g, although not in a dose-dependent fashion. Male offspring showed only a slight, non-significant, reduction of serum testosterone in the highest (5,000 ng/g) exposure group. Following repeated testing in the Cincinnati water

maze, time to escape was significantly improved in female rat dosed with 100 and 500 ng/g chlordane compared to controls; male rats were not affected by treatment. Intromission latency was significantly reduced in 100 and 500 ng/g treated males; however, the high-dose group was similar to controls. Intromissions prior to ejaculation and total intromissions were significantly increased only in the 500 ng/g dose group. Latency to ejaculation was not different among groups. Open field activity was not affected by treatment in male or female offspring. In tests of reaction to auditory startle, only the maximum response parameter was significantly different from controls and only in the 100 ng/g dose group. OEHHA determined that the LOAEL from this study was 100 ng/g chlordane, based on disruption of sex hormone-mediated behaviors. To the LOAEL, OEHHA applied a 3000-fold uncertainty factor (10 for LOAEL to NOAEL, 10 for interspecies extrapolation, 10 for intraspecies variation, and 3 for inadequate database for hematotoxicity, immunotoxicity, neurotoxicity, and the lack of a valid developmental study), leading to an chRD of $3.3x10^{-5}$ mg/kg-day (OEHHA, 2005).

Although Cassidy et al. (1994) was the best study available to establish a chRD, there are significant limitations with the data as noted by U.S. EPA (1997). Nonetheless, OEHHA concludes that it is appropriate to use the chRD for developing a non-cancer FCG for chlordane. FCGs are, as noted, strictly risk-based and, thus, a study need not be eliminated from consideration solely on the basis of data strength. However, in setting an ATL, it is important to balance the risks and benefits of fish consumption (see the Advisory Tissue Level section, later in this document). For this reason, OEHHA has chosen to use the cancer risk basis for establishing the ATL for chlordane (see below), rather than non-cancer risk based on Cassidy et al. (1994), even though this results in a slightly higher ATL. Chlordane is well-established as a potential human carcinogen; thus, protection against the carcinogenic effects of chlordane is generally accepted by regulatory agencies. Additionally, the 3000-fold uncertainty factor incorporated into the Cassidy et al. study-based chRD should not be used to outweigh the certainty of benefits associated with fish consumption. In using the cancer basis for developing the ATL, OEHHA determines that there is still a large margin of safety (approximately 550- to 1,000-fold, over the range of exposures) for potential endocrine-disrupting health effects of chlordane that is adequate to protect children who would also receive the benefits from consuming fish. OEHHA similarly chose to use the cancer endpoint in developing a Public Health Goal (PHG) for chlordane in drinking water (OEHHA, 1997) although non-cancer health effects, based on the Cassidy study, would have resulted in a lower PHG. Thus, the chRD of $3.3x10^{-5}$ will be used to evaluate non-cancer risk for a chlordane FCG, but only cancer risk will be considered in the development of chlordane ATLs.

A cancer slope factor (CSF) is an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen and is expressed as $(mg/kg\text{-}day)^{-1}$ (U.S. EPA, 1989). The higher the CSF, the greater the estimated potency of a carcinogen. As is the case with noncancer endpoints, only animal data are available to quantify the carcinogenic risk of chlordane (U.S. EPA, 1997). In their 1998 cancer assessment, U.S. EPA combined the

results of five liver tumor data sets for male and female CD-1 and B6C3F1 mice and male ICR mice orally exposed to chlordane at doses from 5 to 64 ppm for a period of 78 to 104 weeks (IRDC, 1973; NCI, 1977; Khasawinah and Grutsch 1989b; U.S. EPA, 1997; IRIS, 1998). U.S. EPA used (body weight)$^{3/4}$ scaling and the linearized multistage model in Global 86 software to determine cancer potency. Individual slope factors for each of the data sets ranged from 0.114 to 0.858 (mg/kg-day)$^{-1}$; a geometric mean of these values was then calculated to derive an oral CSF for chlordane of 0.35 (mg/kg-day)$^{-1}$ (IRIS, 1998). At the time of completion of this cancer risk assessment, however, the 1996 Guidelines for Carcinogenic Risk Assessment were still in draft form (U.S. EPA, 1996). U.S. EPA noted that using the LED_{10} alternate method of low-dose extrapolation from the newer guidelines to calculate cancer potency would lead to a slope factor of 0.567 (mg/kg-day)$^{-1}$ (IRIS, 1998). These guidelines have since been finalized by U.S. EPA (U.S. EPA, 2005).

In the PHG for chlordane in drinking water developed by OEHHA, only the male and female CD-1 and B6C3F1 mice studies (IRDC, 1973; NCI, 1977) were used to determine a CSF; the male ICR mice study (Khasawinah and Grutsch,1989b) included in the U.S. EPA assessment (IRIS, 1998) was not used (OEHHA, 1997). An intercurrent mortality correction of approximately 2.4 was used to correct for less than lifetime duration of these four studies. OEHHA employed the methodology from the 1996 Guidelines for Carcinogenic Risk Assessment (U.S. EPA, 1996) to calculate CSFs for these studies. OEHHA's estimates were based on (body weight)$^{3/4}$ scaling and used Tox_Risk software to calculated the LED_{10} because, according to the author, this software had a greater ability to calculate lower bounds on doses in the observed range in the evaluated studies (OEHHA, 1997). OEHHA then calculated the geometric mean of the best fitting four data sets to determine a CSF of 1.3 (mg/kg-day)$^{-1}$. This CSF will be used to evaluate chlordane cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer value used to evaluate chlordane in fish for the development of FCGs will be **$3.3x10^{-5}$ mg/kd-day**. The cancer value used to evaluate chlordane in fish for the development of FCGs and ATLs will be **1.3 (mg/kg-day)$^{-1}$**.

DICHLORODIPHENYLTRICHLOROETHANE AND ITS METABOLITES (DDTs)

DDTs TOXICOLOGY

Dichlorodiphenyltrichloroethane (DDT) is a synthetic organochlorine insecticide once used throughout the world to control insects that transmit malaria, typhus, and other significant diseases (Crosby, 1998). First used in the United States in 1942, its registration was cancelled by U.S. EPA in 1973 after discovery of its environmental persistence, bioaccumulative properties, and induction of eggshell thinning in predatory species of birds (Hodgson et al., 1998). DDT is still used in some developing countries, however, because it is an effective and inexpensive method of vector control (ATSDR, 1994; Eicobichon, 1991). Humans are typically exposed to a mixture of DDT and its principal metabolites, DDD (tetrachlorodiphenylethane) and DDE (dichlorodiphenyl-dichloroethylene) (U.S. EPA, 2000), which are referred to collectively as total DDTs. U.S. EPA recommends that fish consumption limits be based on the sum of DDT, DDD, and DDE (i.e., total DDTs) (U.S. EPA, 2000).

DDTs are very lipid soluble and water insoluble, have relatively low volatility, and are chemically and biologically stable, which leads to their persistence in the environment and biomagnification by organisms (Ecobichon, 1991; Menzer, 1991; WHO, 1989). Bioconcentration factors as high as $1x10^6$ have been reported for DDTs in aquatic species (reported in Ecobichon, 1991). Because of their historical widespread use and chemical properties, DDTs are pervasive environmental contaminants (ATSDR, 2002).

Exposure of humans to DDTs occurs most commonly from food consumption, particularly meat, dairy products, poultry, and fish (ATSDR, 2002). Freshwater and saltwater fish, in fact, typically account for approximately 75 percent and 5 percent of the total dietary exposure to DDTs, respectively (Dougherty et al., 2000). DDTs are absorbed from the gastrointestinal tract following dietary exposure and are then distributed widely by the lymphatic system and blood before being stored primarily in high-lipid tissues such as fat, liver, kidney, and brain (ATSDR, 1994; 2002; U.S. EPA, 2000). Adipose storage of DDTs is considered protective as it lowers the concentration at the target organ (i.e., the brain) (Klaassen, 2001). DDTs are transferred across the placenta to the fetus (Saxena et al., 1981; Waliszewski et al., 2000; 2001) and easily cross the blood-brain barrier (ATSDR, 1994). Although the primary route of DDT excretion is urinary, lesser amounts are also excreted through feces and breast milk (ATSDR, 1994; 2002). Lactation is a significant means of maternal DDT decontamination (Waliszewski et al., 2001). The half-life of DDT in the body is 10-20 years (IRIS, 1996).

ATSDR (1994; 2002) has extensively reviewed the toxicity of DDT and related compounds. DDT has low acute toxicity with no confirmed human deaths reported solely from DDT exposure (ATSDR, 1994). Acute oral exposures to high levels of DDT primarily affect the nervous system in humans. DDT elicits adverse neurological effects

by inhibiting ion movement through neuronal membranes (ATSDR, 1994; 2002) and reducing the rate of depolarization, thereby intensifying the sensitivity of neurons to stimuli (Ecobichon, 2003). Symptoms have been reported to occur at doses of 5-10 mg/kg and above and include paresthesia, anxiety, irritability, vertigo, tremor, and convulsions, (ATSDR, 2002; Ecobichon, 1991; U.S. EPA, 2000). During an acute poisoning episode, tactile or auditory stimuli may induce repetitive tremors and seizures (Ecobichon, 2003).

Chronic oral exposures to moderate DDT levels have been reported to lead to anorexia and weight loss, anemia, tremors, muscular weakness, EEG changes, and anxiety in humans (Ecobichon, 1991). Similar to acute toxicity, the nervous system is considered a principal target following chronic exposure to this chemical (ATSDR, 2002). Subtle neurological deficits have been reported in humans following long-term chronic DDT exposure (van Wendel de Joode et al., 2001). Twenty-seven retired men, aged 55-70, with a history of occupational DDT exposure during the previous 41 years had exposure duration-related reduced neurobehavioral functioning and increased neuropsychological and psychiatric symptoms compared to a reference group. Performance on tests of verbal attention and visuomotor speed and sequencing were the most pronounced differences between groups. Exposure levels were not available.

A few studies have reported an association between plasma DDE levels and altered immune function in humans including lowered mitogen-induced lymphoproliferative activity, increased total lymphocytes, and either increased or decreased immunoglobulins (Vine et al., 2000, 2001; Cooper et al., 2004). Reproductive and developmental effects in humans such as alterations in the duration of lactation, maintenance of pregnancy, fertility, and length of gestation have also been associated with high levels of DDTs in blood and other body tissues (ATSDR, 2002; see, e.g., Gladen and Rogan, 1995; Longecker et al., 2001). Occasional and slight, but significant, decrements on the Bayley scales of infant development were seen in offspring at 6, 12 or 24 months of age corresponding to a ten-fold increase in maternal serum levels of *p,p*'-DDT, *o,p*'-DDT, or *p,p*'-DDE (Eskenazi et al., 2006).

While human epidemiological studies can only suggest a possible causal relationship between a chemical exposure and an adverse effect, animal studies using controlled exposures do demonstrate numerous toxic effects of DDT exposure. Similar to acute high-level DDT exposures in humans, relatively high long-term DDT exposure has been shown to lead to significant neurological signs in non-human primates. Six of 24 cynomolgus and rhesus monkeys given 20 mg/kg DDT for 130 months developed severe irreversible tremors requiring euthanasia during the first seven years of the study. Histological evidence of neurotoxicity was noted on necropsy (Takayama et al., 1999). Neurodevelopmental effects, most notably altered motor behavior in adult mice exposed prenatally, have also been reported in animals exposed to DDT (ATSDR, 2002; Eriksson et al., 1990a, 1990b, 1992).

Although there is no conclusive evidence that DDTs cause hepatic effects in humans (ATSDR, 2002), liver lesions have been shown to be the critical effect following chronic DDT exposure in rodent studies (IRIS, 1996). Laug et al. (1950), for example, found that weanling rats showed dose-related hepatic morphological changes at DDT doses of 5 ppm and above. DDT-induced hepatic effects have also been shown in hamsters, mice and dogs (IRIS, 1996). Fatty liver and histological signs of hepatotoxicity, including toxic hepatitis, coagulation necrosis, and focal liver necrosis, were seen in cynomolgus and rhesus monkeys dosed with 20 mg/kg DDT for 130 months and then followed for 25 years (Takayama et al., 1999).

Rodent studies have shown that DDTs in comparatively high doses have estrogenic properties that result in increased uterine weights and delayed vaginal opening (Clement and Okey, 1972), as well as antiandrogenic activity such as altered reproductive organ development and delayed puberty (Diel et al., 2000) (reported in ASTDR, 2002). Many animal studies have shown that DDTs are reproductive and developmental toxins. However, human studies have shown no clear link between exposure to environmental levels of DDTs and such effects. Intake of other estrogenic substances (as estrogen equivalents) from dietary bioflavonoids, for example, is estimated to be $4x10^7$ times higher than that from estrogenic pesticides (ATSDR, 2002; Safe, 1995).

Numerous epidemiological studies have attempted to determine whether DDTs cause cancer in humans, particularly those of the breast, pancreas, lymph system, prostate, and endometrium (reported in ATSDR, 2002). To date, these studies have not been sufficient to support a causal relationship between DDT exposure and the development of cancer in humans (ATSDR, 2002). However, the IARC has listed DDT as a possible human carcinogen, based on inadequate evidence of carcinogenicity in humans and sufficient evidence in experimental animals (development of liver tumors in several mouse and rat studies) (IARC, 1991). U.S. EPA classifies DDT as a probable human carcinogen, based on development of liver tumors in mice and rats (IRIS, 1996). OEHHA has administratively listed DDTs on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR DDTs

Because DDT dose-response data in humans are inadequate, the U.S.EPA RfD for this chemical was derived from animal data based on hepatic lesions as the critical effect (IRIS, 1996). U.S.EPA chose Laug et al. (1950) as the principal study for the RfD calculation because it had sufficient exposure duration, established the male rat as the most sensitive animal to DDT toxicity, used doses over the range of the dose-response curve, and provided both a NOAEL and LOAEL, including the lowest LOAEL determined for this chemical (IRIS, 1996).

Laug et al. (1950) fed male and female weanling rats diets containing 0, 1, 5, 10 or 50 ppm commercial DDT for 15-27 weeks. No gross signs of toxicity were apparent.

Histological evaluation of liver and kidneys showed centrilobular hepatic cell enlargement at doses of 5 ppm and above, particularly in male rats. The authors concluded that "the difference observed between the control and 5 ppm animals represents the smallest detectable morphologic effects of DDT, based on extensive observations of rat liver as affected by a variety of chemicals" (Laug et al., 1950; IRIS; 1996). The NOAEL and LOAEL values for this study were considered to be 1 and 5 ppm dietary DDT, respectively (IRIS, 1996). To the NOAEL (corresponding to 0.05 mg/kg-day), U.S. EPA applied a 100-fold uncertainty factor (10 for interspecies conversion and 10 to protect sensitive human subpopulations), leading to an RfD of $5x10^{-4}$ mg/kg-day (IRIS, 1996).

ATSDR has developed a minimal risk level (MRL) for DDTs based on neurodevelopmental effects in mice reported by Eriksson and colleagues (ATSDR, 2002; Eriksson and Nordberg, 1986; Eriksson et al., 1990a, 1990b, 1993; Johansson et al., 1995, 1996; Talts et al., 1998). Male suckling mice given a single oral dose of 0.5 mg/kg body weight DDT during the peak period of rapid brain growth (10 days of age) showed increased spontaneous motor activity when subjected to behavioral testing as 4-month old adults, indicating a disruption of habituation (Ericksson et al., 1990a, 1990b, 1992). Similar effects were not seen when exposures occurred either before (3 days of age) or after (19 days of age) this period (Ericksson et al., 1992). These studies identified a LOAEL of 0.5 mg/kg-day, to which ATSDR applied a 1000-fold uncertainty factor (10 for use of a LOAEL, and 10 each for animal to human extrapolation and intrahuman variability). The resulting MRL is identical to the U.S. EPA RfD based on hepatic effects ($5x10^{-4}$ mg/kg-day), which will be used to evaluate DDT non-cancer risk for OEHHA fish consumption guidelines.

Although studies to assess carcinogenicity in humans have been inadequate and conflicting, DDT has been shown to cause benign and malignant tumors in multiple animal studies and is structurally related to other known animal carcinogens such as DDD, DDE, dicofol, and chlorobenzilate (IRIS, 1996). In their 1991 cancer assessment, U.S. EPA combined the results of six liver tumor data sets for male and female CF-1 mice, male BABL/C mice, male MRC Porton rats, and male and female Wistar rats (Turusov et al., 1973; Terracini et al., 1973; Thorpe and Walker, 1973; Tomatis and Turusov, 1975; Cabral et al., 1982; and Rossi et al., 1977) given doses from 2 to 500 ppm in lifetime feeding studies. Individual slope factors from each of the data sets ranged from 0.082 to 1.04 $(mg/kg\text{-}day)^{-1}$; a geometric mean of these values was then calculated to derive an oral CSF for DDT of 0.34 $(mg/kg\text{-}day)^{-1}$. This oral slope factor will be used to evaluate DDT cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer and cancer critical values used to evaluate DDT in fish for the development of consumption guidelines will be **$5x10^{-4}$ mg/kg-day and 0.34 $(mg/kg\text{-}day)^{-1}$**, respectively.

DIELDRIN

DIELDRIN TOXICOLOGY

Dieldrin is a chlorinated cyclodiene insecticide widely used in the United States from the 1950s to 1970 on crops such as corn and cotton and as a termiticide in subsequent years, until its registration was canceled by U.S. EPA in 1989 (ATSDR, 2002; Stevenson et al., 1999; WHO, 1989). As a result of their low volatility, slow degradation rates and lipophilicity, dieldrin and other organochlorine pesticides resist degradation in the environment and are able to bioconcentrate and biomagnify throughout the terrestrial and aquatic food chain (ATSDR, 2002; Ecobichon, 1991). For example, bioconcentration factors of 12,500 and 13,300 have been found for dieldrin in guppies and sculpins, respectively (Fisher, 1999). Dieldrin is extremely persistent (Matsumura, 1985) and, as such, is still found in the environment, particularly in soil, sediment, and animal fat (ATSDR, 2002).

Diet is the main source of dieldrin exposure in most individuals, with foods such as dairy and meat products, fish, garden fruits, and root vegetables providing the largest dietary contribution (ATSDR, 2002; WHO, 1989). Currently, approximately 90 percent of dietary dieldrin exposure is derived from saltwater and freshwater fish, combined (Dougherty et al., 2000). Dieldrin levels in fish are most commonly associated with areas of corn production (ATSDR, 2002). Following oral exposure, dieldrin is absorbed from the gastrointestinal tract and rapidly distributed through the lymphatic system to various body tissues before being stored largely in adipose tissue and bone marrow (ATSDR, 2002; de Vlieger et al., 1968; Morgan and Roan, 1970; Scheele, 1998). Body burdens are positively correlated with total body fat (ATSDR, 2002; Hunter and Robinson, 1967; 1968). Dieldrin is transferred across the placenta to the fetus where it is widely distributed to fetal organs (Curley et al., 1969). During labor, levels in extracted lipids of fetal blood are higher than in maternal blood (ATSDR, 2002; Polishuk et al., 1977; WHO, 1989). Dieldrin also crosses the blood brain barrier (WHO, 1989). The primary route of dieldrin excretion is through feces via the bile (ATSDR, 2002; Richardson and Robinson, 1971; WHO, 1989), although dieldrin is also excreted in breast milk (ATSDR, 2002; Schecter et al., 1989; Stevens et al., 1993). Breast milk dieldrin levels have been reported to be significantly lower in vegetarians whose diets do not contain animal products compared to U.S. population means, even though breast milk lipid levels were similar between groups (Hergenrather et al., 1981). The biological half-life of dieldrin is approximately one year (WHO, 1989).

ATSDR (2002) and WHO (1989) have extensively reviewed the toxicity of dieldrin. Similar to other chlorinated cyclodienes, dieldrin has relatively high acute toxicity following oral or inhalation exposures compared to most organochlorine pesticides with signs and symptoms including dizziness, vomiting, motor hyperexcitability, and convulsions that generally appear within 20 minutes to 24 hours post-exposure (Ecobichon, 1991; 2003; Klassen and Watkins, 1999; WHO, 1989). The nervous system is the most sensitive target organ following acute and chronic oral exposures in humans

(ATSDR, 2002); adverse neurological effects, including electroencephalographic abnormalities, have been reported in workers occupationally exposed to dieldrin (Hoogendam et al., 1962; 1965). The mechanism of neurotoxic action is believed to be inhibition of chloride transport, resulting in only partial repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999). In animals, initial signs of single-dose dieldrin intoxication are irritability and tremor prior to tonic-clonic convulsions; these may occur as little as one hour after exposure (WHO, 1989). The adult human lethal dose is estimated to be five g (WHO, 1989). The single dose oral LD_{50} for dieldrin in the rat is approximately 37 to 46 mg/kg (ATSDR, 2002). Interspecies variation in susceptibility to acute dieldrin toxicity is significant, with toxicity inversely correlated with species total body fat content (Geyer et al., 1993).

Dieldrin may affect the endocrine system in humans. An epidemiological study of blood organochlorine levels found that dieldrin concentrations were inversely correlated with T4 levels in hypothyroid women (Rathore et al., 2002). Correlational studies such as this, however, cannot prove a causal relationship between exposure and adverse effect.

There is no clear evidence that dieldrin causes hepatotoxicity in humans; however, in rodent studies, the liver is the target organ of chronic dieldrin toxicity and liver lesions are considered to be the critical effect (IRIS, 1990). Liver histopathological changes in rats and increased liver weights and liver-to-body weight ratios in rats and dogs were found in response to varying levels of dieldrin exposure for two years (Walker et al., 1969). Hepatomegaly and histopathological evidence of liver damage were also seen in mice exposed to 10 ppm dietary dieldrin for two years (Thorpe and Walker, 1973). Kitselman (1953) showed that dieldrin-induced gross and histopathological liver changes in dogs were reversible after dieldrin was removed from the diet. In a six-year study of monkeys fed 0.01 to 5.0 ppm dietary dieldrin, hepatic microsomal cytochrome P-450 levels were significantly increased in a dose-dependent fashion at doses of 0.1 ppm and above (approximately 25 to 30 µg/kg body weight per day or greater). Other hepatic variables such as liver weights and alkaline phosphatase, glucose-6-phosphatase, and succinic dehydrogenase activities were not affected by treatment, with the exception of slightly increased microsomal protein contents at the highest doses (Wright et al., 1978).

Several studies have indicated that fertility, litter size, and maternal behavior may be adversely affected following dieldrin exposure in rodents (Harr et al., 1970; Good and Ware, 1969; Virgo and Bellward, 1975; Treon and Cleveland, 1955). A small reproductive study in male and female dogs found delayed estrus, decreased libido, lack of mammary function, and increased stillbirths in animals exposed to 0.15 or 0.30 mg/kg-day dieldrin (Deichmann et al., 1971; reported in ATSDR, 2002). Teratogenesis was not observed in offspring of rats and mice fed graded doses of dieldrin during the period of organogenesis; however, fetotoxicity, as evidenced by an increase in the number of supernumerary ribs and decreased numbers of caudal ossification centers, was seen in doses that also caused signs of maternal toxicity (Chernoff et al., 1975).

Dieldrin has been shown to exert neurobehavioral effects in animals. Following a low dose (0.5, 1.5, or 4.5 mg/kg) acute exposure, a dose-related decrement in adaptive capacity to an uncontrollable stressor was seen in adult mice (Carlson and Rosellini, 1987). In a small study, 0.1 mg/kg-day dieldrin for 55 days impaired learning acquisition in monkeys while 0.01 mg/kg-day did not (Smith et al., 1976). Neurodevelopmental changes such as cerebral edema, internal and external hydrocephalus, and focal neuronal degeneration were seen in rat pups whose dams were exposed to 0.004-0.008 mg/kg-day dieldrin during gestation (ATSDR, 2002; Harr et al., 1970). However, inadequacies of study design and statistical analyses limit interpretation of these results (ATSDR, 2002).

Mouse studies have shown that dieldrin may cause immunosuppression, as evidenced by increased lethality of various viruses (ATSDR, 2002). For example, Krzystyniak et al. (1985) found that a single oral dose of 18 or 30 mg/kg dieldrin in mice significantly reduced the mean day of death following exposure to a lethal dose of mouse hepatitis virus 3 (MHV3). Mice fed 1 or 5 ppm dietary dieldrin for 10 weeks (corresponding to doses as low as 0.13 mg/kg/day; ATSDR, 2002) had reduced survival times when infected with *Plasmodium berghei* or *Leishmania tropica* (Loose, 1982).

Whether dieldrin can cause cancer in human populations is controversial. Several long-term epidemiological studies of workers in pesticide manufacturing plants have not found higher cancer mortality rates related to occupational dieldrin exposure in workers compared to controls (Amoateng-Adjepong et al., 1995; Ribbens, 1985; Swaen et al., 2002). Although Quintana et al. (2004) found that cadaver adipose tissue dieldrin levels were positively associated with risk of non-Hodgkin's lymphoma, according to the authors, lack of data on confounding variables in cases and controls or exposure level or duration hamper interpretation of these results. On the other hand, Cantor et al. (2003) did not see an association between pre-diagnostic serum dieldrin levels and risk of non-Hodgkin's lymphoma in matched controls. IARC has listed dieldrin as not classifiable as to its carcinogenicity, based on inadequate evidence of carcinogenicity in humans and limited evidence of carcinogenicity in animals (IARC, 1987). In contrast, U.S.EPA lists dieldrin as a probable human carcinogen, based on development of benign liver tumors and hepatocarcinomas in multiple strains of mice (IRIS, 1993) and OEHHA has administratively listed dieldrin on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR DIELDRIN

Data for determining NOAEL or LOAEL values for dieldrin in humans are inadequate; thus, U.S. EPA derived an RfD for this chemical based on animal studies. In contrast to humans, where neurotoxicity appears to be the most sensitive endpoint for acute and chronic toxicity, hepatic lesions are the chronic critical effect reported in animals (IRIS, 1990). U.S. EPA chose Walker et al. (1969) as the principal study for the RfD because it supported the critical effect and was a comparatively comprehensive chronic toxicity assessment (IRIS, 1990). Although minimal neurotoxic effects were also seen in this

study, they occurred at a 10-fold higher dose level than did the hepatotoxic effects (ATSDR, 2002) and were thus not used in deriving a reference dose.

Walker et al. (1969) fed five-week-old male and female CFE rats diets containing 0, 0.1, 1.0, and 10.0 ppm dieldrin for two years. Body weights, feed intake, hematology, clinical chemistry, and mortality were unaffected by treatment. High-dose animals showed irritability and occasional tremors and convulsions during the course of the study. One- and 10 ppm-treated female rats had increased absolute and relative liver weights compared to controls. Hepatic parenchymal cell changes indicative of organochlorine exposure were found in some 10 ppm-treated male and female rats. U.S. EPA identified 0.1 and 1.0 ppm, respectively, as the NOAEL and LOAEL values for this study (IRIS, 1990). To the NOAEL (corresponding to 0.005 mg/kg-day), U.S. EPA applied a 100-fold uncertainty factor (10 for interspecies conversion and 10 to protect sensitive humans), leading to an RfD of $5x10^{-5}$ mg/kg-day (IRIS, 1990). ATSDR (2002) has developed a chronic oral minimum risk level (MRL) of $5x10^{-5}$ mg/kg-day, also based on the Walker et al. (1969) study, which is identical to the U.S. EPA RfD. This RfD will be used to evaluate dieldrin non-cancer risk for OEHHA fish consumption guidelines.

Studies to assess the carcinogenicity of dieldrin in humans are inadequate; however, dieldrin has been shown to cause cancer in multiple mouse strains (see caveats noted above) and is structurally related to other known rodent carcinogens (e.g., aldrin, chlordane, heptachlor, and heptachlor epoxide) (IRIS, 1993). U.S. EPA combined the results of 13 liver carcinoma data sets for male and female C3H and CF1 mice, and male B63F1, C57B1/6J, and C3H/H3 mice to determine carcinogenicity for this chemical. Individual slope factors for each of the data sets ranged from 7.1 to 55 $(mg/kg\text{-}day)^{-1}$. A geometric mean of those values was used to set an oral slope factor for dieldrin of 16 $(mg/kg\text{-}day)^{-1}$ (IRIS, 1993). This oral slope factor will be used to evaluate dieldrin cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer and cancer critical values used to evaluate dieldrin in fish for the development of consumption guidelines will be **$5x10^{-5}$ mg/kg-day and 16 $(mg/kg\text{-}day)^{-1}$**, respectively.

METHYLMERCURY

METHYLMERCURY TOXICOLOGY

Mercury is a metal found naturally in rocks, soil, air, and water that can be concentrated to high levels in the aquatic food chain by a combination of natural processes and human activities (ATSDR, 1999). The toxicity of mercury to humans is greatly dependent on its chemical form (elemental, inorganic, or organic) and route of exposure (oral, dermal, or inhalation). Methylmercury (an organic form) is highly toxic and can pose a variety of human health risks (NAS/NRC, 2000). Of the total amount of mercury found in fish muscle tissue, methylmercury comprises more than 95 percent (ATSDR, 1999; Bloom, 1992). Because analysis of total mercury is less expensive than that for methylmercury, total mercury is usually analyzed for most fish studies and assumed to be 100 percent methylmercury for the purposes of risk assessment.

In general, mercury concentrations in fish and other biota are dependent on the mercury level of the environment, which can vary based on differences in pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology of individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989). Other factors also affect the accumulation of mercury in fish tissue, including fish diet, species and age (as inferred from length) (WHO, 1989; 1990). Fish at the highest trophic levels (i.e., predatory fish) generally have the highest levels of mercury. Additionally, because of the long biological half-life of methylmercury in fish (approximately 2 years), tissue concentrations in fish increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). As a result, tissue methylmercury concentrations are expected to increase with increasing age and length within a given species, particularly in piscivorous fish.

Fish consumption is the major route of exposure to methylmercury in the United States (ATSDR, 1999). As noted above, almost all fish contain detectable levels of methylmercury, which, when ingested, is almost completely absorbed from the gastrointestinal tract (Aberg et al., 1969; Myers et al., 2000). Once absorbed, methylmercury is distributed throughout the body, reaching the largest concentration in kidneys. Its ability to cross the placenta as well as the blood-brain barrier allows methylmercury to accumulate in the brain and fetus, which are known to be especially sensitive to the toxic effects of this chemical (ATSDR, 1999). In the body, methylmercury is slowly converted to inorganic mercury and excreted predominantly by the fecal (biliary) pathway. Methylmercury is also excreted in breast milk (ATSDR, 1999). The biological half-life of methylmercury is approximately 44-74 days in humans (Aberg, 1969; Smith et al., 1994), meaning that it takes approximately 44-74 days for one-half of a single ingested dose of methylmercury to be eliminated from the body.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan) (Elhassani, 1982-83). The first recorded mass

methylmercury poisoning occurred in the 1950s and 1960s in Minamata, Japan, following the consumption of fish contaminated by industrial pollution (Marsh, 1987). The resulting illness was manifested largely by neurological signs and symptoms such as loss of sensation in the hands and feet, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir et al., 1973; Marsh, 1987). This syndrome was subsequently named Minamata Disease. A second outbreak of methylmercury poisoning occurred in Niigata, Japan, in the mid-1960s. In that case, contaminated fish were also the source of illness (Marsh, 1987). In all, more than 2,000 cases of methylmercury poisoning were reported in Japan, including more than 900 deaths (Mishima, 1992).

The largest outbreak of methylmercury poisoning occurred in Iraq in 1971-1972 and resulted from consumption of bread made from seed grain treated with a methylmercury fungicide (Bakir et al., 1973). This epidemic occurred over a relatively short term (several months) compared to the Japanese outbreak. The mean methylmercury concentration of wheat flour samples was found to be 9.1 micrograms per gram (μg/g). Over 6,500 people were hospitalized, with 459 fatalities. Signs and symptoms of methylmercury toxicity were similar to those reported in the Japanese epidemic. Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). When maternal methylmercury consumption is very high, as happened in Japan and Iraq, significant methylmercury toxicity can occur to the fetus during pregnancy, with only very mild or even in the absence of symptoms in the mother. In those cases, symptoms in children were often not recognized until development of cerebral palsy and/or mental retardation many months after birth (Harada, 1978; Marsh et al., 1980; Marsh et al., 1987; Matsumoto et al., 1964; Snyder, 1971).

IARC has listed methylmercury compounds as possible human carcinogens, based on inadequate data in humans and limited evidence in experimental animals (increased incidence of tumors in mice exposed to methylmercury chloride) (IARC, 1993). U.S. EPA has also listed methylmercury as a possible human carcinogen (IRIS, 2001). OEHHA has administratively listed methylmercury compounds on the Proposition 65 list of chemicals known to the State of California to cause cancer. No estimate of the increased cancer risk from lifetime exposure to a chemical has been developed for methylmercury.

DERIVATION OF REFERENCE DOSES FOR METHYLMERCURY

The first U.S. EPA RfD for methylmercury was developed in 1985 and set at $3x10^{-4}$ mg/kg-day (U.S. EPA, 1997). This RfD was based, in part, on a WHO report summarizing data obtained from several early epidemiological studies on the Iraqi and Japanese methylmercury poisoning outbreaks (WHO, 1976). WHO found that the

earliest symptoms of methylmercury intoxication (paresthesias) were reported in adults at blood and hair concentrations ranging from 200-500 µg/L and 50-125 µg/g, respectively. In cases where ingested mercury dose could be estimated (based, for example, on mercury concentration in contaminated bread and number of loaves consumed daily), an empirical correlation between blood and/or hair mercury concentrations and onset of symptoms was obtained. From these studies, WHO determined that methylmercury exposure equivalent to long-term daily intake of 3-7 µg/kg body weight in adults was associated with an approximately 5 percent prevalence of paresthesias (WHO, 1976). U.S. EPA further cited a study by Clarkson et al. (1976) to support the range of blood mercury concentrations at which paresthesias were first observed in sensitive members of the adult population. This study found that a small percentage of Iraqi adults exposed to methylmercury-treated seed grain developed paresthesias at blood levels ranging from 240 to 480 µg/L. The low end of this range was considered to be a LOAEL and was estimated to be equivalent to a dosage of 3 µg/kg-day. U.S. EPA applied a 10-fold uncertainty factor to the LOAEL to reach what was expected to be the NOAEL. Because the LOAEL was observed in sensitive individuals in the population after chronic exposure, additional uncertainty factors were not considered necessary for exposed adults (U.S. EPA, 1997).

Although this RfD was derived based on effects in adults, even at that time researchers were aware that the fetus might be more sensitive to methylmercury (WHO, 1976). It was not until 1995, however, that U.S. EPA had sufficient data from Marsh et al. (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). Marsh et al. (1987) collected and summarized data from 81 mother and child pairs where the child had been exposed to methylmercury *in utero* during the Iraqi epidemic. Maximum mercury concentrations in maternal hair during gestation were correlated with clinical signs in the offspring such as cerebral palsy, altered muscle tone and deep tendon reflexes, and delayed developmental milestones that were observed over a period of several years after the poisoning. Clinical effects incidence tables included in the critique of the risk assessment for methylmercury conducted by the U.S. Food and Drug Administration (FDA) (Seafood Safety, 1991) provided dose-response data for a benchmark dose approach to the RfD, rather than the previously used NOAEL/LOAEL method. The BMDL was based on a maternal hair mercury concentration of 11 ppm. From that, an average blood mercury concentration of 44 µg/L was estimated based on a hair: blood concentration ratio of 250:1. Blood mercury concentration was, in turn, used to calculate a daily oral dose of 1.1 µg/kg-day, using an equation that assumed steady-state conditions and first-order kinetics for mercury. An uncertainty factor of 10 was applied to this dose to account for variability in the biological half-life of methylmercury, the lack of a two-generation reproductive study and insufficient data on the effects of exposure duration on developmental neurotoxicity and adult paresthesia. The oral RfD was then calculated to be $1x10^{-4}$ mg/kg-day, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

The two previous RfDs for methylmercury were developed using data from high-dose poisoning events. Recently, the National Academy of Sciences (NSA) was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NAS/NRC, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in the Seychelles Islands (Davidson et al., 1995, 1998), the Faroe Islands (Grandjean et al., 1997, 1998, 1999), and New Zealand (Kjellstrom et al., 1986, 1989). The residents of these areas were selected for study because their diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NAS/NRC, 2000).

Although estimated prenatal methylmercury exposures were similar among the three studies, subtle neurobehavioral effects in children, such as problems with attention, fine-motor function, and verbal memory, were found to be associated with maternal methylmercury dose in the Faroe Islands and New Zealand studies, but not in the Seychelle Islands study. The reasons for this discrepancy were unclear; however, it may have resulted from differences in sources of exposure (marine mammals and/or fish), differences in exposure pattern, differences in neurobehavioral tests administered and age at testing, the effects of confounding variables, or issues of statistical analysis (NRC/NAS, 2000). The NAS report supported the current U.S. EPA RfD of $1x10^{-4}$ mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data.

U.S. EPA recently published a new RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). In order to develop an RfD, U.S. EPA used several test scores from the Faroes data, rather than a single measure for the critical endpoint as is customary (IRIS, 2001). U.S. EPA developed BMDLs utilizing test scores for several different neuropsychological effects mentioned above with cord blood as the biomarker for mercury exposure. The BMDLs for different neuropsychological effects in the Faroes study ranged from 46-79 µg mercury/liter blood. U.S. EPA then chose a one-compartment model for conversion of cord blood to ingested maternal dose, which resulted in estimated maternal mercury exposures of 0.857-1.472 µg/kg-day (IRIS, 2001). An uncertainty factor of ten was applied to the oral doses corresponding to the range of BMDLs to account for interindividual toxicokinetic variability in ingested dose estimation from cord-blood mercury levels and pharmacodynamic variability and uncertainty, leading to an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). In support of this RfD, U.S. EPA found that benchmark dose analysis of several neuropsychological endpoints from the Faroe Island and New Zealand studies, as well as an integrative analysis of all three epidemiological studies, converged on an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). U.S. EPA (IRIS, 2001) now considers this RfD to be protective for all populations. However, in their joint Federal Advisory for Mercury in Fish, U.S. EPA and U.S. FDA only apply this RfD to women who are pregnant or might become pregnant, nursing mothers, and young children (U.S. EPA, 2004).

OEHHA finds that there is convincing evidence that the fetus is more sensitive than adults to the neurotoxic and subtle neuropsychological effects of methylmercury. As noted previously, during the Japanese and Iraqi methylmercury poisoning outbreaks, significant neurological toxicity occurred to the fetus even in the absence of symptoms in the mother. In later epidemiological studies at lower exposure levels (e.g., in the Faroe Islands), these differences in maternal and fetal susceptibility to methylmercury toxicity were also observed. Recent evidence has shown that the nervous system continues to develop through adolescence (see, for example, Giedd et al., 1999; Paus et al., 1999; Rice and Barone, 2000). As such, it is likely that exposure to a neurotoxic agent during this time may damage neural structure and function (Adams et al., 2000), which may not become evident for many years (Rice and Barone, 2000). Thus, OEHHA considers the RfD based on subtle neuropsychological effects following fetal exposure to be the best estimate of a protective daily exposure level for women aged 18 to 45 years and children aged 1 to17 years.

In an effort to address the risks of methylmercury contamination in different populations, two separate RfDs will be used to assess risk for different population groups. OEHHA has formerly used a separate methylmercury RfD for sensitive populations to formulate advisories for methylmercury contamination of sport fish (Stratton et al., 1987). Additionally, the majority of states issue separate consumption advice for sensitive (e.g., children) and general population groups**.** OEHHA chooses to use both the current and previous U.S. EPA RfDs to evaluate methylmercury non-cancer risk for fish consumption guidelines for two distinct population groups. In OEHHA advisories, the current RfD of $1x10^{-4}$ mg/kg-day, based on effects in infants, will be used for women 18 to 45 years and children aged 1 to17 years. The previous RfD of $3x10^{-4}$ mg/kg-day, based on effects in adults, will be used for women over 45 years and men.

In summary, the non-cancer critical values used to evaluate methylmercury in fish for development of consumption guidelines will be **$1x10^{-4}$ mg/kg-day** for women aged 18 to 45 years and children aged 1 to 17 years, and **$3x10^{-4}$ mg/kg-day**, for women over 45 years and men.

POLYCHLORINATED BIPHENYLS (PCBs)

PCBs TOXICOLOGY

Polychlorinated biphenyls (PCBs) are a class of synthetic persistent lipophilic organic chemicals containing complex mixtures of biphenyls that are chlorinated to varying degrees (ATSDR, 2000; U.S. EPA, 2000a). The chemical formula for PCBs is $C_{12}H_{10-n}Cl_n$, where n equals the number of chlorine atoms ranging from one to ten (WHO, 1993). PCBs were manufactured in the United States from about 1930 to 1977 for use as coolants in electrical transformers and capacitors, and as hydraulic fluids, lubricating and cutting oils, and plasticizers (ATSDR, 2000; Erickson, 2001). Although there are 209 possible individual chlorinated biphenyl compounds (known as congeners), only approximately 130 are found in commercial products (U.S. EPA, 2000a; WHO, 1993). In the United States, PCBs were generally sold as mixtures of congeners under the trade name Aroclor (ATSDR, 2000; Nessel and Gallo, 1992).

PCBs primarily enter the environment as a result of accidental spills and leaks from products containing Aroclor mixtures and are redistributed among environmental compartments by volatilization and runoff (ATSDR, 2000). Because of their lipophilicity and slow degradation rates, PCBs are very resistant to degradation in the environment (ATSDR, 2000). PCBs are found chiefly in soil, sediment, and fatty biological tissue, where they accumulate and biomagnify in the food chain (Dekoning and Karmaus, 2000; Menzer, 1991; Moser and McLachlan, 2001). Bioconcentration factors of some congeners are reported to reach as high as $1x10^7$ in fish (Erickson, 2001). PCB residue levels in fish are affected by sediment characteristics (e.g., organic carbon content), fish species and lipid content, and trophic structure of the food chain (Eisler, 1996).

The composition of Aroclor mixtures in the environment will change over time as individual PCB congeners undergo differential partitioning, degradation, and biotransformation. This process, referred to as “weathering,” results in differential persistence and bioaccumulation, which changes the PCB pattern found in environmental samples from the original pattern in technical Aroclor mixtures (Erickson, 2001). As a rule, the environmental persistence of PCBs increases with the degree of chlorination (Menzer, 1991). As a result of improved methods and equipment, PCBs in environmental samples can be quantified as congeners and congener patterns can be related to potential sources and to the technical Aroclor mixture they most closely resemble (Newman, et al., 1998).

Saltwater and fresh water fish and shellfish, combined, account for a significant portion of the total dietary exposure to PCBs (Dougherty et al., 2000). In a study comparing frequent and infrequent Great Lakes sport fish consumers, lifetime sport fish consumption was found to be the best predictor of PCB body burdens (Hanrahan et al., 1999). Fishers who consume fish from PCB-contaminated waters have been found to have serum PCB levels several times those of the general population and similar to individuals occupationally exposed to PCBs (Kreiss, 1985).

Absorption of PCBs following oral exposure occurs via passive diffusion and ranges from approximately 75 percent to more than 90 percent (U.S. EPA, 2000a), depending on congener and the diffusion gradient between PCB concentration in the gut contents and serum lipids (Juan et al., 2002; ATSDR, 2000). Once absorbed, PCBs are distributed throughout the body, accumulating primarily in lipid-rich tissues such as liver, adipose tissue, skin, and breast milk (U.S. EPA, 2000a). More than 95 percent of most PCB congeners are absorbed from breast milk (Dahl et al., 1995; McLachlan, 1993). PCBs are also transferred across the placenta to the fetus (ATSDR, 2000; DeKoning and Karmaus, 2000). Excretion of PCBs occurs primarily through the feces and urine as well as breast milk of lactating women (ATSDR, 2000; Moser and McLachlan, 2001). Net absorption (absorption from the gastrointestinal tract minus excretion) is significantly influenced by blood lipid levels, congener body burden (ATSDR, 2000; Schlummer et al., 1998), and body mass index (Juan et al., 2002). Although various studies have shown substantial disparities in estimated half-lives of PCBs (less than one year to greater than 10 years), the best evidence suggests that the majority of PCB congeners found in an occupational setting have half-lives in the human body from one to six years (Shirai and Kissel, 1996; Wolff et al., 1982).

The toxicity of PCBs following occupational exposure has been known since 1936 when the development of chloracne (a severe form of acne) in PCB-exposed workers resulted in the establishment of a workplace threshold limit value for these compounds (Erickson, 2001). Occupational exposure has also been reported to result in ocular effects such as Meibomian gland hypersecretion, swollen eyelids, and abnormal conjunctival pigmentation (ATSDR, 2000). Incidents of purported widespread PCB poisonings occurred in Japan in 1968 ("Yusho") and Taiwan in 1979 ("Yu-Cheng") following consumption of PCB-contaminated rice oil (WHO, 1993). Signs and symptoms in affected persons were primarily ocular and dermatological; edema, alterations in blood chemistry values, and various respiratory, immunological, reproductive, developmental, and neurological disturbances were also seen (ATSDR, 2000; WHO, 1993). Although the clinical syndrome was originally thought to have resulted solely from PCB toxicity, ensuing investigations determined that the co-contaminants polychlorinated dibenzofurans (PCDFs) were the primary causal factors in Yusho and Yu-Cheng diseases (Ikeda, 1996; Kunita et al., 1984; Schantz, 1996; Wilson, 1987; Yao et al., 2002). In a sample of Yusho rice oil, for example, 2,3,4,7,8-pentaCDF was found to contribute the majority (58 percent) of the total toxic equivalents (TEQ), while PCB-126 was the second most abundant contributor to total TEQ (16 percent) (Yao et al., 2002). It is possible, however, that some signs and symptoms in the Yusho and Yu-Cheng poisonings resulted from non-*Ah* receptor mediated mechanisms of PCB toxicity.

Numerous epidemiological studies since that time have attempted to determine whether PCBs pose a human health risk at levels currently found in the environment. Many authors have subsequently reported an association between oral environmental PCB exposures and cancer as well as various adverse neurological, reproductive, and developmental effects (ATSDR, 2000). In particular, several observational cohort studies have found one or more neurodevelopmental deficits in children exposed to PCBs *in*

utero and/or postnatally (see descriptions in Winneke et al., 1998; 2002); however, results have differed with respect to the type and persistence of effects as well as the matrix (e.g., cord blood or breast milk) used to indicate exposure (Winneke et al., 1998). For example, Jacobson et al. (1992) and Jacobson and Jacobson (1996) noted that children exposed to PCBs prenatally through maternal consumption of contaminated Great Lakes fish had poorer performance on cognitive tests for visual, verbal and memory abilities at four years of age, and lowered verbal and full-scale IQ at age eleven compared to children with lower intrauterine PCB exposures. In similarly exposed infants, Gladen et al. (1988) found decreases in psychomotor scores at twelve months as well as delays in motor maturation up to 24 months (Rogan and Gladen, 1991), but no changes in mental scores. These effects were no longer observed at 3-5 years of age (Gladen and Rogan, 1991). Schantz et al. (1999) found no effect on visual-motor coordination or hand steadiness in a population of adults over 50 years of age exposed to PCBs and other contaminants through long-term consumption of large amounts of Great Lakes fish compared to those who consumed little or no Great Lakes fish. However, the same population showed a decrease in verbal memory in one of two standardized tests of memory and learning compared to controls (Schantz et al., 2001). No effects were seen on executive or visual-spatial function. In a study comparing women who had consumed more than 40 pounds of Great Lakes fish over their lifetimes with women who had never consumed Great Lakes fish, Stewart et al. (2000) found a significant linear relationship between highly chlorinated (C17-C19) PCB congeners in cord blood and decreased habituation and autonomic scores in the Neonatal Behavioral Assessment Scale. In a European cohort, Winneke et al. (1998) found the sum of PCBs 138, 153, and 180 in breast milk to be negatively associated with cognitive development, but not motor development or recognition memory in seven-month-old infants. These outcomes were not related to cord plasma PCBs. Neurological effects have also been observed in infants, children, and adults following PCB poisonings (ATSDR, 2000).

Recent data indicate that typical environmental levels of PCBs might affect the developing immune system in humans (Weisglas-Kuperus et al., 2000). Prenatal PCB exposure was positively associated with number of lymphocytes, T cells, and $CD3^{+}CD8^{+}$ (cytotoxic), $CD4^{+}$ $CD45RO^{+}$ (memory), $TcR\alpha\beta^{+}$, and $CD3^{+}$HLA-DR^{+} (activated) T cells and negatively associated with antibody levels to mumps and rubella in 42 month-old children. Current plasma PCB levels were positively associated with prevalence of chicken pox and recurrent middle ear infections, while negatively associated with prevalence of allergic reactions. Increased duration of breast feeding counteracted the negative effects of postnatal PCB exposure (Weisglas-Kuperus et al., 2000).

Human studies have shown inconsistent results with respect to adverse reproductive effects following PCB exposures (ATSDR, 2000). Menstrual cycles were slightly shorter and female fecundity was reduced in women consuming PCB-contaminated Great Lakes fish (Buck et al., 2000; Mendola et al. 1997). However, other studies have shown no adverse reproductive effects in women consuming high-PCB fish when examining endpoints such as increased time-to-pregnancy or risk of spontaneous fetal death (Buck et al., 1997; Courval et al., 1999; Mendola et al., 1995), although there was a small

association between sport-caught fish consumption and conception delay for men (Courval et al., 1999). Results of human studies on potential developmental effects of PCB exposure have also been mixed (ATSDR, 2000). Maternal PCB exposure via fish consumption has been reported to have a negative, positive, or no association with birth weight, head circumference, or gestation age (see, for example, Buck et al., 2003; Dar et al., 1992; Jacobson et al. 1990a, 1990b; Lonky et al., 1996; Rylander et al., 1995; Smith, 1984; ATSDR, 2000).

Most human epidemiological studies examining adverse effects of PCB exposure have been confounded by concomitant exposure to the trace contaminants PCDFs or other workplace chemicals such as solvents, benzene, and lead (Erickson, 2001; Persky, 2001), or have had other serious design or reporting flaws (Swanson et al., 1995). In fact, in a systematic critical evaluation of 72 occupational or environmental PCB exposure studies conducted prior to 1995, Swanson et al. (1995) found that only five of the occupational studies and none of the environmental studies provided either positive or suggestive evidence of a causal relationship between PCB exposure and adverse effects in humans. Most studies were deemed inconclusive. This is particularly true in studies of fish-eating populations as fish are often contaminated with multiple organochlorines and other neurological, developmental or reproductive toxins (Seegal, 1996; 1999). Although human epidemiological studies are quite limited in their ability to prove a causal relationship between PCB exposure and disease (Seegal, 1996), animal studies using controlled exposures to specific Aroclor mixtures do clearly demonstrate adverse effects on the hepatic, hematological, gastrointestinal, immunological, neurological, endocrine, and reproductive systems following oral PCB exposure (ATSDR, 2000). To date, the most sensitive effects of PCB toxicity have been identified in monkeys, including clinical signs showing developmental effects such as ocular exudate, inflamed Meibomian glands, and distorted growth of fingernails and toenails, as well as immunological effects such as decreased antibody response to sheep erythrocytes (IRIS, 1996). Studies showing specific effects are discussed in more detail below.

As has been the case with various non-cancer endpoints, epidemiological research in humans has also found an association between exposure to PCBs and mortality rates from cancers of the liver, gall bladder, biliary tract, and brain, as well as non-Hodgkin's lymphoma and malignant melanoma (see Cogliano, 1998 and ATDSR, 2000, for discussion). Additionally, male Yusho victims were noted to have an increase in mortality from liver cancer when compared to national death rates (Kuratsune et al., 1987); however, this may have resulted from PCDF contamination (Cogliano, 2001). While epidemiological studies cannot prove a causal relationship between exposure and health effects as noted above, numerous experimental investigations in rodents have clearly shown the ability of various commercial Aroclor mixtures to cause cancerous or pre-cancerous hepatic and gastrointestinal lesions (see Cogliano et al., 1998 and ATSDR, 2000, for discussion). IARC has listed PCBs as probable human carcinogens, based on limited evidence of hepatobiliary cancer in humans and sufficient evidence of malignant liver neoplasms in rodents (IARC, 1987). U.S. EPA also designates PCBs as probable human carcinogens based on tumors found in female mice exposed to Aroclors 1260,

1254, 1242, and 1016 and also in male rats exposed to Aroclor 1260 (IRIS, 1997). Based on these actions, OEHHA has administratively listed PCBs on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR PCBs

Studies to identify an RfD or CSF for PCBs have been conducted with the specific Aroclor mixtures that were prevalent as commercial products during the period that Aroclors were actively manufactured and used. However, as noted above, PCBs found in fish or other environmental media have undergone weathering that can selectively increase or decrease individual congeners, possibly increasing the overall toxicity of the mixture (Cogliano, 2001). U.S. EPA has adopted an approach that matches the expected environmental persistence and toxicity of congeners to the congener profile and toxicity of different Aroclors (Cogliano, 2001). Fish consumption is considered an exposure of high risk and persistence, so recommended health effects values are based on the cancer and non-cancer toxicities of Aroclors 1260 and 1254, which show the greatest toxicity and content of environmentally persistent chlorines (U.S. EPA, 1996).

Because PCB dose-response data for non-cancer endpoints in humans are inadequate, the U.S. EPA RfD for these compounds has been derived from animal data. The RfD for Aroclor 1254 of $2x10^{-5}$ mg/kg-day (IRIS, 1996) is based on a series of studies in adult female Rhesus monkeys (Arnold et al., 1993a, 1993b; Tryphonas et al., 1989, 1991a, 1991b) that were treated for 23 to 55 months. The critical effects noted in treated adults were ocular exudate, inflamed Meibomian (tarsal) glands, distorted fingernail and toenail growth, as well as a decreased antibody response to sheep erythrocytes, all of which occurred at the lowest tested dose of 0.005 mg/kg-day (IRIS, 1996). To this LOAEL, an uncertainty factor of three hundred (ten for sensitive individuals, three for extrapolation from rhesus monkey to humans, a partial factor[1] for the use of a minimal LOAEL [i.e., the effects were not severe], and three to convert from subchronic to chronic) was applied to develop the RfD (IRIS, 1996). OEHHA also used the LOAEL from Arnold et al. (1993a, 1993b) and a three hundred-fold uncertainty factor (ten for interindividual variability, ten for interspecies variation and three for mild and reversible effects at the LOAEL) to account for immunological effects of PCBs to derive a PHG (the concentration of a chemical in drinking water determined to present no significant risk to human health when consumed over a lifetime) (Avalos and Brodberg, 2004). Results of continuing studies in which these treated females were mated to untreated males have been published (Arnold et al. 1995; 1997) since the U.S. EPA derived its RfD. These studies present findings on effects on female reproduction and developmental effects in infants following intrauterine and post-parturition exposures (22 weeks via breast milk). Arnold et al. (1995) showed decreased conception rates at 0.02 mg/kg-day and above, but not at 0.005 mg/kg-day. Developmental effects such as inflammation or enlargement of the Meibomian (tarsal) glands, nail lesions and gum recession, as well as a decrease in

[1] IRIS did not stipulate what the "partial factor" was; however, by deduction, it must have been three.

titers to IgM sheep red blood cells and a dose-related decrease in head circumference were seen in infant rhesus monkeys whose mothers were exposed to 0.005 mg/kg-day Aroclor 1254. Studies with other Aroclor compounds (e.g., Aroclor 1016) have shown developmental and neurological effects in monkeys at slightly higher doses with minor morphological effects occurring at levels where no or minimal neurobehavioral effects were manifested (e.g., Shantz et al., 1989). Although the current RfD is derived from a LOAEL from a study in adult monkeys, similar morphological effects in offspring were reported at the same exposure level. Since morphological effects have been found to occur at or below the exposure levels causing developmental neurobehavioral effects (Schantz et al., 1989), the RfD is also expected to be protective of the developing fetus. This RfD of $2x10^{-5}$ mg/kg-day will be used to evaluate PCB non-cancer risk for OEHHA fish consumption guidelines.

Human cancer dose-response data for PCBs are also inadequate and, thus, the PCB CSF has been generated based on animal studies. Because of the differential ability of different PCB mixtures to cause cancer, U.S. EPA developed a range of CSFs based on Aroclors 1016, 1242, 1254, and 1260. These Aroclors include the range of typical congeners found in various environmental media such as water and fish (IRIS, 1997). For food chain exposure, such as fish consumption, where environmental processes increase risk, a "high-risk" cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$ is used based on the carcinogenic potential of Aroclors 1254 and 1260 (U.S. EPA, 1996). This value was derived from a study of male and female rats (Brunner et al., 1996; Norback and Weltman, 1985). A significant, dose-related increase in the number of liver adenomas or carcinomas was found in female rats exposed to all Aroclors and in male rats exposed to Aroclor 1260 (IRIS, 1997). Aroclors 1254 and 1260 are the most frequently detected Aroclors sampled in California fish (Brodberg and Pollock, 1999; LACSD, 2000). The CSF of 2.0 $(mg/kg\text{-}day)^{-1}$ will be used to evaluate PCB cancer risk for OEHHA fish consumption guidelines.

For fish consumption advisories, cancer and non-cancer health effects values are applied to the sum of detected Aroclors (generally 1248, 1254, and 1260) or a sum of congeners in fish tissue, as recommended by U.S. EPA (2000b).

In summary, the non-cancer and cancer critical values used to evaluate PCBs in fish for the development of consumption guidelines will be **$2x10^{-5}$ mg/kg-day** and **2.0 $(mg/kg\text{-}day)^{-1}$**, respectively.

SELENIUM

SELENIUM TOXICOLOGY

Selenium is a metalloid found naturally, but highly variably, throughout the environment (ATSDR, 1999; Reilly, 1996). Although toxic at relatively low levels, selenium is also a required nutrient that functions to protect against oxidative stress, regulate thyroid hormones, and in vitamin C metabolism (IOM, 2000). The current Recommended Dietary Allowance (RDA) for selenium is 55 µg/day for the general adult population, 60 µg/day for pregnant women, and 70 µg/day during lactation (IOM, 2000). Selenium is found in a variety of inorganic and organic forms (Haygarth, 1994); however, in animal tissues, most selenium occurs as the amino acids selenomethionine or selenocysteine (IOM, 2000). Fish and other food samples are analyzed for total selenium content, as nutritional and toxicity values have not been developed for specific chemical forms of the element.

Selenium is dispersed naturally in the environment by weathering of selenium-containing rocks and volcanic eruptions (ATSDR, 2003). Human activities can significantly redistribute environmental selenium; fossil fuel processing and combustion as well as irrigation of seleniferous soils are important origins of localized selenium contamination (Lemly, 1997). Because of the inherent variability in soil selenium concentrations, human and animal selenium exposures can fluctuate quite dramatically by geographic locale. Human selenium intakes in different regions of China known for endemic deficiency and toxicosis, for example, have been shown to range from seven to 38,000 µg/day, respectively (Levander, 1987).

Environmental conditions (e.g., pH and oxidation-reduction potential) dictate the chemical form in which selenium will be found, which, in turn, determines the biological fate of the element (ATSDR, 2003). Water and air selenium levels are generally low except in isolated areas; humans are exposed to selenium primarily through food. Cereals, grains, and forage crops are the largest contributors of selenium to the diet (ATSDR, 2003), although fish also can be a relatively rich source of the element (USDA, 2004). Freshwater fish in the United States have been found to contain a mean concentration of 0.56 ppm selenium, wet weight (May, 1981); however, in areas of California where high-selenium irrigation drainage water contaminated nearby waterways, selenium concentrations in whole body carp were reported up to 60 ppm (Fan, 1988). Brazil nuts, on average, contain the highest selenium concentration of any common food, ranging from 0.03 to 512 ppm, wet weight, depending on geographic location (Chang et al., 1995). Six to eight nuts (one ounce) typically supply approximately ten times (544 µg) the RDA for this nutrient (USDA, 2004).

Following ingestion, most forms of dietary selenium are well absorbed from the gastrointestinal tract (ATSDR, 2003; Barceloux, 1999; Thomson, 1998). Once absorbed, selenium is distributed to many tissues, reaching the highest concentrations in liver and kidney; selenium also crosses the placenta and is found in breast milk (ASTDR, 2003).

Excretion occurs primarily through urine and, to a lesser extent, feces. In cases of excess consumption, selenium is excreted in the breath and sweat as garlic-odored dimethylselenide (IOM, 2000; Klaassen and Watkins, 1999). The half-life of selenomethionine in the human body is 234 days (Klaassen and Watkins, 1999).

The toxicity of selenium was recognized many years before its role as an essential nutrient was discovered in the 1950s by Schwarz and Foltz (1957). Franke and Potter (1935) were the first to prove that selenium was the plant constituent responsible for signs of toxicosis such as hair and hoof loss reported in livestock grazing on the plains of Nebraska and South Dakota (Combs and Combs, 1986). Since that time, selenium toxicity has been well reviewed by many authors (e.g., ATSDR, 2003; Combs and Combs, 1986; Reilly, 1996; Barceloux, 1999; Schrauzer, 2000, 2003) and has been found to be dependent on chemical form and solubility (Klaassen and Watkins, 1999).

Acute, sometimes fatal, selenium toxicity only rarely has been reported in humans and has generally been the result of self-medication, accidental, suicidal, or occupational exposures (Civil and McDonald, 1978; Sioris et al., 1980; Gasmi et al., 1997; Schellmann et al., 1986). Gastrointestinal and neurological signs and symptoms, as well as hair and nail loss, predominate the clinical presentation (Combs and Combs, 1986). At least one case of acute selenium intoxication from a natural source has been noted in the literature. A 54-year-old Venezuelan man suffered anxiety, chills, diarrhea, fever, anorexia, and weakness after consuming 70 to 80 "Coco de Mono" (*Lecythis ollaria*) almonds. Eight days after consuming the nuts, he suffered extensive loss of scalp and body hair (Kerdel-Vegal, 1964). Subsequent studies identified the pharmacologically active agent as selenocystathionine (Aronow and Kerdel-Vegas, 1965; Kerdel-Vegas et al., 1965). Acute selenium poisoning was also reported in five individuals who consumed sodium selenate intended for use as a turkey diet supplement (dose not provided). Symptoms and signs, which resolved within 24 hours, included nausea, vomiting, diarrhea, abdominal pain, chills, and tremors (Sioris et al., 1980). Acute to sub-acute selenium toxicosis occurred in 13 individuals who consumed an improperly formulated over-the-counter selenium supplement (FDA Drug Bulletin, 1984; Jensen et al., 1984; Helzlsouer et al., 1984). Analysis of several tablets revealed that the selenium content was 182 times higher than labeled (approximately 27-30 mg per tablet, in the form of sodium selenate and elemental selenium). Estimates of ingested selenium dose ranged from 27 to 2310 mg (from a single tablet to 77 tablets taken over a 2 ½ month period). Signs and symptoms of toxicity included nausea, abdominal cramps, nail and hair changes (including total hair loss), peripheral neuropathy, garlic breath odor, fatigue, and irritability.

Chronic selenium toxicosis in humans has been well characterized as a result of endemic disease occurring in a seleniferous region of China (Yang et al., 1983, 1989a, 1989b). Excessive selenium intakes (a mean of 4,990 µg/day, versus 116 µg/day in a selenium adequate area) resulted from consumption of high-selenium corn and vegetables during a drought period. Affected individuals suffered nail and hair loss, dermal swelling, erythema and ulcerations, as well as paresthesias. Hair selenium levels were approximately 100 times higher than those found in selenium adequate areas (Yang et al.,

1983). Chronic human selenium toxicity as a consequence of environmental exposures has not been reported in the United States, although ranchers in a seleniferous area of South Dakota were found to consume as much as 724 µg selenium per day (Longnecker et al., 1991).

Although high levels of selenium have been shown to be teratogenic in birds (Ohlendorf, 1986; 1988), there is no evidence that selenium induces terata in humans or other mammals (ATSDR, 2003). Other developmental effects following *in utero* selenium exposure in mammals have only been conclusively demonstrated at doses that cause frank maternal toxicity (Willhite, 1993; ATSDR, 2003).

IARC and U.S. EPA have listed selenium compounds as not classifiable as to their carcinogenicity in humans because of inadequate evidence of carcinogenicity in humans or animals (IARC, 1975; IRIS, 1993). Selenium sulfide, an industrial chemical not present in food, is considered a probable human carcinogen by U.S. EPA (IRIS, 1993) and is listed by OEHHA on the Proposition 65 list of carcinogens.

DERIVATION OF A REFERENCE DOSE FOR SELENIUM

The current U.S. EPA RfD for selenium and selenium compounds was developed in 1991 and set at $5x10^{-3}$ mg/kg-day (IRIS, 1991), corresponding to 350 µg/day for a 70-kg adult or approximately six-fold higher than the RDA for the general adult population. This RfD was based on an epidemiological study of approximately 400 people residing in a seleniferous region of China noted above. Overt signs of clinical selenosis (e.g., garlic breath odor, nail changes, hair and nail loss, decreased hemoglobin, skin lesions, mottled teeth, and central nervous system effects) were reported at whole blood concentrations of 1.35 mg/L, corresponding to a daily selenium intake of 1.261 mg (Yang et al., 1989b; IRIS, 1991). A blood selenium level of 1.0 mg/L (equivalent to an intake of 0.853 mg selenium/day) did not elicit signs of selenium toxicity. Thus, a chronic oral NOAEL and LOAEL of 0.853 and 1.261 mg/day, respectively, were determined from this study and converted to a body weight basis using the average Chinese adult body weight of 55 kg (IRIS, 1991). U.S. EPA also cited a year-long study of individuals from high-selenium areas of South Dakota and Wyoming in support of the RfD (see above, Longnecker et al. 1991). Individuals consuming as much as 0.724 mg Se/day in these regions did not show signs or symptoms associated with selenium toxicity, thus confirming the NOAEL from the Yang et al. (1989b) study. To account for sensitive individuals, U.S. EPA applied a three-fold uncertainty factor to the NOAEL (0.015 mg/kg-day) to derive an RfD of $5x10^{-3}$ mg/kg-day. Because a similar NOAEL was observed in two moderate-sized populations exposed over a lifetime, a full 10-fold uncertainty factor was not considered necessary (IRIS, 1991). ATSDR (2003) also has developed a chronic oral MRL of $5x10^{-3}$ mg/kg-day, based on a follow-up study by Yang and Zhou (1994) that reexamined five individuals included in the original Yang et al. (1989b) paper. This study confirmed the original NOAEL used by U.S. EPA to set the RfD. OEHHA will use this RfD to evaluate selenium non-cancer risk for fish consumption guidelines.

In summary, the non-cancer critical value used to evaluate selenium in fish for the development of consumption guidelines will be **$5x10^{-3}$ mg/kg-day**.

TOXAPHENE

TOXAPHENE TOXICOLOGY

Toxaphene (camphechlor) is an organochlorine insecticide consisting of a mixture of over 670 chlorinated terpenes (ATSDR, 1996; U.S. EPA, 2000). The average chemical formula for toxaphene and related toxaphene-like pesticides is $C_{10}H_{10}C1_8$ (WHO, 1984; ATSDR, 1996; de Geus, 1999). Toxaphene was first produced in 1945, primarily as an insecticidal agent for cotton, but also for parasite control in livestock and to kill unwanted fish species in various water bodies (DHHS, 2002; de Geus, 1999). Once the most heavily used pesticide in the United States (Ribick et al., 1982), U.S. EPA restricted most applications of toxaphene in 1982 and banned it completely in 1990 (DHHS, 2002).

Because of its extensive use, volatility, and resistance to degradation, toxaphene is distributed throughout various environmental matrices worldwide, particularly in freshwater and marine fish (Alder, 1997; ATSDR, 1996; de Geus, 1999). Bioconcentration factors of persistent toxaphene congeners in fish and shellfish have been reported to reach as high as $3.5x10^6$ (Geyer et al., 1999). Biomagnification also occurs in the aquatic food chain (ATSDR, 1996). Fish toxaphene levels have been shown to be positively correlated with fish age and fat content (Alder, 1997). Similar to the case with PCBs, the composition of the toxaphene "technical" mixture is altered in the environment as a result of differential degradation of individual congeners (Stern et al., 1992). The number of congeners decreases with increasing trophic level; approximately twenty, eight and two primary congeners have been found in fish, marine mammals, and humans, respectively (Calciu et al., 1997).

Toxaphene is known to be absorbed from all absorption routes, although dermal absorption is comparatively low (ATSDR, 1996; WHO, 1984). Once absorbed, toxaphene is distributed primarily to fat, but also to liver, bone, kidney, brain, heart, muscle, lung, spleen, adrenal gland, and testis (ATSDR, 1996). Rat studies have shown that only a small percent of a maternal toxaphene dose is transferred to the fetus (Pollock and Hillstrand, 1982); however, toxaphene has been found in human breast milk, particularly in women residing in the Arctic region where dietary organochlorine levels can be very high (Dewailly et al., 1993; Chan and Yeboah, 2000; Newsome and Ryan, 1999; Walker et al., 2003; Vaz and Blomkvist, 1985). Breast milk from Inuit women in northern Quebec, for example, has been reported to contain toxaphene concentrations as high as 294 ng/g on a lipid weight basis (Newsome and Ryan, 1999; Stern et al., 1992). Toxaphene is excreted in both urine and feces with the majority of absorbed toxaphene undergoing metabolic transformation (ASTDR, 1996). The excretion half-life of radiolabeled toxaphene has been shown to be approximately nine days in rodents, with about twice as much excreted in feces as in urine over this time period (ATSDR, 1996). Even though the pesticide has been banned for many years, significant toxaphene residues have recently been found in adipose tissue of children in western Europe (Witt and Niessen, 2000).

The toxicity of toxaphene has been well reviewed by several authors (e.g., ASTDR, 1996; Pollock and Kilgore, 1978; WHO, 1984; Saleh, 1991). Like other cyclodiene insecticides, the mechanism of neurotoxic action is believed to be inhibition of chloride transport, resulting in only partial repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999). Following acute oral toxaphene intoxication in humans, signs and symptoms of central nervous system stimulation are seen such as hypersalivation, restlessness, muscle tremors, and convulsions (U.S. EPA, 1987). Signs often begin within two hours of ingestion; fatal doses generally cause death by respiratory failure within 24 hours (McGee et al., 1952; Wells and Milhorn, 1983). The human acute lethal dose has been estimated to range from 21-100 mg/kg body weight (U.S. EPA, 1987) or about 2 to 7 grams for an adult (WHO, 1984). In addition to nervous system and respiratory effects mentioned above, heart dilation, kidney swelling, and elevated liver enzymes have also been reported in humans following acute toxaphene ingestion (ATSDR, 1996; McGee et al., 1952; Wells and Milhorn, 1983).

In animals, neurological effects similar to those reported in humans have been reported following acute toxaphene toxicity (ATSDR, 1996). Intermediate or chronic toxaphene exposures in various animal species have been shown to cause hepatic and renal effects including increased liver and kidney weights, hepatic enzyme induction, and degenerative histopathological changes in both organs (ATSDR, 1996). Protein deficiency may significantly increase acute toxaphene toxicity (Boyd and Taylor, 1971).

Toxaphene has not been shown to cause reproductive harm in animals at levels that do not also cause parental toxicity. For example, decreased fetal weights, fetal death, or increased incidence of encephaloceles were reported in rats and mice exposed to toxaphene during the period of organogenesis, but only at doses that also caused maternal toxicity and death (Chernoff and Carver, 1976). In a three-generation study, rats fed 0, 25 or 100 ppm toxaphene showed no adverse effects on reproductive outcomes such as litter size, pup survival or weanling body weights; however, liver cytoplasmic vacuolization was seen in the majority of adults at the 100 ppm dose (Kennedy et al., 1973). Similarly, while dietary toxaphene concentrations of 20 ppm and above caused increased liver weights as well as histopathological changes in liver, thyroid and kidney in adults rats during a reproductive study, there were no effects on fertility, litter size, pup weight, or other indices of gestation or survival in rats fed dietary concentrations up to 500 ppm toxaphene (0.38 mg/kg-day) (Chu et al., 1988).

Developmental effects have been reported following toxaphene exposure in rats. Olson et al. (1980) found that juvenile rats exposed to 0.05 mg/kg-day toxaphene in the pre- and postnatal periods had decreased swimming and righting ability compared to controls, although differences in swimming ability between groups had disappeared by postnatal day 16. Time to master righting reflex was also prolonged in offspring of rats exposed to 6 mg/kg-day from gestation day 7 until parturition (Crowder et al., 1980).

A few studies have found immunotoxic effects resulting from toxaphene exposure. Adult mice fed 100 or 200 ppm dietary toxaphene for eight weeks showed a dose-dependent decrease in antibody response to bovine serum albumin (Allen et al., 1983). Liver-to-body weight ratios were also increased at both dose levels and histopathological changes were noted in livers. Immunological effects were more pronounced in offspring exposed *in utero* or during lactation (Allen et al., 1983). An immunotoxicity study in cynomolgus monkeys is described below (Tryphonas et al., 2001). *In vitro* human studies have confirmed that neutrophils are a significant immunologic target of toxaphene toxicity (Gauthier et al., 2001).

There are no data available to evaluate the carcinogenicity of toxaphene in humans; however, toxaphene has been found to be a liver carcinogen in mice and to cause thyroid cancer in rats (Litton Bionetics, 1978; Reuber, 1979; NCI, 1979). IARC has listed toxaphene as a possible human carcinogen, based on inadequate data in humans and sufficient evidence in experimental animals (IARC, 2001). U.S. EPA lists toxaphene as a probable human carcinogen, based on no data in humans and sufficient evidence of carcinogenicity in experimental animals (IRIS, 1991). OEHHA has administratively listed toxaphene on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR TOXAPHENE

U.S. EPA has not developed an RfD for toxaphene. However, in 2003, OEHHA published a PHG for toxaphene in drinking water, selecting a study by Chu et al. (1986) to determine the NOAEL for non-cancer effects (OEHHA, 2003). Rats fed diets containing 20 to 500 ppm toxaphene (corresponding to approximately 0.35 to 63 mg/kg-day) had biologically significant histopathological changes in liver, thyroid, and kidney at doses of approximately 1.8 mg/kg-day and above. Liver-to-body weight ratios and hepatic mixed function oxidase activities were also increased at the highest dose level. The NOAEL and LOAEL values in this study were determined to be 0.35 and 1.8 mg/kg-day, respectively. To the NOAEL, an uncertainty factor of 1000 (10 for interspecies extrapolation, 10 for sensitive individuals, and 10 for extrapolation from subchronic to chronic) can be applied to develop a reference dose of 3.5×10^{-4} mg/kg-day.

A more recent study in cynomolgus monkeys by Tryphonas et al. (2001) can also be used to support the RfD for toxaphene. Monkeys were fed 0, 0.1, 0.4, or 0.8 mg/kg-day toxaphene for 75 weeks. Doses of 0.4 and 0.8 mg/kg-day significantly reduced humoral immunity in female monkeys, as evidenced by decreased primary and secondary immune response to sheep erythrocytes. The NOAEL of 0.1 mg/kg-day in this study was similar to that derived by Chu (Chu et al., 1986). As the Chu et al. study produced the highest NOAEL below the lowest LOAEL, it will be used to set the reference dose to evaluate toxaphene non-cancer risk for fish consumption guidelines.

Human dose-response data for cancer are also inadequate; thus, the toxaphene CSF has been generated from animal studies. Two long-term rodent carcinogenicity assays have been published for toxaphene (Litton Bionetics, 1978; NCI, 1979). In their 1991 carcinogenicity assessment, U.S. EPA chose the Litton Bionetics study for determination of the toxaphene cancer slope factor. A significantly increased incidence of hepatocellular carcinomas was found in male B6C3F1 mice at a dietary dose of 50 ppm. Using a linearized multistage model, U.S. EPA determined the oral CSF for toxaphene in this study to be 1.1 $(mg/kg\text{-}day)^{-1}$ (IRIS, 1991). OEHHA (2003) employed a CSF of 1.2 $(mg/kg\text{-}day)^{-1}$ in their toxaphene PHG, using the same data set as U.S. EPA but making slightly different assumptions regarding the conversion of dietary toxaphene concentrations to mg/kg body weight doses. For the purpose of evaluating cancer risk for fish consumption guidelines, the CSF of 1.2 $(mg/kg\text{-}day)^{-1}$ will be used.

In summary, the non-cancer and cancer critical values used to evaluate toxaphene in fish for the development of consumption guidelines will be **$3.5x10^{-4}$ mg/kg-day** and **1.2 $(mg/kg\text{-}day)^{-1}$**, respectively.

FISH CONTAMINANT GOALS FOR CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

As is also the case for air, drinking water, or any other food, the ultimate goal of agencies responsible for the protection of public health is for fish to be devoid of biological or chemical contamination. FCGs can be derived for chemicals found in fish, comparable to PHGs for drinking water (Health and Safety Code, Section 116365). FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs were developed for chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, feasibility, the counterbalancing benefits of fish consumption, or alternative risks of other protein sources that may be consumed in place of fish.

FCGs can be found in Table 1. OEHHA used the following assumptions in the development of FCGs for fish contaminants. Agencies developing fish tissue-based criteria may choose to alter one or more of these assumptions in order to meet their own specific goals or requirements:

Body Weight:

The default value for adult body weight for these calculations was assumed to be 70 kg, which is recommended in most risk assessment guidelines. While, at one time, 70 kg was the approximate combined average weight for adult males and females in the United States, it is now significantly less than the average weight for both adult females and males in this country (about 75 and 87 kg, respectively) (Ogden et al., 2004). The use of a lower default body weight for risk assessment calculations results in lower allowable contaminant concentrations in fish.

Serving Size and Consumption Rate:

Serving size assumptions vary considerably. The American Heart Association (AHA) recommends eating fish at least two times a week (AHA, 2006), and considers a single serving size to be four ounces (113.5 g) of fish prior to cooking (corresponding to three ounces [85 g] of cooked fish). The Institute of Medicine (IOM) also considers serving size to be three ounces of cooked fish, based on the National Health and Nutrition Examination Survey (NHANES) 1999-2002 data showing three ounces to be the average daily consumption rate for people who eat fish (IOM, 2007). In their 2006 food pyramid, the U.S. Department of Agriculture recommends five to six ounces, *total*, of meat, poultry, fish, dried beans or peas, eggs, nuts, and seeds *per day* for adult women and men,

suggesting that the typical serving size of a single animal protein source in a given day is three to four ounces (USDA, 2006). In contrast, U.S. EPA assumed a serving size of eight ounces of fish, prior to cooking, in their fish advisory guidance document (U.S. EPA, 2000b), as did both U.S. EPA and FDA in their joint national advisory for mercury in fish (U.S. EPA, 2004c). While OEHHA contemplated reducing serving sizes to four ounces, prior to cooking, to align with federal nutrition, IOM and AHA guidelines, focus groups interviewed by the California Department of Public Health indicated that sport fishers typically consume significantly larger portion sizes. Thus, an 8-ounce serving size was retained for use in fish advisories. OEHHA considers it to be a reasonable goal to provide recreational fish that, at a minimum, are safe to eat at the AHA recommended consumption rate for adults of at least eight ounces of fish per week, prior to cooking (an average of 32 g/day) and that this is an appropriate consumption rate for development of an FCG. Because of their smaller body weights, children will be advised to eat approximately one-half as much fish (in either quantity or frequency) as are women aged 18 to 45 years.

Hazard Quotient:

Standard risk assessment guidelines generally recommend limiting non-cancer exposures to no more than the RfD, which results in a hazard quotient (HQ; the ratio of exposure to the RfD) that does not exceed 1. FCGs were set using a maximum HQ of 1 at the consumption rate of 32 g/day.

Risk Level:

FCGs were developed using a maximum cancer risk level (RL) of $1x10^{-6}$, estimating that, at a given consumption rate, not more than one additional cancer case would be expected in a population of one million people consuming fish over a lifetime. This risk level is at the lower end of the acceptable range of risks ($1x10^{-4}$ to $1x10^{-6}$) used by U.S. EPA in regulatory criteria for drinking water (Fed. Reg., 1998) and is provided as an example of an acceptable risk level in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (U.S. EPA, 2000a,b). FCGs were set using a maximum RL of $1x10^{-6}$ at the consumption rate of 32 g/day.

Exposure Duration and Averaging Time:

For carcinogenic chemicals, the exposure duration and averaging time was assumed to be 30 years over a 70 year lifespan, based on the 95th percentile of U.S. residence time (U.S. EPA, 1997). This may be modified in cases where a carcinogenic contaminant is widespread throughout state water bodies and the source is relatively ubiquitous.

Cooking Reduction Factor:

OEHHA strongly recommends to all consumers that they skin and thoroughly cook their fish prior to eating. Skinning and cooking remove or reduce a variety of chemical and

biological hazards. FCGs take into account organochlorine contaminant loss during the cooking process. The concentration of PCBs and other organic contaminants in fish are generally reduced by at least 30 percent, depending on cooking method (Anderson et al., 1993; Sherer and Price, 1993; Santerre, 2000; Wilson et al., 1998; Zabik et al., 1996). As such, a cooking reduction factor of 0.7 was included in the FCG equation for organic compounds (allowing for 70 percent of the contaminant to remain after cooking). Although fish analytical data are generally provided to OEHHA as skin-off fillets, when contaminant levels are determined using skin-on fillets, a cooking and skinning reduction factor of 0.5 is used to account for organic chemical losses of approximately 50 percent that occur during both processes combined (Anderson et al., 1993). Mercury and selenium concentrations in fish are not reduced by cooking or cleaning techniques and, thus, no reduction factor has been applied for these chemicals.

Nutrients:

Unlike the case for other fish contaminants listed above, selenium is a required nutrient and fish are a major dietary source of selenium. Thus, it should be ensured that the FCGs for selenium do not unduly limit sport fish as a potential source of selenium and that they also take into account additional dietary exposures to this element. As reported above, the current RDA for selenium is 55 µg/day for the general adult population, 60 µg/day for pregnant women, and 70 µg/day during lactation (IOM, 2000). Data from NHANES III show that the mean selenium intake for all individuals from diet alone is 113.7 µg/day, while the mean intake from diet plus supplements is 116 µg/day (IOM, 2000). This indicates that most individuals in the United States easily meet their nutritional needs for selenium and do not consume selenium supplements. Thus, the mean selenium intake from diet alone (114 µg/day; IOM, 2000) will be used as the background dietary selenium consumption rate for developing FCGs for selenium. As in all cases of supplement intake, consumers who take selenium supplements should take them with caution and under the advisement of their physician.

Use/Application of FCGs:

OEHHA has developed FCGs, using standard exposure factors and a consumption rate of eight ounces prior to cooking (six ounces after cooking), to provide a starting point to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. Any agency using FCGs provided in this report to establish fish tissue-based criteria for their own purposes must accept the assumptions described herein.

Table 1. Fish Contaminant Goals (FCGs) for Selected Fish Contaminants Based on Cancer and Non-Cancer Risk* Using an 8-Ounce/Week (prior to cooking) Consumption Rate (32 g/day)**	
	FCGs (ppb, wet weight)
Contaminant Cancer Slope Factor $(mg/kg/day)^{-1}$	
Chlordane (1.3)	**5.6**
DDTs (0.34)	**21**
Dieldrin (16)	**0.46**
PCBs (2)	**3.6**
Toxaphene (1.2)	**6.1**
Contaminant Reference Dose (mg/kg-day)	
Chlordane ($3.3x10^{-5}$)	100
DDTs ($5x10^{-4}$)	1600
Dieldrin ($5x10^{-5}$)	160
Methylmercury ($1x10^{-4}$)[S]	**220**
PCBs ($2x10^{-5}$)	63
Selenium ($5x10^{-3}$)	**7400**
Toxaphene ($3.5x10^{-4}$)	1100

*The most health protective Fish Contaminant Goal for each chemical (cancer slope factor- versus reference dose-derived) for each meal category is bolded.
**g/day represents the average amount of fish consumed daily, distributed over a 7-day period, using an 8-ounce serving size, prior to cooking.
[S]Fish Contaminant Goal for sensitive populations (i.e., women aged 18 to 45 years and children aged 1 to 17 years.)

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

EQUATIONS USED TO CALCULATE FISH CONTAMINANT GOALS

The following general equations were used to calculate Fish Contaminant Goals for chemicals at the consumption rates listed in Table 1, using an 8-ounce (prior to cooking) serving size. Separate equations are used for carcinogenic effects, non-carcinogenic effects, and nutrients with non-carcinogenic effects.

The following general equation can be used to calculate Fish Contaminant Goals (in µg/kg) at which the consumption exposure from a chemical with a ***carcinogenic*** effect is equal to the risk level for that chemical at any consumption level:

$$\text{Tissue concentration (ppb)} = \frac{\text{(Risk Level)(kg BW)(1000 µg/mg)}}{\text{[CSF (mg/kg/day)}^{-1}\text{] (CR kg/day)(ED/AT)(CRF)}}$$

As an example, for dieldrin, the Fish Contaminant Goal using a risk level of $1x10^{-6}$ and a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{(1x10^{-6})(70\text{ kg})(1000\text{ µg/mg})}{[16\text{ (mg/kg/day)}^{-1}](0.032\text{ kg/day})(30/70)(0.7)} = 0.46\text{ ppb}$$

The following general equation can be used to calculate Fish Contaminant Goals (in µg/kg) at which the consumption exposure from a chemical with a ***non-carcinogenic effect*** is equal to the reference level for that chemical at any consumption level:

$$\text{Tissue concentration (ppb)} = \frac{\text{(RfD mg/kg-day)(kg BW)(1000 µg/mg)}}{\text{(CR kg/day)(CRF)}}$$

As an example, for mercury, the Fish Contaminant Goal using a consumption rate of one, 8-ounce serving per week (32.0 g/day) for women aged 18 to 45 years and children aged 1 to 17 years would be calculated as follows:

$$\frac{(1x10^{-4}\text{ mg/kg-day})(70\text{ kg BW})(1000\text{ µg/mg})}{(0.032\text{ kg/day})(1)} = 219\text{ ppb}$$

The following general equation can be used to calculate the Fish Contaminant Goals (in mg/kg) at which consumption exposure from a ***nutrient with a non-carcinogenic effect*** is equal to the reference level for that chemical at any consumption level:

Tissue Concentration (ppb) =

$$\frac{\text{[(RfD mg/kg-day)(kg BW) – mg/day Background Dietary Level](1000 µg/mg)}}{\text{(CR kg/day)}}$$

As an example, for selenium, the Fish Contaminant Goal using a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{[(5\times10^{-3}\ \text{mg/kg-day})(70\ \text{kg}) - 0.114\ \text{mg/day}](1000\ \mu\text{g/mg})}{0.032\ \text{kg/day}} = 7{,}375\ \text{ppb}$$

Where,
Risk Level = 1×10^{-6}
BW = Body weight of consumer (70 kg default)
CSF = Cancer Slope Factor
CR = Consumption Rate as the daily amount of fish consumed
CRF = Cooking Reduction Factor (0.7 for organic contaminants in skin-off fillet)
ED/AT = Exposure Duration/Averaging Time (30 yr exposure/70 yr lifetime)
RfD = Chemical specific reference dose or other reference level

POTENTIAL BENEFITS OF FISH CONSUMPTION

Fish consumption advice is generally provided to the public from disparate arms of the biomedical community: physicians and nutritionists, who focus on the health benefits of eating fish, and toxicologists, who concentrate on the risks from exposure to contaminants that may be found in fish. The conflicting messages that often result likely confuse the consumer, who may then ignore recommendations to limit consumption of contaminated fish or, alternatively, avoid eating fish altogether (see, e.g., Oken et al., 2003). Only recently has there been a more focused attempt to craft unified guidance that addresses benefits and risks of fish consumption, although beneficial aspects are generally only discussed qualitatively.

With the discovery in the 1970s that, despite their high fat diet, Greenlandic Eskimos were virtually devoid of ischemic heart disease and diabetes mellitus, came the earliest recognition that fatty acids found in fish and marine mammals may have particular benefits to human health (Bang and Dyerberg, 1972; Dyerberg et al., 1975; Bang et al., 1976; Dyerberg et al., 1978; Dyerberg and Bang, 1979; Bang et al., 1980). The diet and blood lipid profile of the Eskimos were found to be very high in omega-3 fatty acids and very low in omega-6 fatty acids, in direct contrast to a typical "Western" diet in which the reverse is true (Dyerberg et al., 1975; Bang et al., 1980).

Omega-3 fatty acids, such as α-linolenic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are long-chain polyunsaturated fatty acids (PUFAs) with the first double bond inserted at the *third* carbon atom from the methyl end, while omega-6 fatty acids, such as linoleic acid, γ-linolenic acid and arachidonic acid, have the first double bond inserted at the *sixth* carbon atom from the methyl end (IOM, 2005). Fatty acids are designated by their number of carbon atoms, followed by the number of double bonds and the placement of the first double bond. For example, linoleic acid is denoted as 18:2n-6 because it has 18 carbons and two double bonds, with the first double bond located six carbons from the methyl end (the "n" or "omega" position). α-Linolenic (18:3n-3) and linoleic acids cannot be synthesized by humans and are thus required in the diet (IOM, 2005). α-Linolenic acid's only known function is as the precursor to the very long chain PUFAs EPA (20:5n-3) and DHA (22:6n-3), omega-3 fatty acids that are also consumed directly from fish (IOM, 2005). Because the conversion of α-linolenic acid to EPA and DHA is so inefficient (estimated at less than 5 percent) (Wang et al., 2006), and DHA and EPA levels are so low in other foods, fish or fish oil consumption is by far the most important dietary source of these fatty acids (Marszalek and Lodish, 2005). DHA serves as an important structural lipid in nervous tissue, spermatozoa, and the retina, and may be retroconverted to EPA; linoleic acid (18:2n-6), the most common dietary PUFA, is the precursor to arachidonic acid (20:4n-6) (IOM, 2005; Kris-Etherton et al., 2000). Arachidonic acid is also consumed directly from dietary sources such as meat, egg yolk and dairy (Calder, 2006; Richardson, 2006).

Once dietary omega-3 and omega-6 fatty acid precursors are converted *in vivo* to EPA or arachidonic acid, respectively, they can then be metabolized to produce different

eicosanoids, including various prostaglandins, thromboxanes, and leukotrienes, which, in turn, have contravening physiological actions (Robinson and Stone, 2006; Calder, 2006). The omega-3 derived eicosanoids, such as thromboxane A_3 and B_3, prostaglandins PGI_3 and PGE_3, and leukotriene B_5, induce vasodilation, inhibit arrhythmia, decrease platelet aggregation, and are anti-inflammatory. In contrast, eicosanoids derived from omega-6 fatty acids, such as thromboxane A_2 and B_2, prostaglandins PGI_2 and PGE_2, and leukotriene B_4, cause vasoconstriction, are pro-arrhythmic, and increase platelet aggregation and inflammation (Robinson and Stone, 2006; Simopoulos, 1999; DeFilippis and Sperling, 2006). A proper ratio of dietary omega-6 to omega-3 fatty acids is thus imperative to protect health (Simopoulos, 1999; 2002), particularly since high dietary omega-6 levels inhibit the *in vivo* conversion of α-linolenic acid to DHA and EPA (Kris-Etherton et al., 2000). Similarly, high dietary omega-3 fatty acid levels reduce the formation of 2-series eicosanoids from arachidonic acid (IOM, 2005). It has been speculated that conflicting results in clinical trials on the benefits of dietary omega-3 fatty acids may have resulted from failure to take into account background dietary omega-6 fatty acid consumption, high levels of which may inhibit the production of anti-aggregatory eicosanoids and thus undermine the effectiveness of omega-3 fatty acids in disease prevention (Hibbeln et al., 2006).

Humans evolved consuming a diet that was largely equivalent in omega-6 and omega-3 fatty acids. In the 1960s, however, a dramatic shift in the level and composition of dietary fat occurred following the recommendation that saturated fats in the diet be replaced with vegetable oils, such as corn oil and safflower oil, which contain omega-6 to omega-3 ratios greater than 60:1 (Simopoulos, 2001). At the same time, the proportion of farm-raised to wild fish consumption increased (DeFilippis and Sperling, 2006). Farm-raised fish, like farm-raised cows, pigs, and chickens, are often fed diets rich in omega-6 fatty acids and many have tissue omega-6 to omega-3 ratios considerably higher than wild fish of the same species (Hamilton et al., 2005; DeFilippis and Sperling, 2006; Kris-Etherton et al., 2002; Foran et al., 2005; Marszalek and Lodish, 2005). The typical "Western" diet has been estimated to have an omega-6 to omega-3 ratio of 10:1 to 20:1 (Simopoulos, 2003), with a total omega-3 fatty acid consumption of approximately 1.6 g/day (Johnson and Schaefer, 2006). Of that, mean consumption of EPA + DHA is about 0.1 g/day (IOM, 2007). In NHANES 1999-2002, all age/sex population groups were reported to consume an average of less than 0.2 g/day EPA + DHA (IOM, 2007).

Since the Greenlandic Eskimo studies in the 1970s, an explosion of research has examined potential health benefits of fish consumption, with a particular emphasis on omega-3 fatty acids. In 1996, the AHA published their first statement on fish consumption, fish oils, lipids, and coronary heart disease (Stone, 1996). While considering it "premature" at that time to recommend the use of fish oil supplements for the prevention of cardiovascular disease by the general public, the AHA did nonetheless recognize that consumption of marine sources of omega-3 fatty acids seemed "reasonable" because of the low content of saturated fat in fish compared to other meat products and the potential for cardiovascular benefits that might be borne out by future research (Stone, 1996). Subsequently, the most recent AHA statement on the subject

(Kris-Etherton et al., 2002) was strengthened significantly from its original version, as additional research since 1996 has provided even more compelling evidence of the benefits of fish and fish oil consumption.

Currently, the AHA recommends that *individuals without documented coronary heart disease* "eat a variety of (preferably fatty) fish at least twice a week," *individuals with documented coronary heart disease* "consume about 1 g of EPA + DHA per day, preferably from fatty fish (EPA + DHA from capsule form could be considered in consultation with the physician)," and *individuals who need to reduce triglycerides* should consume "two to four grams of EPA + DHA per day provided as capsules under a physician's care" (AHA, 2006). The AHA considers a serving size to be four ounces of fish prior to cooking, or three ounces after cooking, one-half of the serving size typically assumed in fish consumption advisories. The WHO also recommends consumption of 1-2 servings of fish per week (to provide 200-500 mg of EPA + DHA per serving) to protect against coronary heart disease and ischemic stroke (WHO, 2003), while the 2005 Dietary Guidelines Advisory Committee (DGAC) Report concludes that "consumption of two servings (approximately eight ounces) per week of fish high in EPA and DHA is associated with reduced risk of both sudden death and CHD (coronary heart disease) death in adults." The Committee further states that "to benefit from the potential cardioprotective effects of EPA and DHA, the weekly consumption of two serving of fish, particularly fish rich in EPA and DHA, is suggested" (DGAC, 2005). In their report assessing the risks and benefits of fish consumption, the Scientific Advisory Committee on Nutrition (SACN) of the Food Standards Agency and Department of Health in the United Kingdom recommends that all individuals, including pregnant women, "eat at least two portions of fish per week, of which one should be oily," providing approximately 450 mg/day long chain omega-3 fatty acids (SACN, 2004; see also IOM, 2007, for additional discussion).

Presented below is a brief summary of many of the potential benefits of fish or fish oil consumption, given the current state of scientific knowledge. This review is not intended as an exhaustive evaluation of the merits and weaknesses of the vast number of articles on this subject, but merely to be illustrative of significant, and generally recent, research or review articles in the field. Many studies are observational, as is also commonly the case with human toxicity studies on fish contaminants, and cannot prove cause and effect relationships with certainty. Even randomized controlled trials (RCTs), the gold standard of human medical experimentation, may suffer in the case of fish or fish oil studies from the inability to blind the subject to the treatment. Although current scientific consensus recommends fish consumption as a likely way to prevent specific chronic disease conditions, it is unclear to what extent potential benefits from fish or fish oil consumption listed below may be realized through the following mechanisms: increased consumption of omega-3 fatty acids, decreased dietary omega-6 to omega-3 fatty acid ratio (as generally occurs to a lesser extent with fish oil supplementation and to a greater extent with fish consumption), simple replacement of other high fat dietary protein sources with fish, or other nutritive or non-nutritive factors that may covary with fish consumption

(e.g., an overall healthy lifestyle). Many of these issues are discussed in the recent IOM report on balancing the risks and benefits of seafood consumption (IOM, 2007).

Cardiovascular Disease and Total Mortality:

The most thoroughly evaluated potential beneficial effect of fish or fish oil consumption has been on the prevention and treatment of cardiovascular disease. In a recent meta-analysis, Hooper et al. (2006) concluded that evidence to date does not support the position that short or long chain omega-3 fatty acids have a clear effect on this condition. Numerous researchers criticized this review, however, particularly with respect to inappropriate pooling of study participants, outcomes, and marine- and plant-based omega-3 fatty acids, as well as the inclusion of a "methodologically poor" study, which, in and of itself, "changed the conclusion of the meta-analysis from clear benefit to no benefit" (Deckelbaum and Akabas, 2006; Geleijnse et al., 2006; He and Song, 2006; Twisselmann, 2006; von Schacky et al., 2006). A subsequent systematic review of the literature addressed some of these shortcomings (Deckelbaum and Akabas, 2006). After evaluating 46 studies meeting strict selection criteria, Wang et al. (2006) found that omega-3 fatty acids from fish or fish oil supplements, but not α-linolenic acid, appeared to reduce the risk of all-cause mortality, cardiac and sudden death, and stroke. Because RCTs on the effects of omega-3 fatty acids in individuals already suffering from cardiovascular disease (secondary prevention) have been conducted, the strength of the evidence for that outcome is greater than that for prevention of cardiovascular disease in healthy individuals (primary prevention), for which only cohort studies are available (Wang et al., 2006). Mozaffarian and Rimm (2006) also reported that evidence generated from pooling published prospective or randomized primary and secondary prevention trials indicated that consumption of 250 to 500 mg/d of EPA + DHA reduced the relative risk of coronary heart disease death by 36 percent compared to little or no EPA + DHA intake. Additional intake did not appear to confer additional benefits; risk reduction was most closely linked to consumption of fatty fish, not lean fish. Other recent meta-analyses or systematic literature reviews have supported the conclusion that omega-3 fatty acid consumption has a significant beneficial effect on cardiovascular disease (He et al., 2004a; Bucher et al., 2002; Jacobson, 2006; Whelton et al., 2004; Konig et al., 2005; Harper et al., 2005).

Several studies have suggested that mercury may attenuate cardioprotective effects of omega-3 fatty acids in fish (e.g., Salonen et al., 1995; Rissanen et al., 2000; Guallar et al., 2002; Virtanen et al., 2005), particularly in Finnish men, although at least one study did not find such an association (Yoshizawa et al., 2002). Current evidence suggests that fish or fish oils provide more health benefits to those individuals who also have low methylmercury body burdens (IOM, 2007).

Stroke:

Early research on the potentially protective effects of omega-3 fatty acid and/or fish consumption and stroke showed conflicting results (see, for example, Gillum et al., 1996;

Keli et al., 1994; Orencia et al., 1996). This may have occurred, in part, because of a failure to differentiate ischemic and hemorrhagic strokes in study populations (He et al., 2004b), which are caused by opposing mechanisms. A recent meta-analysis of nine cohorts suggested that fish consumption and ischemic stroke were inversely related, with the possibility that as few as one to three fish meals a month might significantly reduce the incidence of this disorder (He et al., 2004b). In a study of 79,839 women, Iso et al. (2001) found that risk of thrombotic infarction was decreased 48 percent for women who ate fish two to four times per week compared to those who ate fish less than once per month. In another analysis of published studies, Bouzan et al. (2005) found that any fish consumption provided significant reduction in stroke risk compared to no fish consumption. The authors noted that an incremental increase in fish consumption may reduce stroke risk even further. In a review of the literature, Wang et al. (2006) found that studies on the effect of marine-based omega-3 fatty acids on stroke were not consistent, but suggested a possible role of fish or fish oils in the prevention of stroke.

Cognitive Function:

Brain tissue is highly enriched in DHA, which is considered essential for the functional development of neural tissues. Much of DHA and other long chain PUFA content of fetal brain is obtained from the maternal blood supply, as *in vivo* synthesis from shorter chain PUFAs is minimal during this period (Cheruku et al., 2002; Marszalek and Lodish, 2005; Uauy and Dangour, 2006). Studies have suggested that fish consumption by the mother during pregnancy or by the young child may improve several neurological outcomes during early development (Mozaffarian and Rim, 2006). Language and social skills, for example, were higher in 6- and 12-month-old infants who ate fish once or more per week compared to those who rarely or never ate fish (Daniels et al., 2004). Maternal fish intake was also positively associated with infant cognitive scores in this study. Sleep-state patterns indicative of greater cognitive maturity were seen in infants whose mothers had higher plasma phospholipid DHA levels compared to those whose mothers had lower plasma phospholipid DHA levels (Cheruku et al., 2002). Oken et al. (2005) showed that infant cognitive scores were positively correlated with fish consumption, but inversely related to maternal hair mercury concentrations. Scores were highest among infants whose mothers had hair mercury concentrations of 1.2 ppm or less and consumed two or more fish meals per week. Conversely, scores were lowest among infants whose mothers had hair mercury concentrations greater than 1.2 ppm and ate two or fewer fish meals per week. Hibbeln et al. (2007) found that, after adjusting for 28 potentially confounding variables, the risk of suboptimal scores for verbal intelligence, prosocial behavior, fine motor, communication, and social development in children six months to eight years old was greater when maternal fish consumption was less than 340 g per week compared to when maternal fish consumption was greater than 340 g per week.

Several studies have shown that DHA levels are reduced in brain and plasma of patients with Alzheimer disease (AD) or other forms of dementia (Johnson and Schaefer, 2006). Potential mechanisms by which these fatty acids may modify the risk for dementia include the prevention or reduction of atherosclerosis, thrombosis, and inflammation

(Barberger-Gateau et al., 2002). In one of the first studies to investigate the potential relationship between fish consumption and dementia, Kalmijn et al. (1997) found that the incident risk of developing all forms of dementia was reduced 60 percent in people 55 years or older who consumed 18.5 or more g/day of fish compared to those consuming 3.0 or fewer g/day fish. The risk for developing AD without cerebrovascular disease in these respective populations was reduced 70 percent. Similarly, Morris et al. (2003) found that people who ate fish at least once per week reduced their risk of incident AD by 60 percent compared to those who rarely or never ate fish. In a subsequent study using the same population group, fish consumption was also found to be significantly inversely related to expected cognitive decline in individuals 65 years and older over a six year period (Morris et al., 2005). Fatty fish consumption and EPA + DHA consumption were also inversely related to mild cognitive decline in a cross-sectional study of middle-aged males and females (Kalmijn et al., 2004). Huang et al. (2005) specifically showed that fatty fish consumption, but not consumption of lean or fried fish, decreased the risk of dementia in a dose-dependent fashion in individuals who did not carry the *APOE* ε4 allele (a risk factor for AD). Fatty fish consumption more than twice per week decreased the risk of incident dementia and AD by 28 and 41 percent, respectively, compared to those eating fish less than once per month. Using a more accurate estimate of omega-3 fatty acid exposure, Heude et al. (2003) found that omega-3 fatty acid concentration and omega-3 to omega-6 ratio of erythrocyte membranes was inversely related to cognitive decline in 63-74 year-old men and women over a four year period.

Although omega-3 fatty acids are often considered the physiologically active agents responsible for positive health effects of fish, some research indicates that other components may have benefits as well. For example, fish, but not omega-3 fatty acid, consumption was inversely associated with a reduced rate of cognitive deterioration over a six-year period in a study of 6,158 males and females, aged 65 or older (Morris et al., 2005). Consumers who ate fish once a week or more maintained the mental status of a person three to four years younger compared to those who ate fish less than once a week.

Preliminary studies have found that omega-3 fatty acids mitigate symptoms in some children with attention-deficit/hyperactivity disorder; however, other studies have not supported these results (Richardson, 2006; Young and Conquer, 2005). Additionally, several epidemiological studies and intervention trials have shown that fish or omega-3 fatty acid consumption may be useful for the prevention or treatment of depression or other mood disorders, which may reflect the well-recognized link between depression and cardiovascular disease (see Parker et al., 2006; Nemets et al., 2006). Numerous authors have reported decreased blood omega-3 fatty acid levels in patients with psychiatric disorders (Tiemeier et al., 2003; Peet and Stokes, 2005; Sublette et al., 2006; Young and Conquer, 2005; Richardson, 2006). Additional research is needed to elucidate the potential role of fish or fish oils in the treatment of neuropsychiatric disorders (Parker et al., 2006; Richardson, 2006; Young and Conquer, 2005).

Visual Function:

DHA is found in very high concentrations in the retina and has a functional role in visual development (Connor et al., 1992; Neuringer, 2000; Cho et al., 2001; Uauy and Dangour, 2006; Johnson and Schaefer, 2006). As noted above, fetal DHA is largely obtained through the maternal blood supply and, postnatally, through breast milk (Marszalek and Lodish, 2005). The degree to which DHA supplementation of infant formulas is necessary or beneficial is not known (Mozaffarian and Rimm, 2006), although the evidence supporting its benefit for preterm infants is more persuasive than it is for term infants (Heird and Lapillonne, 2005; Cheatham et al., 2006). A recent meta-analysis of 14 controlled trials of DHA supplementation of infant formulas showed a strong positive relationship between DHA dose and visual acuity measurements in four-month-old infants (Uauy et al., 2003). Some studies show that the relationship between low dietary omega-3 fatty acids and slowed development of visual acuity may be transitory; however, long-term sequelae of early visual impairments that may occur with low-DHA diets have not been studied and could be significant (Neuringer, 2000).

Numerous studies have also shown that fish and/or omega-3 fatty acid consumption provides benefits to the aging eye and may protect against retinal pathologies associated with ischemia, light, oxygen, inflammation, and age (SanGiovanni and Chew, 2005). Age-related macular degeneration (AMD) is the primary cause of visual disability and blindness in older Americans (Chua et al. 2006; Seddon et al., 2006). In a cross-sectional population-based study, Smith et al. (2000) reported that individuals consuming fish more than once per week were at significantly lower risk of developing late AMD than individuals consuming fish less than once per month. Similarly, in two large prospective cohort studies, fish consumption was inversely related to AMD development; consumption of four or more servings per week reduced the risk of AMD 35 percent compared to eating fish three or fewer times per week. DHA consumption had a smaller, but still significant, inverse relation with AMD development, indicating that substances in fish other than fatty acids may also decrease AMD risk (Cho et al., 2001). In prospective cohort and case control studies, Seddon et al. (2001; 2003; 2006) showed that the risk for development and progression of AMD was significantly reduced or slowed, respectively, with increasing fish or omega-3 fatty acid consumption. In two of the three studies, however, this relationship existed only if consumption of linoleic acid was also low, indicating that the omega-6 to omega-3 ratio may be an important component to the protective effect of omega-3 fatty acids in the development and progression of this disease (Seddon et al., 2006). Chua et al. (2006) found that weekly fish consumption reduced the 5-year incidence of early AMD about 40 percent, while eating fish three times per week or more reduced the 5-year incidence of late AMD about 75 percent. In a review of published studies, Hodge et al. (2006) found that, while there is evidence to suggest that omega-3 fatty acids may play a role in prevention of AMD, variability among studies and the lack of a RCT prevent clinical conclusions from being drawn.

Inflammatory Diseases:

The effect of omega-3 fatty acids on inflammation and inflammatory diseases has been recently reviewed (Ariza-Ariza et al., 1998; Calder, 2006; Cleland et al., 2005; Simopoulos, 2002). Omega-3 fatty acids have been theorized to be useful as anti-inflammatory agents because they generate anti-inflammatory mediators, decrease production of arachidonic acid-derived pro-inflammatory eicosanoids, and modify the expression of inflammatory genes (Calder, 2006). Research has strongly supported the role of long-chain omega-3 fatty acids in the treatment of rheumatoid arthritis (Calder, 2006), including the reduced need for traditional non-steroidal anti-inflammatory drugs (NSAIDS) in patients taking sufficient doses of fish oils (Ariza-Ariza et al., 1998; Cleland, 2005; 2006). However, the data are less robust for the use of long chain omega-3 fatty acids in the treatment of other inflammatory diseases, such as inflammatory bowel disease or asthma, and additional clinical trials are recommended to further define their potential role in the treatment of these conditions (Calder, 2006). Currently, the effective dose for anti-inflammatory effect in rheumatoid arthritis is estimated to be 2.7 g/day EPA + DHA (Cleland, 2005), a dose not easily obtainable through fish consumption alone. It is recommended that this dose not be achieved through the use of cod liver oil supplementation because of the high vitamin A concentration of this product (Cleland, 2005). The shorter chain α-linolenic acid has not been shown to possess anti-inflammatory properties at practical intakes (Calder, 2006).

CONSIDERATION OF THE RISKS AND BENEFITS OF FISH CONSUMPTION

Since the recognition in the 1960s and 1970s that dietary fish might play a significant role in both health and disease, a vast number of studies have been conducted on the benefits and risks of fish consumption. As noted above, though, these areas of research are typically evaluated independently. Risk assessments on contaminants found in fish are occasionally published in the peer-reviewed literature (e.g., Hites et al., 2004; Mahaffey et al., 2004; Knobeloch et al., 2006); a recent risk assessment of organic contaminants in wild and farmed salmon (Hites et al., 2004) sparked intense controversy over whether the known benefits of fish consumption had been adequately considered in comparison to the relatively small lifetime cancer risks associated with organochlorine compounds (Stokstad, 2004; Rembold, 2004; Tuomisto et al., 2004; Lund et al., 2004; Foran et al., 2006; Willett, 2005; 2006). Recently, a few authors have published risk-benefit analyses for fish consumption that considered one or more contaminants and incorporated a quantitative estimate of benefit (Anderson and Wiener, 1995; Foran et al. 2005; Cohen et al., 2005; Gochfeld and Burger, 2005; Ponce et al., 2000; Sidhu, 2003). Using one method of calculating the combined risks and benefits of fish consumption, for example, Foran et al. (2005) found that consumption of farmed salmon was estimated to prevent nearly 300 times more cardiac-related deaths than it potentially caused from PCB-associated cancer. In most assessments, the comparative risks of alternate foods are not taken into account. Other sources of animal protein that may be consumed in place of fish, such as beef, pork, or chicken, also contain undesirable components (e.g., PCBs, dioxins, saturated fat, and hormone or antibiotic residues) whose risk has not been characterized or estimated in a fashion similar to that of fish.

As early as 1986, OEHHA held a workshop on balancing the risks and benefits of fish consumption (CDHS, 1988). In more recent years, OEHHA, and similar agencies from other states, have incorporated benefit statements into their fish consumption advisories that assure the public that fish should be part of a healthy diet. In a technical memorandum describing the derivation of a noncommercial fish consumption recommendation for women who may become pregnant, pregnant women, nursing mothers, and young children, U.S. EPA and FDA noted that their advice "balances the risk from mercury with the benefits of fish" (U.S. EPA, 2004).

Conclusions:

OEHHA determines that there is a significant body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality**.** As is the case with all foods, fish contain constituents that may be harmful when consumed in unrestricted quantities. However, because of the unique health benefits associated with fish consumption, the advisory process should be

expanded beyond a simple risk paradigm in order to best promote the overall health of the fish consumer.

ADVISORY TISSUE LEVELS FOR CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

To include the benefits of fish consumption in the advisory process, ATLs were calculated for each of the contaminants for which FCGs were derived. In comparison to FCGs, which were based on a single meal frequency, ATLs were calculated for several meal frequency categories that are used to provide advice to the consumer that balances the benefits and risks of fish consumption. This yields a range of corresponding contaminant concentrations in fish within categories as shown in Table 2. ATLs were calculated using the same general formulas as those used to calculate FCGs, with some adjustments in order to incorporate the benefits of fish consumption. Because benefits are integrated differently into ATL equations for cancer and non-cancer risk, these methods are discussed separately. All factors and assumptions not specifically addressed are the same as those used to develop FCGs.

Cancer Risk:

$$\text{Tissue concentration (ppb)} = \frac{\text{(Risk Level)(kg BW)(1000 µg/mg)}}{\text{[CSF (mg/kg/day)}^{-1}\text{] (CR kg/day)(ED/AT)(CRF)}}$$

Risk Level:

For FCGs, the maximum risk level was set at $1x10^{-6}$, estimating that, at the given consumption rate, not more than one additional cancer case would be expected in a population of one million people consuming fish over a lifetime. OEHHA acknowledges that, while it should be a goal to maintain a risk level of $1x10^{-6}$ for fish and other foods, the counterbalancing nutritional benefits of foods, particularly the unique benefits of fish, must be considered. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued through fish consumption.

Thus, OEHHA concludes that, for the purposes of developing fish consumption advisories, ATLs should be calculated using a maximum risk level of $1x10^{-4}$, estimating that, at the given consumption rate, not more than one additional cancer case would be expected in a population of 10,000 people consuming fish over a lifetime. This risk level is within the acceptable range of risks ($1x10^{-4}$ to $1x10^{-6}$) used by U.S. EPA in regulatory criteria for drinking water (Fed. Reg., 1998) and is provided as an example of a maximum acceptable risk level in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (U.S. EPA, 2000a). OEHHA considers that a maximum risk level of $1x10^{-4}$ appropriately balances the cancer risk associated with fish consumption with the numerous known health benefits that can be accrued from eating fish. Because each meal frequency category encompasses a range of fish

contaminant levels (see consumption rate discussion and ATL table below), fishers, over time, will be exposed to a range of risk levels as they catch and eat different fish. Thus, when the *maximum* risk level is set at $1x10^{-4}$ for each meal frequency category, the actual *average* cancer risk for fish consumers over their lifetime is less than $1x10^{-4}$ (ranging from approximately $5x10^{-5}$ to $1x10^{-4}$), when consumption advisories are based on carcinogens detected in fish.

Consumption Rate (CR):

FCGs were calculated using a single consumption rate (32 g/day, or a single serving of eight ounces of fish, prior to cooking, per week) aligning with the AHA's minimum recommended fish consumption rate for adults and exceeding the typical consumption rate for the vast majority of sport fishers (see, for example, SFEI, 2000). This consumption rate is also used to begin issuing fish consumption advisories that are based on cancer risk using the ATLs and other considerations. Because OEHHA also considers it important to offer advice for the small segment of fishers who choose to consume fish more frequently than one 8-ounce serving per week, ATLs for two and three 8-ounce servings per week, prior to cooking (64 and 96 g/day, respectively), were also calculated based on cancer risk.

Example Calculation:

Using a risk level of $1x10^{-4}$, the slope factor for each chemical, and consumption rates of 32, 64, and 96 g of fish/day in the above equation will yield three numbers that are the cutoff values for one, two, and three servings per week, respectively, for cancer risk.

As an example, for dieldrin, the ATL using a risk level of $1x10^{-4}$ and a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{(1x10^{-4})(70\text{ kg})(1000\ \mu g/mg)}{[16\ (mg/kg/day)^{-1}](0.032\text{ kg/day})(30/70)(0.7)} = 46\text{ ppb}$$

Thus, fish containing 46 ppb dieldrin, or less, can be consumed in the amount of at least one, 8-ounce serving per week.

Non-Cancer Risk:

$$\text{Tissue concentration (ppb)} = \frac{(\text{RfD mg/kg-day})(\text{kg BW})(1000\ \mu g/mg)}{(\text{CR kg/day})(\text{CRF})}$$

Hazard Quotient and Consumption Rate:

For FCGs, the maximum HQ was set at 1, indicating that the *maximum* exposure (based on CR in the equation) is equivalent to the RfD. In order to balance the risks and benefits

of fish consumption when considering non-cancer risk, however, OEHHA determined that the *average* exposure should be equivalent to the RfD. With the ATLs, each meal frequency category (one, two and three servings per week) encompasses a range of fish contaminant levels, as noted above. Thus, fishers over time will be exposed to a range of HQs as they catch and eat different fish. When the *maximum* HQ for each meal consumption frequency is set at 1, using the maximum consumption rate in the equation (32, 64, and 96 g/day for one, two, and three servings per week, respectively) to set the cutoff for each meal frequency leads to an actual *average* HQ for fish consumers, over a multiple week basis, of less than 1. This is because the majority of fish caught in each meal frequency category will have a lower contaminant level than the maximum contaminant level used to set the cutoff. However, if the cutoffs are adjusted slightly so that the *average* rather than the maximum HQ is 1, over a multiple week basis, and an acceptable maximum HQ is still maintained, fishers who follow the advice will be able to consume a greater amount of fish and consequently enjoy a higher level of health benefits without incurring significant non-cancer risks from contaminants in fish.

U.S. EPA adjusted a meal frequency cutoff to establish its national advisory for mercury of one serving per week of sport fish from untested water bodies. They combined several meal categories (two, three and four servings per month), as do many states, in order to balance the risks and benefits of fish consumption and simplify communication (U.S. EPA, 2004). U.S. EPA used the contaminant concentration that would otherwise be associated with a recommendation of two servings per month as the cutoff for the one serving per week advice. Although this results in an HQ higher than 1 for some fish that fall into the 1 serving per week category, this advice is still health protective because, on average, fishers will be consuming fish with lower mercury levels than those used to establish the one serving per week cutoff.

OEHHA incorporated an "average HQ" concept into the ATLs by modifying the fish consumption rate used in the ATL equation. As explained above, one, 8-ounce serving of fish per week is equivalent to a consumption rate of 32 g/day. Consumption of two servings of fish per month would be equivalent to 0.5 servings per week, or 16 g/day. Following the example of U.S. EPA in their national advisory (see above), OEHHA also used a 16 g/d consumption rate to calculate the cutoff for the one serving per week category when considering non-cancer risk for the ATLs. As can be seen in the sample calculation below, this allows for greater consumption of fish (and a better balancing of risks and benefits) than if a consumption rate of 32 g/day were used. In a similar fashion, OEHHA used a consumption rate of 48 g/day (approximately 1.5 servings per week) to compute the ATLs for the two servings per week category for non-cancer risk. A consumption rate of 96 g/day was used, as it was for cancer risk, to determine the ATLs for three servings per week. As a consequence of making these adjustments, the *average* HQ, over the entire range of potential exposures, is approximately 1. OEHHA considers this average HQ appropriate to balance the risk and benefits of fish consumption when considering non-cancer risk.

Example Calculation:

Using the RfD for each chemical, and consumption rates of 16, 48, and 96 g/day, in the above equation will yield three numbers that are the cutoff values for one, two, and three servings per week, respectively, for non-cancer risk.

As an example, for mercury, the ATL for one, 8-ounce serving per week for women aged 18-45 years would be calculated as follows:

$$\frac{(1\times10^{-4}\ \text{mg/kg-day})(70\ \text{kg BW})(1000\ \mu\text{g/mg})}{(0.016\ \text{kg/day})(1)} = 440\ \text{ppb}$$

Thus, fish containing 440 ppb mercury, or less, can be consumed in the amount of at least one, 8-ounce serving per week.

Final ATL Calculations:

For each chemical, ATLs were calculated separately for cancer and non-cancer risk, if appropriate, for consumption frequency categories of one, two, and three 8-ounce servings per week. Values for cancer and non-cancer risk were then compared to determine whether the cancer or non-cancer value was the most health-protective. For all chemicals except DDTs, either cancer or non-cancer risk determined the ATL for each consumption frequency category. For DDTs, consumption advice for one serving per week was based on cancer risk, while consumption advice for two and three servings per week was based on non-cancer risk.

OTHER CONSIDERATIONS USED IN THE DEVELOPMENT OF FISH CONSUMPTION ADVISORIES AND SAFE EATING GUIDELINES

ATLs are used as part of the process to develop traditional health advisories (which focus on fish whose consumption should be restricted or avoided altogether) as well as the newer "safe eating guidelines," which inform consumers of fish with low contaminant levels considered safe to eat frequently. Other factors, including the following, will also be used by OEHHA to develop advisories and safe eating guidelines, as appropriate.

Omega-3 Fatty Acid Levels:

The fatty acid content of fish is highly variable within and among species; fish diet, sex, age, and reproductive status, as well as location and season all affect the total concentration and composition of tissue fat (Nettleton, 1995). At the present time, omega-3 fatty acids levels are not available specifically for California sport fish, although applicable national averages have been published for some species. If acceptable surrogate or actual omega-3 fatty acid data exist for California sport fish, this information may be used to alter fish consumption advice. For example, OEHHA may recommend higher consumption of fish with high omega-3 levels than fish with identical levels of contaminants but lower omega-3 levels.

Contaminant Data:

Once the consumption frequency categories and ATLs are established, the data must then be carefully examined to determine what contaminant values will be compared to the ATLs. Fish contaminant data collected from a water body are often highly variable, reflecting environmental factors such as seasonal effects and localized sources or sediment methylation processes. Evaluating these data prior to developing site-specific (water body) or regional consumption advice is a complex process that may involve one or more approaches. The most common and simplest method of interpreting fish contaminant data collected from a site is to calculate a value of central tendency such as the geometric mean, arithmetic mean, median or mode. OEHHA often uses the arithmetic mean for developing safe eating guidelines; however, each of these measurements is helpful in interpreting the distribution of the data. Another method of interpreting a data set is to examine the regression line between species length and chemical contaminant level. Consumption guidance can then be tailored to different fish size classes or to the predicted contaminant concentration of the most typical length of fish consumed, provided adequate creel data are available to make this determination. This method is most useful for contaminants, such as mercury, where the concentration is largely dependent on fish size in specific fish species.

After careful selection of an appropriate contaminant concentration for each species at a site (e.g., an arithmetic mean, mode or a regression analysis), that value or values can then be compared to the range of concentrations presented in the ATL table (Table 2).

Risk Communication:

After thorough evaluation of fish contaminant data for a site and comparison of appropriate contaminant values to the ATLs, OEHHA may determine that strict adherence to established consumption frequency categories results in consumption advice that is too complex for the fisher to follow, particular for large water bodies. In these cases, OEHHA may make minor adjustments to recommended consumption limits for a species in order to best facilitate communication. For example, if contaminant levels in a species vary along a discreet coastal region, OEHHA may choose the most restrictive or most common advice for that species for the entire region, depending on circumstances and communication considerations. Additionally, in safe eating guidelines, fishers who do not skin or cook their fish may be advised to consume less fish than guidelines recommend for their population group, if organochlorine contaminants are present in quantities that affect consumption guidelines. Skinning and cooking do not reduce methylmercury concentrations in fish tissue. Serving sizes are based on fish consumption by an average 160 pound person. Individuals weighing less than 160 pounds will be encouraged to eat proportionately smaller amounts. As noted previously, because of their smaller body weights, children will be advised to eat approximately one-half as much fish (in either quantity or frequency) as are women of childbearing age.

Conclusions:

The ATLs described in this report should not be misinterpreted as static “bright lines” that others can use to duplicate state fish consumption advisories. As noted, ATLs are but one component of a complex process of data evaluation and interpretation used by OEHHA in the assessment and communication of fish consumption risks. The nature of the contaminant data or omega-3 fatty acid concentrations in a given species in a water body, as well as risk communication needs, may alter strict application of ATLs when developing site-specific advisories. For example, OEHHA may recommend that consumers eat fish containing low levels of omega-3 fatty acids less often than the ATL table would suggest based solely on contaminant concentrations. OEHHA will use the guidelines set forth in this report as a framework, along with best professional judgment, to provide fish consumption guidance on an *ad hoc* basis that best combines the needs for health protection and ease of communication for each site.

Table 2. Advisory Tissue Levels (ATLs) for Selected Fish Contaminants Based on Cancer or Non-Cancer Risk Using an 8-Ounce Serving Size (Prior to Cooking) (ppb, wet weight)				
Contaminant	**Three 8-ounce Servings* a Week**	**Two 8-ounce Servings* a Week**	**One 8-ounce Servings* a Week**	**No Consumption**
Chlordane[c]	≤190	>190-280	>280-560	>560
DDTs[nc**]	≤520	>520-1,000	>1,000-2,100	>2,100
Dieldrin[c]	≤15	>15-23	>23-46	>46
Methylmercury (Women aged 18-45 years and children aged 1-17 years)[nc]	≤70	>70-150	>150-440	>440
Methylmercury (Women over 45 years and men)[nc]	≤220	>220-440	>440-1,310	>1,310
PCBs[nc]	≤21	>21-42	>42-120	>120
Selenium[nc]	≤2500	>2500-4,900	>4,900-15,000	>15,000
Toxaphene[c]	≤200	>200-300	>300-610	>610

[c]ATLs are based on cancer risk
[nc]ATLs are based on non-cancer risk
*Serving sizes are based on an average 160 pound person. Individuals weighing less than 160 pounds should eat proportionately smaller amounts (for example, individuals weighing 80 pounds should eat one 4-ounce serving a week when the table recommends eating one 8-ounce serving a week).
**ATLS for DDTs are based on non-cancer risk for two and three servings per week and cancer risk for one serving per week.

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

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APPENDIX 1: RESPONSE TO COMMENTS

Comments and Responses to the Original Draft Document:
Development of Guidance Tissue Levels and Screening Values for Common Contaminants in California Sport Fish:
Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene.

Commenter 1:
Sheila Hamilton
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Comment 1.1
Because the final guidance tissue levels and screening values will, no doubt, play a significant role in future regulatory decisions throughout the state, we urge OEHHA to be more specific on the proper and improper use of these proposed thresholds. For example, the State Water Resources Control Board recently misinterpreted OEHHA's screening values (SVs) as thresholds defining impaired water quality. The report does not caution against using the screening values as informal Water Quality Objectives or Maximum Contaminant Levels.

Response 1.1
OEHHA has reconsidered the usefulness of establishing SVs as part of our protocol to develop fish consumption recommendations and determined that the SVs should be removed from the final document. We are providing Fish Contaminant Goals that can be used as a starting point for agencies to develop fish tissue-based criteria. Agencies that require screening criteria for mandated activities may still seek OEHHA's advice for their development. Any screening criteria employ numerous assumptions, particularly the consumption rate and risk level, and may be targeted to different population groups. These issues must be considered and agreed upon as relevant to the purpose of the criteria prior to their development and use by any agency.

Comment 1.2
The draft document was developed using a wide variety of assumptions. We recommend that these assumptions be summarized in a single table.

Response 1.2
The assumptions are explained carefully and individually in the text where they are used, which is considered most appropriate.

Comment 1.3
Table 1 shows a range of recommended GTLs that vary in relation to the average amount of fish consumed in a month. The presentation should be expanded to show how changes in other key assumptions will cause the GTL or SV to increase or decrease.

Response 1.3
While Fish Contaminant Goals (FCGs) and GTLs (now the Advisory Tissue Levels, or ATLs) will change if the assumptions change, the assumptions made by OEHHA in development of this document are fairly standard in risk assessment and have been clearly described in the document. As OEHHA is responsible for issuing sport fish consumption guidelines in the state of California, there is no reason to present alternative assumptions that will not be used to issue fish consumption advice.

Comment 1.4:
We recommend that OEHHA develop a simple spreadsheet tool, based on the equations shown on page 39-40 (now page 43-44) of the draft report, that allow end users to modify the underlying assumption and graph the range of recommended values. With minor modifications, that tool could be adapted for general use by other state agencies.

Response 1.4:
As noted previously, it is OEHHA's mandate to issue health advisories for sport fish consumption in the State of California. As such, OEHHA is the only "end user" of the GTLs (now ATLs), although the ATLs may be used by counties to issue interim advice in consultation with OEHHA. The sole purpose of releasing the document was to improve transparency of the fish advisory process, not to provide other agencies with a tool to provide their own fish consumption advice to the public. To prevent such confusion in the future, OEHHA will rename the final document: Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, selenium, and toxaphene. OEHHA recognizes that use of the word "guidance" in Guidance Tissue Level has led some to think that this is a "guidance document" to be used by other agencies in developing their own advisories. We are making the change to correct this misinterpretation.

Comment 1.5:
The draft document does not describe what constitutes "sufficient fish tissue data" (p. 2) nor does it provide an explanation as to how to perform the highly-specialized risk analyses recommended.

Response 1.5:
The GTL (now ATL) document is not intended as a guidance document to be used by other agencies (see response to comments above) to develop their own advisories. OEHHA performs the risk analyses; recommendations provided to other agencies responsible for data collection and analyses are provided in another document (Gassel and Brodberg, 2006; General Protocol for Sport Fish Sampling and Analysis). Because each water body is unique, agencies should consult OEHHA prior to collecting fish from

California water bodies so that OEHHA can direct sampling and analysis to collect data sufficient to adequately estimate human health risks. The discussion of sampling and analysis has been removed from the document.

Comment 1.6:
We are concerned that OEHHA elected to make very large adjustments to the estimated reference dose to account for various "uncertainty factors." The published GTLs and SVs should be presented with and without such adjustments so that it is clear to other state agencies that a safety factor has already been applied. Otherwise, it is likely that other agencies will incorrectly assume that the GTL or SV represents the No-Observed-Effect-Threshold and seek to add on their own safety factors. It would be useful to explain that the magnitude of adjustment applied was somewhat arbitrary. Higher or lower multipliers may be equally well justified.

Response 1.6:

Uncertainty factors (UFs) are always included in the development of an RfD. After evaluating the original toxicity data, toxicologists apply uncertainty factors to the point of departure value (e.g., the NOAEL or LOAEL), taking into account any deficiencies in the data (such as short-term exposure, the use of an animal model, or lack of a reproductive study) in order to arrive at the RfD. UFs are not arbitrary but are routinely and rather consistently applied using accepted risk assessment principles. With the exception of toxaphene and chlordane, the UFs and RfDs used for each chemical in this document were originally developed by U.S. EPA and are in general use by the risk assessment community. After reviewing the most current literature, OEHHA has chosen to maintain these RfDs. Again, other agencies should not attempt to modify OEHHA advisories by manipulating any of the parameters used by OEHHA in developing the advisories.

Comment 1.7:
It is unclear if OEHHA considered the published recommendation of other federal agencies (e.g., FDA's less restrictive "Action Levels") and, if so, why those recommendations were rejected. Nor is it clear why OEHHA declined to use EPA's more stringent recommendations.

Response 1.7:

OEHHA conducted a thorough evaluation of federal and other state's methods of providing fish consumption recommendations and selected methods that appropriately balanced benefits and risks. FDA action levels are not appropriate for setting sport fish consumption guidelines. In their guidance document, U.S. EPA does not propose a single, specific method of providing fish consumption recommendations but, instead, illustrates one possible scenario using only the RfD and a risk level of 1×10^{-5}. The U.S. EPA acknowledges that states and tribes may modify this method in multiple ways to make it more or less conservative as they see fit. Examples of RLs from 10^{-4} to 10^{-7} are also included in their guidance document. OEHHA uses the most up-to-date data and

methodology and considers sensitive populations. OEHHA's advisories are within the range of guidance provided by U.S. EPA but, in several cases, are more conservative.

Commenter 2:
Alyce Ujihara
Diana Lee
Sharon Lee
Elana Silver
California Department of Health Services
Environmental Health Investigations Branch
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Comment 2.1
Clarification of the reduction factor for organic chemicals for skinning of fillets is needed. You have applied a reduction factor to your GTL calculations that assumes people consume fish as skin-off fillets. Since you assume a 30% reduction due to contaminant loss during cooking and you assume a 50% loss due to cooking and skinning combined, skinning alone appears to account for about a 20% reduction in contaminants in your calculations. This reduction factor for skinning should be explicitly stated.

Response 2.1
Data on the contaminant reduction achieved by various trimming and cooking techniques are variable. It is known that removing the skin and associated fat as well as cooking remove a significant amount of organic contaminants. The general cooking reduction factors of 50% and 30% are typical values that have been generated with experiments using either skin-on or skin-off fillets, respectively. Therefore, there is no explicit reduction factor for skinning alone. The 30% and 50% reduction factors are used, for example, by the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory and by other states in their fish consumption advisories.

Comment 2.2
Incorporating an assumption that people eat skin-off fillets results in GTLs that are not adequately health protective for a significant number of people. In a survey of San Francisco Bay anglers (SFEI 2001), DHS found that significant numbers of anglers report eating the skin of fish. Specifically, we found that 21% of striped bass consumers and 38% of white croaker consumers reported eating the skin more than half of the time. Generally, among anglers who reported eating skin, there were more non-white anglers, particularly African Americans and Asians. Thus, using a skin-off fillet as the default to develop GTLs for organic chemicals will disproportionately affect these groups.

Response 2.2
OEHHA recommends fish preparation methods, such as skinning, that allow anglers to safely eat more fish. In order to protect anglers who choose not to follow these guidelines, however, OEHHA may provide separate advice, as part of risk

communication, to fishers who do not skin or otherwise trim fish or cook it by methods recommended to reduce contaminant levels when guidance is based on chlorinated hydrocarbon contaminants.

Comment 2.3
The draft document states that "if fishers choose not to follow this advice and cook fish as skin-on fillets, they should reduce their consumption by approximately one-fourth…to achieve and equivalent exposure." From a practical perspective, it does not make sense to base the GTLs on a consumption pattern that people "should" follow, rather than what they already do. The GTLs should not assume that a significant proportion of people will take additional measures in order for the advisory to be adequately health protective. Furthermore, advisory messages need to be as simple as possible. Adding another qualifier to the advisory message (e.g., this advice will only be health protective if you remove the skin) complicates the message.

Response 2.3
Based on the study cited, the majority of anglers *do* skin fish, whether doing this of their own accord or following recommendations that OEHHA provides. OEHHA does not issue consumption and cleaning/cooking advice only to protect the most exposed individual but makes recommendations that all fishers can choose to follow – or not – to lower their exposure to contaminants. Fishers who do not follow advice to skin and/or cook their fish also may not follow advice to limit fish consumption. In the case of mercury, separate advice is provided for two populations groups so that less sensitive individuals (women beyond childbearing age and men) do not have their fish consumption unduly restricted by the needs of the other group (women of childbearing age and children). So it should be with cooking and cleaning methods, i.e., the majority of fishers who do consume/prepare fish in the safest manner should be offered advice that allows them to consume the most fish safely while fishers who choose to eat the skin or prepare fish in a way that does not reduce contaminant loads should be offered separate advice tailored to their needs. This is particularly important in the case of subsistence fishers, for example, where unwarranted fish consumption restrictions may impose an economic burden. The draft report recommended that fishers who do not follow advice to skin fish should reduce their consumption by approximately one-fourth. However, newer data indicate that the amount of contaminants found in skin may be more variable (and ultimately higher) that previously thought. In some cases, fish that could be eaten once or twice a week without skin will fall into the "do not consume" category with skin. For additional consideration in the final report and in future advisories for chlorinated hydrocarbons, OEHHA will consider site- or species-specific advice to reduce consumption if fishers do not cook or clean their fish in the safest manner.

Comment 2.4
Additionally, the decision to use skin-off fillets for scaled fish is not consistent with U.S. EPA guidance for fish advisories. U.S. EPA recommends that contaminant concentrations be measured using skin-on fillets for scaled fish species and skinless fillets for scaleless fish species (e.g., catfish).

Response 2.4
Historically, fish monitoring programs in California have analyzed skinless fillets of fish. See response 2.3 for further discussion. Analyzing skin-on fillets actually dilutes the measured mercury concentrations, making the advice less conservative. As mercury is the predominant fish contaminant in California, OEHHA recommends measuring contaminant concentrations in skin-off fillets.

Comment 2.5
On page 39, a correction to the example equation for dieldrin is needed; 1000 µg/kg should be 1000 µg/mg.

Response 2.5
Corrected. The mistake was the result of a typographical error. Calculated values were correct in the original version.

Commenter 3:
Roberta Blank
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U.S. EPA
Region IX
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Comment 3.1
A major component of the EPA Institutional Controls Program for the Palos Verdes Shelf site is educating the public on the current state sport fish consumption guidelines. The current state fish advisory for DDTs uses an excess cancer risk of 10^{-5}. The proposed GTLs use a 10^{-4} level. The GTLs guidance cites that other states (e.g., Georgia and West Virginia) use the risk level of 10^{-4} in fish consumption advisories. However, these states have not used a risk level of 10^{-5} before, while California has been using 10^{-5} cancer risk endpoint for at least 15 years. No rationale for this change is provided.

Response 3.1
The rationale for the current protocol was discussed in the draft document. The 10^{-5} risk level was not consistently used for all chemicals in the Southern California sport fish consumption guidelines and has not been the basis for other advisories. Over the last 15 years, a tremendous amount of data has been published on the benefits of fish consumption – information that was not available when the 10^{-5} risk level was initially used. As scientific knowledge and protocols continue to expand or develop, our understanding of the risk and benefits of fish consumption have increased. The revised document has greatly expanded the discussion of the benefits of fish consumption and the reasoning behind the choice of the 10^{-4} risk level. In their fish advisory guidance document, U.S. EPA allows states to choose risk levels ranging from 10^{-4} to 10^{-7}. OEHHA concludes that, while it should be a goal to maintain a risk level of $1x10^{-6}$, when considering the counterbalancing benefits of fish consumption, a risk level of $1x10^{-4}$ is

appropriate. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption.

Comment 3.2
The draft GTLs are consistent with the FDA cancer risk level used for establishing tolerance levels in fish. However, the underlying assumptions used in the FDA methodology were not intended to be protective of recreational, ethnic, and subsistence fishers who typically consume larger quantities of fish than the general population and often harvest the fish and shellfish they consume from the same local water bodies repeatedly over many years, such as in the case for PV Shelf. The EPA national guidance states that "the FDA action levels and tolerances are indicators of chemical residue levels in fish and shellfish typically purchased in supermarkets or fish markets that sell products that are harvested from a wide geographic area, including imported fish and shellfish products."

Response 3.2
The reference to the FDA tolerance level for PCBs has been removed.

Comment 3.3
Using a cooking reduction of 30% in volume of fish consumed would increase the allowable contaminant intake in the screening value. Using this factor is inconsistent with the EPA national guidance for fish advisories. In addition, the assumption of skin-off fillet is not protective of sensitive populations such as ethnic populations who often eat whole fish, and fish stew and/or soup.

Response 3.3
Appendix C in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol. 2, discusses dose modifications that may be used to adjust for food preparation and cooking. Various surveys in California have shown that the majority of fishers eat skin-off, cooked fish. OEHHA will provide differential advice for those that prepare and cook fish in the safest manner as well as those that do not (see 2.3 above).

Comment 3.4
For chlordane, DDT and PCBs, the noncancer endpoint is not protective of effects for children. The 10^{-5} indirectly provides protection to these sensitive populations as the 10^{-5} value is the more conservative value. However, the use of 10^{-4} risk level does not provide this indirect buffer.

Response 3.4
OEHHA is not aware of any compelling evidence that children have increased susceptibility to DDTs that is not accounted for by the current RfD. OEHHA is currently assessing whether children may have increased susceptibility to PCBs under our SB 25 toxic air contaminants program. RfDs are generated taking into account the most

sensitive population; in particular, the RfD for PCBs is deemed protective of neurodevelopmental effects in fetuses and children as those occurred at a higher dose than the critical effect. The RfDs for DDTs and PCBs have uncertainty factors of 100 and 300, respectively, which should offer ample protection should additional adverse effects of these contaminants be determined later. If new research allows development of a childhood-specific RfD, like that for mercury or chlordane, OEHHA will reevaluate fish consumption guidelines at that time.

Comment 3.5
The draft GTLs guidance states that "Even if fishers fish the same location for 70 years, their exposure to such chemicals will undoubtedly decline significantly over this period" due to decline in levels in the environment. When the duration of exposure increases, even if there is a decline in contaminant levels, it is possible that the increase in the exposure time outweighs the decline in contaminant levels. At this time, we have not fully evaluated the existing and current data to corroborate the assumption that the levels of these contaminants are declining in the environment.

Response 3.5
The assumption of a 30 year exposure from fish consumption for a particular water body is a reasonable high-end health protective assumption for assessing risk from carcinogens, given current knowledge about population mobility from various studies. This assumption may need further consideration for bioaccumulating, carcinogenic contaminants ubiquitously present in water bodies.

Commenter 4
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Director
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Staff Scientist
Heal the Bay
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Comment 4.1
OEHHA should decrease the allowed cancer risk level in calculating GTLs and SVs to maintain the 10^{-5} end point for carcinogens to adequately protect sensitive subpopulations such as ethnic subsistence fishers, pregnant women and children. The lines of reasoning provided by OEHHA for the 10^{-4} risk level are not sufficient to justify the increase in allowed cancer risk. The FDA methodology used to calculate their level of acceptable risk cited in the draft report assumes that the population consumes a smaller number of fish from multiple sources; in this case, the draft report calculations are intended to protect people who consume fish from *local* water bodies. Finally, the draft report implies that consuming a certain amount of fish may be more important than avoiding contaminant exposure. Not only does this conclusion appear to be outside the purview of OEHHA, it is not well justified in the draft report. In sum, there is no appropriate

rationale provided in the Draft Report to justify the change to a less protective endpoint. OEHHA should use an allowed cancer risk level of 10^{-5} in calculating GTLs and SVs to be sufficiently protective of human health particularly under circumstances that occur in California. This lower value would serve as a "buffer" for other non-conservative assumptions relied upon by OEHHA as discussed below.

Reponse 4.1
OEHHA has removed the SVs from the draft report; see additional discussion below. Instead, OEHHA has provided Fish Contaminant Goals (FCGs) that maintain very conservative assumptions and may be used by other agencies as a starting point for developing fish tissue-based criteria.

The reference to the FDA tolerance limit for PCBs has been removed.

OEHHA (formerly of the Department of Health Services) has discussed balancing the risk and benefits of fish consumption since as early as 1986 (California Department of Health Services. Balancing the scales: Weighing the benefits and risks of fish consumption. Proceedings of a workshop held in Concord, California, October 20, 1988.). With the vast amount of data that has become available on the benefits of fish consumption in the last few years, OEHHA determined that this section should be significantly expanded in the final report. OEHHA believes that using a 10^{-4} risk level best balances known health benefits with cancer risks of fish consumption. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption.

Comment 4.2
OEHHA should ensure that GTLs and SVs are protective of the entire population including several sensitive subpopulations. The GTLs and SVs are not protective of certain highly relevant population groups, including children, pregnant women, and ethnic subsistence fishers. For example, the authors make various assumptions about the consumer in developing the GTLs and SVs, such as assuming a body weight of 160 pounds and a normal meal size of 6 ounces after cooking. While these assumptions are accounted for somewhat in the Draft Report by including recommendations to adjust the amount of fish consumed based on the weight of the consumer, OEHHA is also proposing to base the screening values upon the same characteristics of an average adult, thus failing to account for other routinely exposed groups of the population. In addition, under this assumption, OEHHA appears to recommend that children under 40 pounds should not eat any fish at all and kids under 80 pounds should not eat a tuna fish sandwich (based on a 2 oz serving size). This is not realistic. There is ample evidence that children in California consume local fish regularly and often, and thus are exposed to these contaminants. To adequately protect all consumers, OEHHA should use a much more conservative (lower) body weight in calculating the GTLs and SVs.

Response 4.2
The assumption of a 70 kg adult body weight is standard risk assessment protocol and six ounces after cooking is considered a standard fish meal size. Because there is a strong positive correlation between food consumption and body weight, particularly when averaged over a lifetime as the risks and hazards are, most risk assessments simply assume the concomitantly reduced consumption rate for lower body weights rather than stating it explicitly. In the final document, simplified instructions will be added to reduce meal sizes proportionately to body weight. Additionally, 70 kg is currently well below the average adult body weight for males and females, making the use of this default value a conservative assumption.

Comment 4.3
The cooking reduction factor of 30 percent and skin-on reduction factor of 20 percent should be removed from the calculations of GTLs and SVs. The GTL calculations also incorporate a cooking reduction factor of 30 percent and a skin-on reduction factor of 20 percent based on a theory that the process of heating the fish will break down organic contaminants and most consumers do not eat skin-on fish. This may be appropriate under some circumstances, but not in *all* cases. First, the specific method of cooking may determine the extent of breakdown of these organic constituents. For instance, searing the fish or cooking the fish in a stew may lead to a reduction in organic contaminants that is much lower than 30 percent. Second, methylmercury will not likely breakdown during the cooking process. Third, ethnic subsistence fishermen are put at additional risk under this assumption because they often use the whole fish (not a fillet) with skin-on. For instance, a fish consumption study found that of Asian anglers surveyed, 50 percent consume the whole fish. In fact, white croaker, a popular fish in Asian communities, is *rarely* eaten as a fillet. Thus, as just one example, Asian populations are not properly protected using these reduction factor assumptions. And again, while the draft report recommends reducing consumption if skin-on fillets are used, the screening values do not take this variable into account. Plainly, the reduction factors increase the allowable contaminated fish consumption in the screening values and will lead to fewer fish advisories and thus less protection for all groups of consumers. OEHHA should remove the 30 percent cooking reduction factor and 20 percent skin-on reduction factor in calculating the GTLs and SVs.

Response 4.3
See response to comments 2.2, 2.3, and 3.3. As noted in the draft document, the cooking and skinning reduction factors are not applied to mercury data. Mercury analysis of skin-off fillets provides more conservative fish consumption advice than analysis of skin-on fillets would (see response 2.4).

Comment 4.4
OEHHA should consider the policy implications of the draft report. There are additional water quality policy issues tied to the finalization of this draft report. Currently, California's Clean Water Act 303(d) list relies heavily on OEHHA Screening Values to determine fish tissue impairment. In fact, the *Water Quality Control Policy for*

Developing California's Clean Water Act 303(d) List ("Listing Policy") specifies that evaluation guidelines for protection from the consumption of fish and shellfish published by OEHHA can be used in evaluating fish tissue data for 303(d) listing and de-listing purposes. (Listing Policy at 20.) As a result, various listings and delistings in the Draft 2006 303(d) List are based upon the current OEHHA SVs or "benchmarks." In addition, the Listing Policy specifies that a waterbody "…shall be placed on the section 303(d) list if a health advisory against the consumption of edible resident organisms, or a shellfish harvesting ban has been issued by the Office of Environmental Health Hazard Assessment (OEHHA)." (Listing Policy at 5.) Further, numeric targets in certain TMDLs are derived from these screening values.

As discussed above, the Draft Report uses a risk level of 10^{-4}. In contrast, water quality standards, such as CTR standards, were set using the 10^{-6} risk level. Thus, there may be conflict between the protection offered through the Clean Water Act and policy decisions based upon the GTLs and SVs that are calculated using the 10^{-4} risk levels. In addition, the SVs included in the Draft Report are as much as 6 times higher than the 1999 OEHHA SVs. This may result in many inappropriate de-listings from the 303(d) list, resulting, in turn, in a failure to address the underlying problem at the source. Given the seriousness of the risks here, this is entirely inappropriate.

Response 4.4
As noted above, the SVs have been removed from the final document. Fish Contaminant Goals (FCGs), developed in this final report, use a 10^{-6} risk level. Agencies can use these values as a starting point to develop fish tissue-based criteria. GTLs (now ATLs) are not regulatory standards. OEHHA does not determine policies developed by other state programs. However, if other state programs choose to consider or use values that OEHHA has developed for some other purpose, then it is advisable that they consult with OEHHA to avoid any misuse or misinterpretation. (See response 1.1).

Comment 4.5
In general, OEHHA will be taking a step backward in terms of protecting public health if it adopts the non-conservative assumptions proposed in this Draft Report. As discussed above, there are major implications for sensitive subpopulations – particularly children and ethnic Asian subpopulations. An allowable cancer risk level of one in 10,000 is just not acceptable given these variable consumption patterns and practices. Therefore, we *strongly* urge OEHHA to maintain the 10^{-5} endpoint, as well as to use more conservative assumptions in calculating the GTLs and SVs.

Response 4.5
OEHHA has addressed the "non-conservative" assumptions in prior responses to comments. OEHHA has determined that highly conservative assumptions, as used in traditional risk assessment paradigms, are not protective of overall health when considering fish consumption. However, in response to comments regarding the cooking reduction factor, separate advice may be tailored to those who do not cook or clean according to OEHHA recommendations. OEHHA maintains that using a 10^{-4} risk level

best balances the cancer risks and benefits (health and economic) of sport fish consumption as well as the risks of alternate protein sources that might be consumed in place of sport fish. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption. OEHHA does not agree with the premise that "sensitive subpopulations" are not accounted for in the advisory process. All consumers who follow the advice are equally protected based on known sensitivities. When there is compelling evidence that women or children are more susceptible to a contaminant (e.g., mercury), the advisories provide separate advice for their protection.

Commenter 5
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Comment 5.1
This is a wonderfully well done report that should be viewed as "state of the art" in its niche.

Comment 5.2
"Avians" is not an accepted noun.

Response 5.2
Changed "avians" to birds.

Comment 5.3
It would be helpful to provide the reference dose as µg/day, in addition to mg/kg-day, to facilitate comparison to the RDA.

Response 5.3
Additional units included.

Comment 5.4
Is the advice for reducing consumption by approximately one-fourth for skin-on fillets really applicable to selenium?

Response 5.4
Language altered to indicate that, of the chemicals evaluated, reduction of contaminant levels by cooking and skinning is only applicable to chlorinated hydrocarbons, rather than "organics" as stated.

Comment 5.5
The equations presented on page 39 result in calculated outcomes expressed on a ppm (mg/kg) basis, yet the summary table of outcomes, Table 1, presents everything on a ppb basis. It would be an improvement to make the equations and outcomes table internally consistent.

Response 5.5
The equations include mg/kg units because the reference doses and cancer slope factors are presented in those units. Conversion factors were included in the equations to change the outcome units to ppb (µg/kg), to coincide with the most convenient way of expressing fish contaminant levels as presented in Table 1 and Table 2.

Comment 5.6
The selenium screening value is expressed on a wet weight basis. Many historic fish tissue databases are expressed on a dry weight basis without corresponding percent moistures and, thus, there is no way to convert the values to a wet weight basis. EPAs new tissue-based chronic criterion value for selenium will be issued on a dry weight basis. It would be useful to provide a conversion to dry weight basis for a range of fish species.

Response 5.6
Screening values have been eliminated from the document. However, fish collected for human health assessments must be based on wet weight analysis; dry weight data for individual or composite fish samples are not consistently available. OEHHA will leave developing national conversion factors for multiple species to other agencies.

Commenter 6
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Division of Environmental Health
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Olympia, WA 94504

Comment 6.1
Overall the document read well and its purpose was clearly stated. Calculations of GTLs and screening level values were checked and consistent with our calculations. Appropriate studies are cited to support your selection of toxicity criteria.

Comment 6.2
Within the introduction, it may be useful to give subheadings to the sections dealing with the development of screening level values and for establishing GTLs. A brief description of the equation for deriving GTLs for cancer endpoints similar to the noncancer equation would be useful. The differences in the two equations could be explained, briefly describing the differences in averaging times used in the two calculations.

Response 6.2
An equation for deriving GTLs (now ATLs) for cancer endpoints was included. The SVs are no longer included in the final document.

Comment 6.3
Within the introduction, it would be helpful to list major data sources and give a brief description of the programs that they are collected under. Fish tissue collection and analysis is often conducted for reasons other than to evaluate human health concerns. Therefore, the adequacy of the database should first be determined.

Response 6.3
This information is outside the scope of this document. It is presented in the Health Advisory and Safe Eating Guidelines for each water body. Recommendations for sampling are included in the report "General Protocol for Sport Fish Sampling and Analysis," by Gassel and Brodberg, 2006.

Comment 6.4
A summary table should be included with the contaminants of concern and their corresponding cancer and noncancer values separate from the GTL calculated concentrations.

Response 6.4
Cancer and noncancer values are presented in at least two places in the document, including Table 1. OEHHA feels that including another separate table of these values is not necessary, given that they are clearly presented in the toxicology profiles and in the derivation of the ATLs.

Comment 6.5
A brief discussion on the consumption rate used to establish screening level values. What are they based on and what populations do they protect or not protect?

Response 6.5
The screening values have been removed from the final document.

Comment 6.6
The discussion of the Guidance Tissue Levels for the various contaminants is easy to follow and provides appropriate background on use of various parameters considered.

Comment 6.7
Consider graphing contaminant meal recommendations with contaminant concentrations.

Response 6.7
Graphs were presented by the commenter as another way of looking at GTLs (now ATLs). We didn't find that these added to the clarity or usefulness of the document.

Comment 6.8
We find that people often get hung up on the numbers such as GTLs but are unaware that these values are generally a starting point in determining what the recommended meal limits should be. Left out of the discussion is the risk management and risk communication aspects in evaluating fish.

Response 6.8
OEHHA agrees that the ATLs are just a starting point for developing fish consumption guidelines. We have attempted to strengthen the language in the document to make that point. A brief discussion of risk communication has been added to the document, but risk communication details are developed as part of individual safe eating guidelines for specific water bodies.

DEVELOPMENT OF FISH CONTAMINANT GOALS AND ADVISORY TISSUE LEVELS FOR COMMON CONTAMINANTS IN CALIFORNIA SPORT FISH:

CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

June 2008

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State of California

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California Environmental Protection Agency

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Director
Office of Environmental Health Hazard Assessment

DEVELOPMENT OF FISH CONTAMINANT GOALS AND ADVISORY TISSUE LEVELS FOR COMMON CONTAMINANTS IN CALIFORNIA SPORT FISH: CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

June 2008

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The authors would like to specifically thank Margy Gassel for many discussions that were helpful in the completion of this document.

FOREWORD

This report describes the process of developing Fish Contaminant Goals and Advisory Tissue Levels for evaluating methylmercury, chlordane, DDTs, dieldrin, PCBs, selenium, and toxaphene, common contaminants in California sport fish. Fish provide unique nutritional benefits while also serving as a significant exposure pathway for several chemicals of concern. Fish Contaminant Goals (FCGs) are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs prevent consumers from being exposed to more than the daily RfD for non-carcinogens or to a risk level greater than $1x10^{-6}$ for carcinogens (not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime). FCGs are based solely on public health considerations without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption.

Advisory Tissue Levels (ATLs), while still conferring no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, were developed with the recognition that there are unique health benefits associated with fish consumption and that the advisory process should be expanded beyond a simple risk paradigm in order to best promote the overall health of the fish consumer. ATLs provide a number of recommended fish servings that correspond to the range of contaminant concentrations found in fish and are used to provide consumption advice to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). ATLs are designed to encourage consumption of fish that can be eaten in quantities likely to provide significant health benefits, while discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be eaten in amounts recommended for improving overall health (eight ounces total, prior to cooking, per week). ATLs are one of the criteria that will be used by OEHHA for issuing fish consumption guidelines.

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EXECUTIVE SUMMARY

Chemical contamination of fish is a global problem that has resulted in the issuance of fish consumption advisories in most states, including California. Although mercury contamination is a frequent basis for these advisories, polychlorinated biphenyls (PCBs) and chlorinated pesticides such as chlordane and dichlorodiphenyltrichloroethane (DDT) are also often implicated. In California, the Office of Environmental Health Hazard Assessment (OEHHA) is the agency solely responsible for evaluating the potential public health risks of chemical contaminants in sport fish and issuing state advisories, when appropriate. OEHHA is also consulted by other agencies interested in assessing the health risks of fish consumption during the process of developing water quality or clean-up "criteria." There are key differences between fish consumption advisories and other environmental risk criteria; advisories consider the significant benefits of fish consumption, while criteria may be strictly risk-based and may not take into account other factors.

In order to develop water quality criteria or fish consumption advisories, appropriate toxicity values for a chemical must be established. In this document, cancer and non-cancer health effects were evaluated for seven common contaminants found in California sport fish: chlordane, DDT and its metabolites (DDTs), dieldrin, mercury (as methylmercury), PCBs, selenium, and toxaphene. For each chemical, the toxicological literature was reviewed to establish an acceptable non-cancer reference dose (RfD; an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime) and/or a cancer slope factor (an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen).

Fish Contaminant Goals (FCGs) were then developed for these seven contaminants. FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs prevent consumers from being exposed to more than the daily RfD for non-carcinogens or to a risk level greater than $1x10^{-6}$ for carcinogens (not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime). FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption. FCGs were developed using an 8-ounce (227 g) serving size (prior to cooking; approximately six ounces after cooking) for adults who weigh 70 kg.

As a prelude to developing tissue-based values to be used for advisories, OEHHA reviewed the scientific literature on the benefits of fish and fish oil consumption. Although decreased incidence of coronary heart disease is perhaps the most recognized benefit of fish consumption, there is considerable evidence that other, particularly

inflammatory, disorders may also be mitigated or prevented by inclusion of fish in the diet. Additionally, maternal fish consumption is likely to provide cognitive benefits to the fetus. Following this review, OEHHA determined that there is a compelling body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality. With the recognition that there are unique health benefits associated with fish consumption, it was concluded that the advisory process should be expanded beyond a simple risk paradigm, as is used in criteria development, in order to best promote the overall health of the fish consumer.

The first step in the advisory process, then, was to develop Advisory Tissue Levels (ATLs). ATLs were calculated using the same general formulas as those used to calculate FCGs, with some adjustments in order to incorporate the benefits of fish consumption. ATLs provide a number of recommended fish servings that correspond to the range of contaminant concentrations found in fish and are designed to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). The use of ATLs still confers no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, while encouraging consumption of fish that can be eaten in quantities likely to provide significant health benefits and discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be recommended in amounts suggested for improving overall health (i.e., eight ounces total, prior to cooking, per week).

ATLs are used as part of the process to develop traditional health advisories (which focus on fish whose consumption should be avoided) as well as the newer "safe eating guidelines," which inform consumers of fish with low contaminant levels considered safe to eat frequently. ATLs should not be misinterpreted as static "bright lines" that others can use to duplicate state fish consumption advisories. ATLs are but one component of a complex process of data evaluation and interpretation used by OEHHA in the assessment and communication of fish consumption risks. The nature of the contaminant data or omega-3 fatty acid concentrations in a given species in a water body, as well as risk communication needs, may alter strict application of ATLs when developing site-specific advisories. OEHHA will use the guidelines set forth in this report as a framework, along with best professional judgment, to provide fish consumption guidance on an *ad hoc* basis that best combines the need for health protection and ease of communication for each site.

This document represents current knowledge of the toxicity of seven common fish contaminants and the overall benefits of fish consumption; FCGs and ATLs for individual chemicals may be revised, if necessary, as information becomes available. FCGs and ATLs may also be developed in the future for additional contaminants, as appropriate, using the same methodology.

INTRODUCTION

Fish consumption advisories have been issued in most states and cover approximately 35 percent and 24 percent of the country's total lake acreage and river miles, respectively (U.S. EPA, 2004a). Mercury contamination of fish, in particular, is a national problem that resulted in the issuance of 222 new advisories in 2003 alone (U.S. EPA, 2004a). Polychlorinated biphenyls (PCBs) and chlorinated pesticides such as chlordane and dichlorodiphenyltrichloroethane (DDT) are also a frequent basis for fish consumption advisories throughout the United States (U.S. EPA, 2004a). In California, the Office of Environmental Health Hazard Assessment (OEHHA) is the agency responsible for evaluating potential public health risks from chemical contamination of sport fish. This includes issuing state advisories, when appropriate, based on mandates in the California Health and Safety Code, Section 59009, to protect public health, and Section 59011, to advise local health authorities, and the California Water Code, Section 13177.5, to issue health advisories. OEHHA is also consulted by other agencies interested in assessing the health risks of fish consumption during the process of developing water quality or clean-up "criteria." There are key differences between fish consumption advisories and other environmental risk criteria; advisories consider the significant benefits of fish consumption, while criteria may be strictly risk-based and may not take into account other factors.

In order to develop advisories or criteria, appropriate toxicity values for a chemical must be established. In this document, cancer and non-cancer health effects were evaluated for seven common contaminants found in California sport fish: chlordane, DDT and its metabolites (DDTs), dieldrin, mercury (as methylmercury), PCBs, selenium, and toxaphene. For each chemical, the toxicological literature was reviewed to establish an acceptable non-cancer reference dose (RfD; an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime) and/or a cancer slope factor (an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen). Limited background information on the chemistry, environmental fate, metabolism, and typical exposure routes for each chemical is also provided.

Fish Contaminant Goals (FCGs) were then developed for these seven contaminants. FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption.

FCGs for non-cancer risk for non-nutrients were derived from the following basic equation:

$$\text{Tissue concentration} = \frac{(\text{Reference dose})(\text{Body weight})}{\text{Daily consumption rate}}$$

FCGs for cancer risk for non-nutrients were derived from the following basic equation:

$$\text{Tissue concentration} = \frac{(\text{Risk level})(\text{Body weight})}{(\text{Cancer slope factor})(\text{Daily consumption rate})}$$

Additional discussion and examples of FCG development can be found in the section "Equations used to calculate Fish Contaminant Goals."

As a prelude to developing tissue-based values to be used for advisories, OEHHA reviewed the scientific literature on the benefits of fish and fish oil consumption to determine to what degree the advisory process should be expanded beyond a simple risk paradigm, as is used in criteria development, in order to best promote the overall health of the fish consumer. Advisory Tissue Levels (ATLs), while still conferring no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, use the same general equations as those used to develop FCGs, with some adjustments to take into account benefits that are provided by fish consumption. ATLs were designed to encourage consumption of fish that can be eaten in quantities likely to provide significant health benefits, while discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be recommended in amounts suggested for improving overall health (i.e., eight ounces total, prior to cooking, per week).

This report provides critical toxicity values, FCGs and ATLs for seven common contaminants in California sport fish. Most fish advisories in the United States are issued for mercury, PCBs, chlordane, dioxins, and DDTs (U.S. EPA, 2005). OEHHA also included toxaphene and selenium in this document because of historic use in the state and natural occurrence, respectively. At this time, limited available analytical data for dioxins in fish throughout the state do not show widespread or high dioxin contamination. Several former point sources have been eliminated and subsequent concentrations in fish at associated sites were below a level of concern (Fan, 1994). Consequently, OEHHA did not develop an FCG or ATLs for dioxins at this time. However, FCGs and ATLs may be developed in the future for dioxins or other contaminants, as resources permit, using the same methodology. OEHHA staff is available for consultation on any fish contaminant of concern.

TOXICOLOGY AND CRITICAL TOXICITY VALUES FOR COMMON CONTAMINANTS IN CALIFORNIA SPORT FISH

CHLORDANE

CHLORDANE TOXICOLOGY

Chlordane is a chlorinated cyclodiene insecticide that was used in the United States beginning in 1948 for a variety of agricultural and structural pest control purposes (ATSDR, 1994; Ecobichon, 1991; Matsumura, 1985; U.S. EPA, 1997). Technical chlordane, the commercial mixture, is comprised of approximately 60 percent *cis* and *trans* chlordane isomers and about 40 percent other related compounds (e.g., *cis*-nonachlor, *trans*-nonachlor and oxychlordane) (U.S. EPA, 1997). As a result of their lipophilicity, low volatility and slow degradation rates, chlordane and other organochlorine pesticides are exceptionally persistent in the environment and are able to bioconcentrate and biomagnify throughout the food chain (Ecobichon, 1991). Bioconcentration factors (the quotient of the concentration of a chemical in an organism divided by the concentration of the chemical in the ambient water) for chlordane in various marine and freshwater fish, for example, have been reported as high as 3,000 to 37,800 (ATSDR, 1994; Fisher, 1999). Because of this, as well as concerns over human cancer risk and hazards to wildlife, the use of chlordane was severely restricted in the United States in 1978 and ultimately banned in 1988 (ATSDR, 1994; U.S. EPA, 2000). Chlordane remains a contaminant in many soils and waterways, however, with the most frequent source of human exposure being consumption of contaminated foods, especially fish (ATSDR, 1994). Saltwater and fresh water fish and shellfish, combined, account for approximately 95 percent of the total dietary exposure to chlordane (Dougherty et al., 2000).

Chlordane is readily absorbed by all exposure routes (ATSDR, 1994). Once absorbed, chlordane is rapidly distributed to the liver and kidneys, whereupon it undergoes transformation to a number of metabolites. Chlordane excretion is mainly through bile and breast milk (ATSDR, 1994). Chlordane that is not excreted is deposited in adipose tissue, primarily as the metabolites oxychlordane and heptachlor epoxide (ATSDR, 1994; U.S. EPA, 1997). The elimination half-life of chlordane in humans reported in different studies has ranged from 21to 88 days (Aldrich and Holmes, 1969; ATSDR, 1994; Curley and Garrettson, 1969; Olanoff et al., 1983).

The Agency for Toxic Substances and Disease Registry (ATSDR, 1994), U.S. Environmental Protection Agency (U.S. EPA, 1997), and OEHHA (1997) have extensively reviewed the toxicity of chlordane. Following acute oral exposures (14 days or less), chlordane is considered moderately to highly toxic to humans (U.S. EPA, 2000). The World Health Organization (WHO, 1984) estimated the acute human lethal dose to be between 25 and 50 mg/kg body weight. Acute poisoning symptoms include vomiting, diarrhea, seizures, anuria, ataxia, tremors, coma, and respiratory failure (ATSDR, 1994;

Curley and Garrettson, 1969; NIOSH, 1981, 2003; Olanoff et al., 1983), and can occur within 45 minutes of exposure (Grutsch and Khasawinah, 1991). The difference between the no-effect and the fatal serum levels in humans is small (approximately 3 to 5 times), indicating a steep dose-response curve (Grutsch and Khasawinah, 1991). Death is rare following acute oral poisoning, however, because the individual generally vomits, reducing the available dose (Grutsch and Khasawinah, 1991). Apparent recovery in non-fatal cases is rapid (Aldrich and Holmes, 1969; Curley and Garrettson, 1969; Grutsch and Khasawinah, 1991), although chemical hepatitis may develop subsequent to the acute phase (Olanoff et al., 1983). Acute chlordane toxicity in animals also results in neurotoxicity signs such as hyper-excitability, tremors, convulsions, hind limb paralysis and hypothermia (ATSDR, 1994; Grutsch and Khasawinah, 1991). Like other cyclodiene insecticides, the mechanism of neurotoxic action is believed to be inhibition of chloride transport, causing incomplete repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999).

Subchronic or chronic chlordane toxicity in humans has been difficult to quantify because of problems with dose determination and confounding exposures. Some humans living in chlordane-treated homes have developed hepatic and neurological signs such as jaundice and grand-mal seizures, respectively. The exact dose-response relationship has not been determined, however (ATSDR, 1994). In their review of the literature, Grutsch and Khasawinah (1991) reported that chronic, low-level chlordane exposure via inhalation, oral, or dermal routes has not been found to elicit signs or symptoms indicative of chlordane toxicity. ATSDR (1994) also noted that adverse health effects resulting from chlordane exposures have not been confirmed in studies of workers engaged in the manufacture of chlordane. More recent epidemiological studies, though, have indicated that chlordane may cause neurotoxicity following chronic exposures in humans (IRIS, 1998). In a cross-sectional study, Kilburn and Thornton (1995) found that neurobehavioral functions such as reaction times, verbal recall, and trail-making were impaired in 216 adults exposed to chlordane via inhalation compared to an unexposed referent population matched by age and educational level. However, effect levels could not be assigned because data on exposure, dose-response or potential co-exposure to other neurotoxicants were not available (U.S. EPA, 1997). In a subsequent study of nine chlordane-exposed patients seen consecutively for effects of chemical exposure, Kilburn (1997) noted that neurobehavioral functions such as balance, reaction times, verbal recall, and color discrimination were also diminished in the exposed group compared to a control population. Exposure dose was unknown and exposure duration ranged from 50 minutes to 18 years. Potential limitations associated with experimental design, including selection bias and an inadequately matched control population, severely limit interpretation of this study.

In rodent studies, the liver is clearly the target organ of chronic chlordane toxicity and hepatic necrosis has been deemed the critical effect (U.S. EPA, 1997). Khasawinah and Grutsch (1989a, 1989b) conducted the most extensive rat and mice toxicity studies available for chlordane, at similar dose-rates, which indicated that the mouse is more susceptible to the hepatotoxic effects of chlordane than is the rat (U.S. EPA, 1997).

Additional hepatic toxicity signs in mice included increased liver weights and elevated serum aspartate transferase (AST) and alanine transferase (ALT) levels (Khasawinah and Grutsch, 1989b).

Reproductive toxicity has been shown to occur following oral exposure to relatively high levels of chlordane in male mice. Balash et al. (1987) found that mature male mice orally gavaged with chlordane for 30 days had dose-related histological changes in seminiferous tubules. Similarly, Al-Omar et al. (2000) determined that mice gavaged with approximately 20 or 70 percent of the median lethal dose of chlordane suffered damage to testicular tissues, including decreased seminiferous tubule diameter, and reduced numbers of spermatogonia, spermatocytes and spermatids.

Developmental effects have also been reported in response to chlordane exposure in mice and rats (ATSDR, 1994). A series of neurobehavioral tests given to mice offspring following third-trimester fetal exposure to chlordane found depressed avoidance response acquisition and increased seizure threshold and exploratory activity, suggesting an effect on fetal brain (ATSDR, 1994; Al-Hachim and Al-Baken, 1973). Cassidy et al. (1994) showed that male and female rats exposed to low levels of chlordane *in utero* and during the early postnatal period (Day 4 of gestation through Day 21 of lactation) had gender-dependent alterations of sexually dimorphic functions and behaviors such as spatial abilities and auditory startle-evoked responses. Based on these results, the authors suggested that chlordane mimics and/or alters sex steroid concentrations and, thus, has a masculinizing effect on fetal and/or neonatal rats. In their review of the paper, however, U.S. EPA (1997) noted that dose-response relationships were inconsistent, as effects in high-dose animals were often similar to controls. Additionally, testosterone levels in males and females were not systematically related to the observed behavioral changes. U.S. EPA thus questioned the authors' interpretation of the study results and indicated that further research was necessary to confirm a relationship between these behavioral effects and low-dose chlordane exposure.

Immunological studies in mice indicated that *in utero* and neonatal treatment with chlordane suppressed cell-mediated immunity (Barnett et al., 1985a, 1985b; 1990a, 1990b; Blaylock et al., 1990; IRIS, 1998; Menna et al., 1985). Reported effects following such chlordane exposures included decreased fetal hematopoietic activity, delayed-type hypersensitivity-mediated pathology, and mixed lymphocyte reactivity. However, in some experiments, this suppression led to increased survival following influenza virus infection during young adulthood (Barnett et al., 1985a; Blaylock et al., 1990; Menna et al., 1985). More recent research has shown a variety of immunotoxic responses of rats following 28-day oral gavage of *cis*-nonachlor, *trans*-nonachlor and technical chlordane (Tryphonas et al., 2003). In those studies, *cis*- and *trans*-nonachlor were more likely to cause immunotoxic effects than technical chlordane, with these results more pronounced in females.

Oxychlordane, one of the principal metabolites of chlordane, is the second most common chlordane-related residue found in food, following *trans*-nonachlor (Bondy et al., 2003).

A series of twenty-eight-day feeding studies in female rats showed that oxychlordane caused weight loss and histopathological changes in the liver, thymus, and thyroid and produced signs of toxicity at doses approximately eight times lower than *cis*- or *trans*-nonachlor (Bondy et al., 2003). The authors suggested that exposure to oxychlordane may prove to be a more significant human health hazard than exposure to other chlordane compounds found in foods.

Information regarding the potential carcinogenicity of chlordane in humans is conflicting. A few studies have shown an association between chronic chlordane inhalation exposure in humans and the development of various blood dyscrasias, such as leukemia (reported in ATSDR, 1994; U.S. EPA, 1997). In contrast, Brown et al. (1990; 1993) failed to find a relationship between leukemia or multiple myeloma and chlordane inhalation exposure in adult men (U.S. EPA, 1997). A retrospective mortality study of workers in the chlordane manufacturing industry (Brown, 1992) indicated that workers exposed to chlordane and other organochlorines had lower than expected mortality from all causes as well as from all malignant neoplasms (ATSDR, 1994). Yet, in two case-control studies, Cantor et al. (1992) and Woods and Polissar (1989) found that non-Hodgkin's lymphoma patients were more likely to have had previous inhalation exposure to chlordane than healthy controls, although this association was only significant in the Cantor et al. study. U.S.EPA (1997) notes that there is no evidence to support the conclusion that oral exposure to chlordane from food or drinking water causes human carcinogenicity; however, the weight of evidence following high-level, long-term dermal or inhalation exposures does suggest that chlordane is likely a human carcinogen.

The International Agency for Research on Cancer (IARC) has listed chlordane as a possible human carcinogen, based on inadequate evidence in humans and sufficient evidence in experimental animals (IARC, 2001). U.S. EPA has classified chlordane as a likely human carcinogen, based on limited epidemiological evidence in humans, development of hepatocellular carcinomas in multiple strains of mice and liver toxicity in rats, and the structural resemblance of chlordane to other rodent hepatic carcinogens (IRIS, 1998; U.S. EPA, 1997). Chlordane is on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR CHLORDANE

A chronic reference dose (RfD) is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), expressed in units of mg/kg-day (IRIS, 1995). This estimate includes a factor to account for data uncertainty. The underlying assumption of an RfD is that, unlike most carcinogens, there is a threshold dose below which certain toxic effects will not occur. The RfD for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals and/or humans. These studies are used to determine a No-Observed-Adverse-Effect-Level (NOAEL; the highest dose at which no adverse effect is seen), a Lowest-Observed-Adverse-Effect-Level

(LOAEL; the lowest dose at which any adverse effect is seen), or a benchmark dose level (BMDL; a statistical lower confidence limit of a dose that produces a certain percent change in the risk of an adverse effect) (IRIS, 1995). Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, an RfD is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the probability of adverse effects occurring has increased (IRIS, 1993).

Because chlordane dose-response data in humans are inadequate, the U.S. EPA RfD for this chemical was derived from animal data based on hepatic necrosis as the critical effect (IRIS, 1998; U.S. EPA, 1997). Although several studies have indicated that chronic chlordane exposure may also result in neurobehavioral or other neurotoxic effects, reliable dose-response information as well as data to support a plausible mode-of-action are not available for these endpoints (U.S. EPA, 1997). U.S. EPA thus chose Khasawinah and Grutsch (1989b) as the principal study for the RfD because of the clear dose-related incidence of hepatic effects, overall strength of the study, and comparatively low adverse effect level (IRIS, 1998; U.S. EPA, 1997). Newer chlordane toxicity studies published since the RfD was developed do not have sufficient data to determine acceptable exposure values and/or have not shown a lower adverse effect level.

Khasawinah and Grutsch (1989b) fed 80 ICR mice per sex per group 0, 1, 5, or 12.5 parts per million (ppm) dietary chlordane (estimated to be 0, 0.15, 0.75, and 1.875 mg/kg-day, respectively) for 104 weeks. Hepatocellular swelling was seen in both male and female mice at doses of 5 and 12.5 ppm dietary chlordane; incidence of hepatic necrosis was also significantly elevated at those dose levels, but only in male mice. Other hepatic effects, such as increased relative liver weights and alanine transferase activity, were seen at varying dose levels. The NOAEL and LOAEL values for this study were considered to be 1 and 5 ppm, respectively. To the NOAEL, U.S. EPA applied a 300-fold uncertainty factor (10 for interspecies extrapolation, 10 for intraspecies variation, and 3 for lack of a multigenerational reproductive study), leading to an RfD of $5x10^{-4}$ mg/kg-day (IRIS, 1998; U.S. EPA, 1997).

As required under Health and Safety Code Section 901(g), OEHHA developed a child-specific reference dose (chRD) for chlordane for the purpose of assessing risk at proposed or existing California school sites (OEHHA, 2005). The Cassidy et al. (1994) paper was selected as the most useful study for determination of a chRD, based on endocrine disruption in the developing offspring. Pregnant Sprague-Dawley rats were fed doses of 100, 500, or 5,000 ng/g technical chlordane from day 4 of gestation until day 21 of lactation. Offspring were dosed from postnatal day (PND) 22 to PND 80 and began behavioral testing on PND 76; serum testosterone was measured on PND 85. Body weights were significantly increased in the 500 ng/g dose group compared to controls for females only. Serum testosterone levels were significantly reduced in female offspring dosed with 500 and 5,000 ng/g, although not in a dose-dependent fashion. Male offspring showed only a slight, non-significant, reduction of serum testosterone in the highest (5,000 ng/g) exposure group. Following repeated testing in the Cincinnati water

maze, time to escape was significantly improved in female rat dosed with 100 and 500 ng/g chlordane compared to controls; male rats were not affected by treatment. Intromission latency was significantly reduced in 100 and 500 ng/g treated males; however, the high-dose group was similar to controls. Intromissions prior to ejaculation and total intromissions were significantly increased only in the 500 ng/g dose group. Latency to ejaculation was not different among groups. Open field activity was not affected by treatment in male or female offspring. In tests of reaction to auditory startle, only the maximum response parameter was significantly different from controls and only in the 100 ng/g dose group. OEHHA determined that the LOAEL from this study was 100 ng/g chlordane, based on disruption of sex hormone-mediated behaviors. To the LOAEL, OEHHA applied a 3000-fold uncertainty factor (10 for LOAEL to NOAEL, 10 for interspecies extrapolation, 10 for intraspecies variation, and 3 for inadequate database for hematotoxicity, immunotoxicity, neurotoxicity, and the lack of a valid developmental study), leading to an chRD of $3.3x10^{-5}$ mg/kg-day (OEHHA, 2005).

Although Cassidy et al. (1994) was the best study available to establish a chRD, there are significant limitations with the data as noted by U.S. EPA (1997). Nonetheless, OEHHA concludes that it is appropriate to use the chRD for developing a non-cancer FCG for chlordane. FCGs are, as noted, strictly risk-based and, thus, a study need not be eliminated from consideration solely on the basis of data strength. However, in setting an ATL, it is important to balance the risks and benefits of fish consumption (see the Advisory Tissue Level section, later in this document). For this reason, OEHHA has chosen to use the cancer risk basis for establishing the ATL for chlordane (see below), rather than non-cancer risk based on Cassidy et al. (1994), even though this results in a slightly higher ATL. Chlordane is well-established as a potential human carcinogen; thus, protection against the carcinogenic effects of chlordane is generally accepted by regulatory agencies. Additionally, the 3000-fold uncertainty factor incorporated into the Cassidy et al. study-based chRD should not be used to outweigh the certainty of benefits associated with fish consumption. In using the cancer basis for developing the ATL, OEHHA determines that there is still a large margin of safety (approximately 550- to 1,000-fold, over the range of exposures) for potential endocrine-disrupting health effects of chlordane that is adequate to protect children who would also receive the benefits from consuming fish. OEHHA similarly chose to use the cancer endpoint in developing a Public Health Goal (PHG) for chlordane in drinking water (OEHHA, 1997) although non-cancer health effects, based on the Cassidy study, would have resulted in a lower PHG. Thus, the chRD of $3.3x10^{-5}$ will be used to evaluate non-cancer risk for a chlordane FCG, but only cancer risk will be considered in the development of chlordane ATLs.

A cancer slope factor (CSF) is an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen and is expressed as $(mg/kg\text{-}day)^{-1}$ (U.S. EPA, 1989). The higher the CSF, the greater the estimated potency of a carcinogen. As is the case with noncancer endpoints, only animal data are available to quantify the carcinogenic risk of chlordane (U.S. EPA, 1997). In their 1998 cancer assessment, U.S. EPA combined the

results of five liver tumor data sets for male and female CD-1 and B6C3F1 mice and male ICR mice orally exposed to chlordane at doses from 5 to 64 ppm for a period of 78 to 104 weeks (IRDC, 1973; NCI, 1977; Khasawinah and Grutsch 1989b; U.S. EPA, 1997; IRIS, 1998). U.S. EPA used (body weight)$^{3/4}$ scaling and the linearized multistage model in Global 86 software to determine cancer potency. Individual slope factors for each of the data sets ranged from 0.114 to 0.858 (mg/kg-day)$^{-1}$; a geometric mean of these values was then calculated to derive an oral CSF for chlordane of 0.35 (mg/kg-day)$^{-1}$ (IRIS, 1998). At the time of completion of this cancer risk assessment, however, the 1996 Guidelines for Carcinogenic Risk Assessment were still in draft form (U.S. EPA, 1996). U.S. EPA noted that using the LED_{10} alternate method of low-dose extrapolation from the newer guidelines to calculate cancer potency would lead to a slope factor of 0.567 (mg/kg-day)$^{-1}$ (IRIS, 1998). These guidelines have since been finalized by U.S. EPA (U.S. EPA, 2005).

In the PHG for chlordane in drinking water developed by OEHHA, only the male and female CD-1 and B6C3F1 mice studies (IRDC, 1973; NCI, 1977) were used to determine a CSF; the male ICR mice study (Khasawinah and Grutsch,1989b) included in the U.S. EPA assessment (IRIS, 1998) was not used (OEHHA, 1997). An intercurrent mortality correction of approximately 2.4 was used to correct for less than lifetime duration of these four studies. OEHHA employed the methodology from the 1996 Guidelines for Carcinogenic Risk Assessment (U.S. EPA, 1996) to calculate CSFs for these studies. OEHHA's estimates were based on (body weight)$^{3/4}$ scaling and used Tox_Risk software to calculated the LED_{10} because, according to the author, this software had a greater ability to calculate lower bounds on doses in the observed range in the evaluated studies (OEHHA, 1997). OEHHA then calculated the geometric mean of the best fitting four data sets to determine a CSF of 1.3 (mg/kg-day)$^{-1}$. This CSF will be used to evaluate chlordane cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer value used to evaluate chlordane in fish for the development of FCGs will be **$3.3x10^{-5}$ mg/kd-day**. The cancer value used to evaluate chlordane in fish for the development of FCGs and ATLs will be **1.3 (mg/kg-day)$^{-1}$**.

DICHLORODIPHENYLTRICHLOROETHANE AND ITS METABOLITES (DDTs)

DDTs TOXICOLOGY

Dichlorodiphenyltrichloroethane (DDT) is a synthetic organochlorine insecticide once used throughout the world to control insects that transmit malaria, typhus, and other significant diseases (Crosby, 1998). First used in the United States in 1942, its registration was cancelled by U.S. EPA in 1973 after discovery of its environmental persistence, bioaccumulative properties, and induction of eggshell thinning in predatory species of birds (Hodgson et al., 1998). DDT is still used in some developing countries, however, because it is an effective and inexpensive method of vector control (ATSDR, 1994; Eicobichon, 1991). Humans are typically exposed to a mixture of DDT and its principal metabolites, DDD (tetrachlorodiphenylethane) and DDE (dichlorodiphenyl-dichloroethylene) (U.S. EPA, 2000), which are referred to collectively as total DDTs. U.S. EPA recommends that fish consumption limits be based on the sum of DDT, DDD, and DDE (i.e., total DDTs) (U.S. EPA, 2000).

DDTs are very lipid soluble and water insoluble, have relatively low volatility, and are chemically and biologically stable, which leads to their persistence in the environment and biomagnification by organisms (Ecobichon, 1991; Menzer, 1991; WHO, 1989). Bioconcentration factors as high as $1x10^6$ have been reported for DDTs in aquatic species (reported in Ecobichon, 1991). Because of their historical widespread use and chemical properties, DDTs are pervasive environmental contaminants (ATSDR, 2002).

Exposure of humans to DDTs occurs most commonly from food consumption, particularly meat, dairy products, poultry, and fish (ATSDR, 2002). Freshwater and saltwater fish, in fact, typically account for approximately 75 percent and 5 percent of the total dietary exposure to DDTs, respectively (Dougherty et al., 2000). DDTs are absorbed from the gastrointestinal tract following dietary exposure and are then distributed widely by the lymphatic system and blood before being stored primarily in high-lipid tissues such as fat, liver, kidney, and brain (ATSDR, 1994; 2002; U.S. EPA, 2000). Adipose storage of DDTs is considered protective as it lowers the concentration at the target organ (i.e., the brain) (Klaassen, 2001). DDTs are transferred across the placenta to the fetus (Saxena et al., 1981; Waliszewski et al., 2000; 2001) and easily cross the blood-brain barrier (ATSDR, 1994). Although the primary route of DDT excretion is urinary, lesser amounts are also excreted through feces and breast milk (ATSDR, 1994; 2002). Lactation is a significant means of maternal DDT decontamination (Waliszewski et al., 2001). The half-life of DDT in the body is 10-20 years (IRIS, 1996).

ATSDR (1994; 2002) has extensively reviewed the toxicity of DDT and related compounds. DDT has low acute toxicity with no confirmed human deaths reported solely from DDT exposure (ATSDR, 1994). Acute oral exposures to high levels of DDT primarily affect the nervous system in humans. DDT elicits adverse neurological effects

by inhibiting ion movement through neuronal membranes (ATSDR, 1994; 2002) and reducing the rate of depolarization, thereby intensifying the sensitivity of neurons to stimuli (Ecobichon, 2003). Symptoms have been reported to occur at doses of 5-10 mg/kg and above and include paresthesia, anxiety, irritability, vertigo, tremor, and convulsions, (ATSDR, 2002; Ecobichon, 1991; U.S. EPA, 2000). During an acute poisoning episode, tactile or auditory stimuli may induce repetitive tremors and seizures (Ecobichon, 2003).

Chronic oral exposures to moderate DDT levels have been reported to lead to anorexia and weight loss, anemia, tremors, muscular weakness, EEG changes, and anxiety in humans (Ecobichon, 1991). Similar to acute toxicity, the nervous system is considered a principal target following chronic exposure to this chemical (ATSDR, 2002). Subtle neurological deficits have been reported in humans following long-term chronic DDT exposure (van Wendel de Joode et al., 2001). Twenty-seven retired men, aged 55-70, with a history of occupational DDT exposure during the previous 41 years had exposure duration-related reduced neurobehavioral functioning and increased neuropsychological and psychiatric symptoms compared to a reference group. Performance on tests of verbal attention and visuomotor speed and sequencing were the most pronounced differences between groups. Exposure levels were not available.

A few studies have reported an association between plasma DDE levels and altered immune function in humans including lowered mitogen-induced lymphoproliferative activity, increased total lymphocytes, and either increased or decreased immunoglobulins (Vine et al., 2000, 2001; Cooper et al., 2004). Reproductive and developmental effects in humans such as alterations in the duration of lactation, maintenance of pregnancy, fertility, and length of gestation have also been associated with high levels of DDTs in blood and other body tissues (ATSDR, 2002; see, e.g., Gladen and Rogan, 1995; Longecker et al., 2001). Occasional and slight, but significant, decrements on the Bayley scales of infant development were seen in offspring at 6, 12 or 24 months of age corresponding to a ten-fold increase in maternal serum levels of *p,p*'-DDT, *o,p*'-DDT, or *p,p*'-DDE (Eskenazi et al., 2006).

While human epidemiological studies can only suggest a possible causal relationship between a chemical exposure and an adverse effect, animal studies using controlled exposures do demonstrate numerous toxic effects of DDT exposure. Similar to acute high-level DDT exposures in humans, relatively high long-term DDT exposure has been shown to lead to significant neurological signs in non-human primates. Six of 24 cynomolgus and rhesus monkeys given 20 mg/kg DDT for 130 months developed severe irreversible tremors requiring euthanasia during the first seven years of the study. Histological evidence of neurotoxicity was noted on necropsy (Takayama et al., 1999). Neurodevelopmental effects, most notably altered motor behavior in adult mice exposed prenatally, have also been reported in animals exposed to DDT (ATSDR, 2002; Eriksson et al., 1990a, 1990b, 1992).

Although there is no conclusive evidence that DDTs cause hepatic effects in humans (ATSDR, 2002), liver lesions have been shown to be the critical effect following chronic DDT exposure in rodent studies (IRIS, 1996). Laug et al. (1950), for example, found that weanling rats showed dose-related hepatic morphological changes at DDT doses of 5 ppm and above. DDT-induced hepatic effects have also been shown in hamsters, mice and dogs (IRIS, 1996). Fatty liver and histological signs of hepatotoxicity, including toxic hepatitis, coagulation necrosis, and focal liver necrosis, were seen in cynomolgus and rhesus monkeys dosed with 20 mg/kg DDT for 130 months and then followed for 25 years (Takayama et al., 1999).

Rodent studies have shown that DDTs in comparatively high doses have estrogenic properties that result in increased uterine weights and delayed vaginal opening (Clement and Okey, 1972), as well as antiandrogenic activity such as altered reproductive organ development and delayed puberty (Diel et al., 2000) (reported in ASTDR, 2002). Many animal studies have shown that DDTs are reproductive and developmental toxins. However, human studies have shown no clear link between exposure to environmental levels of DDTs and such effects. Intake of other estrogenic substances (as estrogen equivalents) from dietary bioflavonoids, for example, is estimated to be $4x10^7$ times higher than that from estrogenic pesticides (ATSDR, 2002; Safe, 1995).

Numerous epidemiological studies have attempted to determine whether DDTs cause cancer in humans, particularly those of the breast, pancreas, lymph system, prostate, and endometrium (reported in ATSDR, 2002). To date, these studies have not been sufficient to support a causal relationship between DDT exposure and the development of cancer in humans (ATSDR, 2002). However, the IARC has listed DDT as a possible human carcinogen, based on inadequate evidence of carcinogenicity in humans and sufficient evidence in experimental animals (development of liver tumors in several mouse and rat studies) (IARC, 1991). U.S. EPA classifies DDT as a probable human carcinogen, based on development of liver tumors in mice and rats (IRIS, 1996). OEHHA has administratively listed DDTs on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR DDTs

Because DDT dose-response data in humans are inadequate, the U.S.EPA RfD for this chemical was derived from animal data based on hepatic lesions as the critical effect (IRIS, 1996). U.S.EPA chose Laug et al. (1950) as the principal study for the RfD calculation because it had sufficient exposure duration, established the male rat as the most sensitive animal to DDT toxicity, used doses over the range of the dose-response curve, and provided both a NOAEL and LOAEL, including the lowest LOAEL determined for this chemical (IRIS, 1996).

Laug et al. (1950) fed male and female weanling rats diets containing 0, 1, 5, 10 or 50 ppm commercial DDT for 15-27 weeks. No gross signs of toxicity were apparent.

Histological evaluation of liver and kidneys showed centrilobular hepatic cell enlargement at doses of 5 ppm and above, particularly in male rats. The authors concluded that "the difference observed between the control and 5 ppm animals represents the smallest detectable morphologic effects of DDT, based on extensive observations of rat liver as affected by a variety of chemicals" (Laug et al., 1950; IRIS; 1996). The NOAEL and LOAEL values for this study were considered to be 1 and 5 ppm dietary DDT, respectively (IRIS, 1996). To the NOAEL (corresponding to 0.05 mg/kg-day), U.S. EPA applied a 100-fold uncertainty factor (10 for interspecies conversion and 10 to protect sensitive human subpopulations), leading to an RfD of $5x10^{-4}$ mg/kg-day (IRIS, 1996).

ATSDR has developed a minimal risk level (MRL) for DDTs based on neurodevelopmental effects in mice reported by Eriksson and colleagues (ATSDR, 2002; Eriksson and Nordberg, 1986; Eriksson et al., 1990a, 1990b, 1993; Johansson et al., 1995, 1996; Talts et al., 1998). Male suckling mice given a single oral dose of 0.5 mg/kg body weight DDT during the peak period of rapid brain growth (10 days of age) showed increased spontaneous motor activity when subjected to behavioral testing as 4-month old adults, indicating a disruption of habituation (Ericksson et al., 1990a, 1990b, 1992). Similar effects were not seen when exposures occurred either before (3 days of age) or after (19 days of age) this period (Ericksson et al., 1992). These studies identified a LOAEL of 0.5 mg/kg-day, to which ATSDR applied a 1000-fold uncertainty factor (10 for use of a LOAEL, and 10 each for animal to human extrapolation and intrahuman variability). The resulting MRL is identical to the U.S. EPA RfD based on hepatic effects ($5x10^{-4}$ mg/kg-day), which will be used to evaluate DDT non-cancer risk for OEHHA fish consumption guidelines.

Although studies to assess carcinogenicity in humans have been inadequate and conflicting, DDT has been shown to cause benign and malignant tumors in multiple animal studies and is structurally related to other known animal carcinogens such as DDD, DDE, dicofol, and chlorobenzilate (IRIS, 1996). In their 1991 cancer assessment, U.S. EPA combined the results of six liver tumor data sets for male and female CF-1 mice, male BABL/C mice, male MRC Porton rats, and male and female Wistar rats (Turusov et al., 1973; Terracini et al., 1973; Thorpe and Walker, 1973; Tomatis and Turusov, 1975; Cabral et al., 1982; and Rossi et al., 1977) given doses from 2 to 500 ppm in lifetime feeding studies. Individual slope factors from each of the data sets ranged from 0.082 to 1.04 $(mg/kg\text{-}day)^{-1}$; a geometric mean of these values was then calculated to derive an oral CSF for DDT of 0.34 $(mg/kg\text{-}day)^{-1}$. This oral slope factor will be used to evaluate DDT cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer and cancer critical values used to evaluate DDT in fish for the development of consumption guidelines will be **$5x10^{-4}$ mg/kg-day and 0.34 $(mg/kg\text{-}day)^{-1}$**, respectively.

DIELDRIN

DIELDRIN TOXICOLOGY

Dieldrin is a chlorinated cyclodiene insecticide widely used in the United States from the 1950s to 1970 on crops such as corn and cotton and as a termiticide in subsequent years, until its registration was canceled by U.S. EPA in 1989 (ATSDR, 2002; Stevenson et al., 1999; WHO, 1989). As a result of their low volatility, slow degradation rates and lipophilicity, dieldrin and other organochlorine pesticides resist degradation in the environment and are able to bioconcentrate and biomagnify throughout the terrestrial and aquatic food chain (ATSDR, 2002; Ecobichon, 1991). For example, bioconcentration factors of 12,500 and 13,300 have been found for dieldrin in guppies and sculpins, respectively (Fisher, 1999). Dieldrin is extremely persistent (Matsumura, 1985) and, as such, is still found in the environment, particularly in soil, sediment, and animal fat (ATSDR, 2002).

Diet is the main source of dieldrin exposure in most individuals, with foods such as dairy and meat products, fish, garden fruits, and root vegetables providing the largest dietary contribution (ATSDR, 2002; WHO, 1989). Currently, approximately 90 percent of dietary dieldrin exposure is derived from saltwater and freshwater fish, combined (Dougherty et al., 2000). Dieldrin levels in fish are most commonly associated with areas of corn production (ATSDR, 2002). Following oral exposure, dieldrin is absorbed from the gastrointestinal tract and rapidly distributed through the lymphatic system to various body tissues before being stored largely in adipose tissue and bone marrow (ATSDR, 2002; de Vlieger et al., 1968; Morgan and Roan, 1970; Scheele, 1998). Body burdens are positively correlated with total body fat (ATSDR, 2002; Hunter and Robinson, 1967; 1968). Dieldrin is transferred across the placenta to the fetus where it is widely distributed to fetal organs (Curley et al., 1969). During labor, levels in extracted lipids of fetal blood are higher than in maternal blood (ATSDR, 2002; Polishuk et al., 1977; WHO, 1989). Dieldrin also crosses the blood brain barrier (WHO, 1989). The primary route of dieldrin excretion is through feces via the bile (ATSDR, 2002; Richardson and Robinson, 1971; WHO, 1989), although dieldrin is also excreted in breast milk (ATSDR, 2002; Schecter et al., 1989; Stevens et al., 1993). Breast milk dieldrin levels have been reported to be significantly lower in vegetarians whose diets do not contain animal products compared to U.S. population means, even though breast milk lipid levels were similar between groups (Hergenrather et al., 1981). The biological half-life of dieldrin is approximately one year (WHO, 1989).

ATSDR (2002) and WHO (1989) have extensively reviewed the toxicity of dieldrin. Similar to other chlorinated cyclodienes, dieldrin has relatively high acute toxicity following oral or inhalation exposures compared to most organochlorine pesticides with signs and symptoms including dizziness, vomiting, motor hyperexcitability, and convulsions that generally appear within 20 minutes to 24 hours post-exposure (Ecobichon, 1991; 2003; Klassen and Watkins, 1999; WHO, 1989). The nervous system is the most sensitive target organ following acute and chronic oral exposures in humans

(ATSDR, 2002); adverse neurological effects, including electroencephalographic abnormalities, have been reported in workers occupationally exposed to dieldrin (Hoogendam et al., 1962; 1965). The mechanism of neurotoxic action is believed to be inhibition of chloride transport, resulting in only partial repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999). In animals, initial signs of single-dose dieldrin intoxication are irritability and tremor prior to tonic-clonic convulsions; these may occur as little as one hour after exposure (WHO, 1989). The adult human lethal dose is estimated to be five g (WHO, 1989). The single dose oral LD_{50} for dieldrin in the rat is approximately 37 to 46 mg/kg (ATSDR, 2002). Interspecies variation in susceptibility to acute dieldrin toxicity is significant, with toxicity inversely correlated with species total body fat content (Geyer et al., 1993).

Dieldrin may affect the endocrine system in humans. An epidemiological study of blood organochlorine levels found that dieldrin concentrations were inversely correlated with T4 levels in hypothyroid women (Rathore et al., 2002). Correlational studies such as this, however, cannot prove a causal relationship between exposure and adverse effect.

There is no clear evidence that dieldrin causes hepatotoxicity in humans; however, in rodent studies, the liver is the target organ of chronic dieldrin toxicity and liver lesions are considered to be the critical effect (IRIS, 1990). Liver histopathological changes in rats and increased liver weights and liver-to-body weight ratios in rats and dogs were found in response to varying levels of dieldrin exposure for two years (Walker et al., 1969). Hepatomegaly and histopathological evidence of liver damage were also seen in mice exposed to 10 ppm dietary dieldrin for two years (Thorpe and Walker, 1973). Kitselman (1953) showed that dieldrin-induced gross and histopathological liver changes in dogs were reversible after dieldrin was removed from the diet. In a six-year study of monkeys fed 0.01 to 5.0 ppm dietary dieldrin, hepatic microsomal cytochrome P-450 levels were significantly increased in a dose-dependent fashion at doses of 0.1 ppm and above (approximately 25 to 30 µg/kg body weight per day or greater). Other hepatic variables such as liver weights and alkaline phosphatase, glucose-6-phosphatase, and succinic dehydrogenase activities were not affected by treatment, with the exception of slightly increased microsomal protein contents at the highest doses (Wright et al., 1978).

Several studies have indicated that fertility, litter size, and maternal behavior may be adversely affected following dieldrin exposure in rodents (Harr et al., 1970; Good and Ware, 1969; Virgo and Bellward, 1975; Treon and Cleveland, 1955). A small reproductive study in male and female dogs found delayed estrus, decreased libido, lack of mammary function, and increased stillbirths in animals exposed to 0.15 or 0.30 mg/kg-day dieldrin (Deichmann et al., 1971; reported in ATSDR, 2002). Teratogenesis was not observed in offspring of rats and mice fed graded doses of dieldrin during the period of organogenesis; however, fetotoxicity, as evidenced by an increase in the number of supernumerary ribs and decreased numbers of caudal ossification centers, was seen in doses that also caused signs of maternal toxicity (Chernoff et al., 1975).

Dieldrin has been shown to exert neurobehavioral effects in animals. Following a low dose (0.5, 1.5, or 4.5 mg/kg) acute exposure, a dose-related decrement in adaptive capacity to an uncontrollable stressor was seen in adult mice (Carlson and Rosellini, 1987). In a small study, 0.1 mg/kg-day dieldrin for 55 days impaired learning acquisition in monkeys while 0.01 mg/kg-day did not (Smith et al., 1976). Neurodevelopmental changes such as cerebral edema, internal and external hydrocephalus, and focal neuronal degeneration were seen in rat pups whose dams were exposed to 0.004-0.008 mg/kg-day dieldrin during gestation (ATSDR, 2002; Harr et al., 1970). However, inadequacies of study design and statistical analyses limit interpretation of these results (ATSDR, 2002).

Mouse studies have shown that dieldrin may cause immunosuppression, as evidenced by increased lethality of various viruses (ATSDR, 2002). For example, Krzystyniak et al. (1985) found that a single oral dose of 18 or 30 mg/kg dieldrin in mice significantly reduced the mean day of death following exposure to a lethal dose of mouse hepatitis virus 3 (MHV3). Mice fed 1 or 5 ppm dietary dieldrin for 10 weeks (corresponding to doses as low as 0.13 mg/kg/day; ATSDR, 2002) had reduced survival times when infected with *Plasmodium berghei* or *Leishmania tropica* (Loose, 1982).

Whether dieldrin can cause cancer in human populations is controversial. Several long-term epidemiological studies of workers in pesticide manufacturing plants have not found higher cancer mortality rates related to occupational dieldrin exposure in workers compared to controls (Amoateng-Adjepong et al., 1995; Ribbens, 1985; Swaen et al., 2002). Although Quintana et al. (2004) found that cadaver adipose tissue dieldrin levels were positively associated with risk of non-Hodgkin's lymphoma, according to the authors, lack of data on confounding variables in cases and controls or exposure level or duration hamper interpretation of these results. On the other hand, Cantor et al. (2003) did not see an association between pre-diagnostic serum dieldrin levels and risk of non-Hodgkin's lymphoma in matched controls. IARC has listed dieldrin as not classifiable as to its carcinogenicity, based on inadequate evidence of carcinogenicity in humans and limited evidence of carcinogenicity in animals (IARC, 1987). In contrast, U.S.EPA lists dieldrin as a probable human carcinogen, based on development of benign liver tumors and hepatocarcinomas in multiple strains of mice (IRIS, 1993) and OEHHA has administratively listed dieldrin on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR DIELDRIN

Data for determining NOAEL or LOAEL values for dieldrin in humans are inadequate; thus, U.S. EPA derived an RfD for this chemical based on animal studies. In contrast to humans, where neurotoxicity appears to be the most sensitive endpoint for acute and chronic toxicity, hepatic lesions are the chronic critical effect reported in animals (IRIS, 1990). U.S. EPA chose Walker et al. (1969) as the principal study for the RfD because it supported the critical effect and was a comparatively comprehensive chronic toxicity assessment (IRIS, 1990). Although minimal neurotoxic effects were also seen in this

study, they occurred at a 10-fold higher dose level than did the hepatotoxic effects (ATSDR, 2002) and were thus not used in deriving a reference dose.

Walker et al. (1969) fed five-week-old male and female CFE rats diets containing 0, 0.1, 1.0, and 10.0 ppm dieldrin for two years. Body weights, feed intake, hematology, clinical chemistry, and mortality were unaffected by treatment. High-dose animals showed irritability and occasional tremors and convulsions during the course of the study. One- and 10 ppm-treated female rats had increased absolute and relative liver weights compared to controls. Hepatic parenchymal cell changes indicative of organochlorine exposure were found in some 10 ppm-treated male and female rats. U.S. EPA identified 0.1 and 1.0 ppm, respectively, as the NOAEL and LOAEL values for this study (IRIS, 1990). To the NOAEL (corresponding to 0.005 mg/kg-day), U.S. EPA applied a 100-fold uncertainty factor (10 for interspecies conversion and 10 to protect sensitive humans), leading to an RfD of $5x10^{-5}$ mg/kg-day (IRIS, 1990). ATSDR (2002) has developed a chronic oral minimum risk level (MRL) of $5x10^{-5}$ mg/kg-day, also based on the Walker et al. (1969) study, which is identical to the U.S. EPA RfD. This RfD will be used to evaluate dieldrin non-cancer risk for OEHHA fish consumption guidelines.

Studies to assess the carcinogenicity of dieldrin in humans are inadequate; however, dieldrin has been shown to cause cancer in multiple mouse strains (see caveats noted above) and is structurally related to other known rodent carcinogens (e.g., aldrin, chlordane, heptachlor, and heptachlor epoxide) (IRIS, 1993). U.S. EPA combined the results of 13 liver carcinoma data sets for male and female C3H and CF1 mice, and male B63F1, C57B1/6J, and C3H/H3 mice to determine carcinogenicity for this chemical. Individual slope factors for each of the data sets ranged from 7.1 to 55 $(mg/kg\text{-}day)^{-1}$. A geometric mean of those values was used to set an oral slope factor for dieldrin of 16 $(mg/kg\text{-}day)^{-1}$ (IRIS, 1993). This oral slope factor will be used to evaluate dieldrin cancer risk for OEHHA fish consumption guidelines.

In summary, the non-cancer and cancer critical values used to evaluate dieldrin in fish for the development of consumption guidelines will be **$5x10^{-5}$ mg/kg-day and 16 $(mg/kg\text{-}day)^{-1}$**, respectively.

METHYLMERCURY

METHYLMERCURY TOXICOLOGY

Mercury is a metal found naturally in rocks, soil, air, and water that can be concentrated to high levels in the aquatic food chain by a combination of natural processes and human activities (ATSDR, 1999). The toxicity of mercury to humans is greatly dependent on its chemical form (elemental, inorganic, or organic) and route of exposure (oral, dermal, or inhalation). Methylmercury (an organic form) is highly toxic and can pose a variety of human health risks (NAS/NRC, 2000). Of the total amount of mercury found in fish muscle tissue, methylmercury comprises more than 95 percent (ATSDR, 1999; Bloom, 1992). Because analysis of total mercury is less expensive than that for methylmercury, total mercury is usually analyzed for most fish studies and assumed to be 100 percent methylmercury for the purposes of risk assessment.

In general, mercury concentrations in fish and other biota are dependent on the mercury level of the environment, which can vary based on differences in pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology of individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989). Other factors also affect the accumulation of mercury in fish tissue, including fish diet, species and age (as inferred from length) (WHO, 1989; 1990). Fish at the highest trophic levels (i.e., predatory fish) generally have the highest levels of mercury. Additionally, because of the long biological half-life of methylmercury in fish (approximately 2 years), tissue concentrations in fish increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). As a result, tissue methylmercury concentrations are expected to increase with increasing age and length within a given species, particularly in piscivorous fish.

Fish consumption is the major route of exposure to methylmercury in the United States (ATSDR, 1999). As noted above, almost all fish contain detectable levels of methylmercury, which, when ingested, is almost completely absorbed from the gastrointestinal tract (Aberg et al., 1969; Myers et al., 2000). Once absorbed, methylmercury is distributed throughout the body, reaching the largest concentration in kidneys. Its ability to cross the placenta as well as the blood-brain barrier allows methylmercury to accumulate in the brain and fetus, which are known to be especially sensitive to the toxic effects of this chemical (ATSDR, 1999). In the body, methylmercury is slowly converted to inorganic mercury and excreted predominantly by the fecal (biliary) pathway. Methylmercury is also excreted in breast milk (ATSDR, 1999). The biological half-life of methylmercury is approximately 44-74 days in humans (Aberg, 1969; Smith et al., 1994), meaning that it takes approximately 44-74 days for one-half of a single ingested dose of methylmercury to be eliminated from the body.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan) (Elhassani, 1982-83). The first recorded mass

methylmercury poisoning occurred in the 1950s and 1960s in Minamata, Japan, following the consumption of fish contaminated by industrial pollution (Marsh, 1987). The resulting illness was manifested largely by neurological signs and symptoms such as loss of sensation in the hands and feet, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir et al., 1973; Marsh, 1987). This syndrome was subsequently named Minamata Disease. A second outbreak of methylmercury poisoning occurred in Niigata, Japan, in the mid-1960s. In that case, contaminated fish were also the source of illness (Marsh, 1987). In all, more than 2,000 cases of methylmercury poisoning were reported in Japan, including more than 900 deaths (Mishima, 1992).

The largest outbreak of methylmercury poisoning occurred in Iraq in 1971-1972 and resulted from consumption of bread made from seed grain treated with a methylmercury fungicide (Bakir et al., 1973). This epidemic occurred over a relatively short term (several months) compared to the Japanese outbreak. The mean methylmercury concentration of wheat flour samples was found to be 9.1 micrograms per gram (μg/g). Over 6,500 people were hospitalized, with 459 fatalities. Signs and symptoms of methylmercury toxicity were similar to those reported in the Japanese epidemic. Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). When maternal methylmercury consumption is very high, as happened in Japan and Iraq, significant methylmercury toxicity can occur to the fetus during pregnancy, with only very mild or even in the absence of symptoms in the mother. In those cases, symptoms in children were often not recognized until development of cerebral palsy and/or mental retardation many months after birth (Harada, 1978; Marsh et al., 1980; Marsh et al., 1987; Matsumoto et al., 1964; Snyder, 1971).

IARC has listed methylmercury compounds as possible human carcinogens, based on inadequate data in humans and limited evidence in experimental animals (increased incidence of tumors in mice exposed to methylmercury chloride) (IARC, 1993). U.S. EPA has also listed methylmercury as a possible human carcinogen (IRIS, 2001). OEHHA has administratively listed methylmercury compounds on the Proposition 65 list of chemicals known to the State of California to cause cancer. No estimate of the increased cancer risk from lifetime exposure to a chemical has been developed for methylmercury.

DERIVATION OF REFERENCE DOSES FOR METHYLMERCURY

The first U.S. EPA RfD for methylmercury was developed in 1985 and set at $3x10^{-4}$ mg/kg-day (U.S. EPA, 1997). This RfD was based, in part, on a WHO report summarizing data obtained from several early epidemiological studies on the Iraqi and Japanese methylmercury poisoning outbreaks (WHO, 1976). WHO found that the

earliest symptoms of methylmercury intoxication (paresthesias) were reported in adults at blood and hair concentrations ranging from 200-500 µg/L and 50-125 µg/g, respectively. In cases where ingested mercury dose could be estimated (based, for example, on mercury concentration in contaminated bread and number of loaves consumed daily), an empirical correlation between blood and/or hair mercury concentrations and onset of symptoms was obtained. From these studies, WHO determined that methylmercury exposure equivalent to long-term daily intake of 3-7 µg/kg body weight in adults was associated with an approximately 5 percent prevalence of paresthesias (WHO, 1976). U.S. EPA further cited a study by Clarkson et al. (1976) to support the range of blood mercury concentrations at which paresthesias were first observed in sensitive members of the adult population. This study found that a small percentage of Iraqi adults exposed to methylmercury-treated seed grain developed paresthesias at blood levels ranging from 240 to 480 µg/L. The low end of this range was considered to be a LOAEL and was estimated to be equivalent to a dosage of 3 µg/kg-day. U.S. EPA applied a 10-fold uncertainty factor to the LOAEL to reach what was expected to be the NOAEL. Because the LOAEL was observed in sensitive individuals in the population after chronic exposure, additional uncertainty factors were not considered necessary for exposed adults (U.S. EPA, 1997).

Although this RfD was derived based on effects in adults, even at that time researchers were aware that the fetus might be more sensitive to methylmercury (WHO, 1976). It was not until 1995, however, that U.S. EPA had sufficient data from Marsh et al. (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). Marsh et al. (1987) collected and summarized data from 81 mother and child pairs where the child had been exposed to methylmercury *in utero* during the Iraqi epidemic. Maximum mercury concentrations in maternal hair during gestation were correlated with clinical signs in the offspring such as cerebral palsy, altered muscle tone and deep tendon reflexes, and delayed developmental milestones that were observed over a period of several years after the poisoning. Clinical effects incidence tables included in the critique of the risk assessment for methylmercury conducted by the U.S. Food and Drug Administration (FDA) (Seafood Safety, 1991) provided dose-response data for a benchmark dose approach to the RfD, rather than the previously used NOAEL/LOAEL method. The BMDL was based on a maternal hair mercury concentration of 11 ppm. From that, an average blood mercury concentration of 44 µg/L was estimated based on a hair: blood concentration ratio of 250:1. Blood mercury concentration was, in turn, used to calculate a daily oral dose of 1.1 µg/kg-day, using an equation that assumed steady-state conditions and first-order kinetics for mercury. An uncertainty factor of 10 was applied to this dose to account for variability in the biological half-life of methylmercury, the lack of a two-generation reproductive study and insufficient data on the effects of exposure duration on developmental neurotoxicity and adult paresthesia. The oral RfD was then calculated to be $1x10^{-4}$ mg/kg-day, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

The two previous RfDs for methylmercury were developed using data from high-dose poisoning events. Recently, the National Academy of Sciences (NSA) was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NAS/NRC, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in the Seychelles Islands (Davidson et al., 1995, 1998), the Faroe Islands (Grandjean et al., 1997, 1998, 1999), and New Zealand (Kjellstrom et al., 1986, 1989). The residents of these areas were selected for study because their diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NAS/NRC, 2000).

Although estimated prenatal methylmercury exposures were similar among the three studies, subtle neurobehavioral effects in children, such as problems with attention, fine-motor function, and verbal memory, were found to be associated with maternal methylmercury dose in the Faroe Islands and New Zealand studies, but not in the Seychelle Islands study. The reasons for this discrepancy were unclear; however, it may have resulted from differences in sources of exposure (marine mammals and/or fish), differences in exposure pattern, differences in neurobehavioral tests administered and age at testing, the effects of confounding variables, or issues of statistical analysis (NRC/NAS, 2000). The NAS report supported the current U.S. EPA RfD of $1x10^{-4}$ mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data.

U.S. EPA recently published a new RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). In order to develop an RfD, U.S. EPA used several test scores from the Faroes data, rather than a single measure for the critical endpoint as is customary (IRIS, 2001). U.S. EPA developed BMDLs utilizing test scores for several different neuropsychological effects mentioned above with cord blood as the biomarker for mercury exposure. The BMDLs for different neuropsychological effects in the Faroes study ranged from 46-79 µg mercury/liter blood. U.S. EPA then chose a one-compartment model for conversion of cord blood to ingested maternal dose, which resulted in estimated maternal mercury exposures of 0.857-1.472 µg/kg-day (IRIS, 2001). An uncertainty factor of ten was applied to the oral doses corresponding to the range of BMDLs to account for interindividual toxicokinetic variability in ingested dose estimation from cord-blood mercury levels and pharmacodynamic variability and uncertainty, leading to an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). In support of this RfD, U.S. EPA found that benchmark dose analysis of several neuropsychological endpoints from the Faroe Island and New Zealand studies, as well as an integrative analysis of all three epidemiological studies, converged on an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). U.S. EPA (IRIS, 2001) now considers this RfD to be protective for all populations. However, in their joint Federal Advisory for Mercury in Fish, U.S. EPA and U.S. FDA only apply this RfD to women who are pregnant or might become pregnant, nursing mothers, and young children (U.S. EPA, 2004).

OEHHA finds that there is convincing evidence that the fetus is more sensitive than adults to the neurotoxic and subtle neuropsychological effects of methylmercury. As noted previously, during the Japanese and Iraqi methylmercury poisoning outbreaks, significant neurological toxicity occurred to the fetus even in the absence of symptoms in the mother. In later epidemiological studies at lower exposure levels (e.g., in the Faroe Islands), these differences in maternal and fetal susceptibility to methylmercury toxicity were also observed. Recent evidence has shown that the nervous system continues to develop through adolescence (see, for example, Giedd et al., 1999; Paus et al., 1999; Rice and Barone, 2000). As such, it is likely that exposure to a neurotoxic agent during this time may damage neural structure and function (Adams et al., 2000), which may not become evident for many years (Rice and Barone, 2000). Thus, OEHHA considers the RfD based on subtle neuropsychological effects following fetal exposure to be the best estimate of a protective daily exposure level for women aged 18 to 45 years and children aged 1 to17 years.

In an effort to address the risks of methylmercury contamination in different populations, two separate RfDs will be used to assess risk for different population groups. OEHHA has formerly used a separate methylmercury RfD for sensitive populations to formulate advisories for methylmercury contamination of sport fish (Stratton et al., 1987). Additionally, the majority of states issue separate consumption advice for sensitive (e.g., children) and general population groups**.** OEHHA chooses to use both the current and previous U.S. EPA RfDs to evaluate methylmercury non-cancer risk for fish consumption guidelines for two distinct population groups. In OEHHA advisories, the current RfD of $1x10^{-4}$ mg/kg-day, based on effects in infants, will be used for women 18 to 45 years and children aged 1 to17 years. The previous RfD of $3x10^{-4}$ mg/kg-day, based on effects in adults, will be used for women over 45 years and men.

In summary, the non-cancer critical values used to evaluate methylmercury in fish for development of consumption guidelines will be **$1x10^{-4}$ mg/kg-day** for women aged 18 to 45 years and children aged 1 to 17 years, and **$3x10^{-4}$ mg/kg-day**, for women over 45 years and men.

POLYCHLORINATED BIPHENYLS (PCBs)

PCBs TOXICOLOGY

Polychlorinated biphenyls (PCBs) are a class of synthetic persistent lipophilic organic chemicals containing complex mixtures of biphenyls that are chlorinated to varying degrees (ATSDR, 2000; U.S. EPA, 2000a). The chemical formula for PCBs is $C_{12}H_{10-n}Cl_n$, where n equals the number of chlorine atoms ranging from one to ten (WHO, 1993). PCBs were manufactured in the United States from about 1930 to 1977 for use as coolants in electrical transformers and capacitors, and as hydraulic fluids, lubricating and cutting oils, and plasticizers (ATSDR, 2000; Erickson, 2001). Although there are 209 possible individual chlorinated biphenyl compounds (known as congeners), only approximately 130 are found in commercial products (U.S. EPA, 2000a; WHO, 1993). In the United States, PCBs were generally sold as mixtures of congeners under the trade name Aroclor (ATSDR, 2000; Nessel and Gallo, 1992).

PCBs primarily enter the environment as a result of accidental spills and leaks from products containing Aroclor mixtures and are redistributed among environmental compartments by volatilization and runoff (ATSDR, 2000). Because of their lipophilicity and slow degradation rates, PCBs are very resistant to degradation in the environment (ATSDR, 2000). PCBs are found chiefly in soil, sediment, and fatty biological tissue, where they accumulate and biomagnify in the food chain (Dekoning and Karmaus, 2000; Menzer, 1991; Moser and McLachlan, 2001). Bioconcentration factors of some congeners are reported to reach as high as $1x10^7$ in fish (Erickson, 2001). PCB residue levels in fish are affected by sediment characteristics (e.g., organic carbon content), fish species and lipid content, and trophic structure of the food chain (Eisler, 1996).

The composition of Aroclor mixtures in the environment will change over time as individual PCB congeners undergo differential partitioning, degradation, and biotransformation. This process, referred to as “weathering,” results in differential persistence and bioaccumulation, which changes the PCB pattern found in environmental samples from the original pattern in technical Aroclor mixtures (Erickson, 2001). As a rule, the environmental persistence of PCBs increases with the degree of chlorination (Menzer, 1991). As a result of improved methods and equipment, PCBs in environmental samples can be quantified as congeners and congener patterns can be related to potential sources and to the technical Aroclor mixture they most closely resemble (Newman, et al., 1998).

Saltwater and fresh water fish and shellfish, combined, account for a significant portion of the total dietary exposure to PCBs (Dougherty et al., 2000). In a study comparing frequent and infrequent Great Lakes sport fish consumers, lifetime sport fish consumption was found to be the best predictor of PCB body burdens (Hanrahan et al., 1999). Fishers who consume fish from PCB-contaminated waters have been found to have serum PCB levels several times those of the general population and similar to individuals occupationally exposed to PCBs (Kreiss, 1985).

Absorption of PCBs following oral exposure occurs via passive diffusion and ranges from approximately 75 percent to more than 90 percent (U.S. EPA, 2000a), depending on congener and the diffusion gradient between PCB concentration in the gut contents and serum lipids (Juan et al., 2002; ATSDR, 2000). Once absorbed, PCBs are distributed throughout the body, accumulating primarily in lipid-rich tissues such as liver, adipose tissue, skin, and breast milk (U.S. EPA, 2000a). More than 95 percent of most PCB congeners are absorbed from breast milk (Dahl et al., 1995; McLachlan, 1993). PCBs are also transferred across the placenta to the fetus (ATSDR, 2000; DeKoning and Karmaus, 2000). Excretion of PCBs occurs primarily through the feces and urine as well as breast milk of lactating women (ATSDR, 2000; Moser and McLachlan, 2001). Net absorption (absorption from the gastrointestinal tract minus excretion) is significantly influenced by blood lipid levels, congener body burden (ATSDR, 2000; Schlummer et al., 1998), and body mass index (Juan et al., 2002). Although various studies have shown substantial disparities in estimated half-lives of PCBs (less than one year to greater than 10 years), the best evidence suggests that the majority of PCB congeners found in an occupational setting have half-lives in the human body from one to six years (Shirai and Kissel, 1996; Wolff et al., 1982).

The toxicity of PCBs following occupational exposure has been known since 1936 when the development of chloracne (a severe form of acne) in PCB-exposed workers resulted in the establishment of a workplace threshold limit value for these compounds (Erickson, 2001). Occupational exposure has also been reported to result in ocular effects such as Meibomian gland hypersecretion, swollen eyelids, and abnormal conjunctival pigmentation (ATSDR, 2000). Incidents of purported widespread PCB poisonings occurred in Japan in 1968 ("Yusho") and Taiwan in 1979 ("Yu-Cheng") following consumption of PCB-contaminated rice oil (WHO, 1993). Signs and symptoms in affected persons were primarily ocular and dermatological; edema, alterations in blood chemistry values, and various respiratory, immunological, reproductive, developmental, and neurological disturbances were also seen (ATSDR, 2000; WHO, 1993). Although the clinical syndrome was originally thought to have resulted solely from PCB toxicity, ensuing investigations determined that the co-contaminants polychlorinated dibenzofurans (PCDFs) were the primary causal factors in Yusho and Yu-Cheng diseases (Ikeda, 1996; Kunita et al., 1984; Schantz, 1996; Wilson, 1987; Yao et al., 2002). In a sample of Yusho rice oil, for example, 2,3,4,7,8-pentaCDF was found to contribute the majority (58 percent) of the total toxic equivalents (TEQ), while PCB-126 was the second most abundant contributor to total TEQ (16 percent) (Yao et al., 2002). It is possible, however, that some signs and symptoms in the Yusho and Yu-Cheng poisonings resulted from non-*Ah* receptor mediated mechanisms of PCB toxicity.

Numerous epidemiological studies since that time have attempted to determine whether PCBs pose a human health risk at levels currently found in the environment. Many authors have subsequently reported an association between oral environmental PCB exposures and cancer as well as various adverse neurological, reproductive, and developmental effects (ATSDR, 2000). In particular, several observational cohort studies have found one or more neurodevelopmental deficits in children exposed to PCBs *in*

utero and/or postnatally (see descriptions in Winneke et al., 1998; 2002); however, results have differed with respect to the type and persistence of effects as well as the matrix (e.g., cord blood or breast milk) used to indicate exposure (Winneke et al., 1998). For example, Jacobson et al. (1992) and Jacobson and Jacobson (1996) noted that children exposed to PCBs prenatally through maternal consumption of contaminated Great Lakes fish had poorer performance on cognitive tests for visual, verbal and memory abilities at four years of age, and lowered verbal and full-scale IQ at age eleven compared to children with lower intrauterine PCB exposures. In similarly exposed infants, Gladen et al. (1988) found decreases in psychomotor scores at twelve months as well as delays in motor maturation up to 24 months (Rogan and Gladen, 1991), but no changes in mental scores. These effects were no longer observed at 3-5 years of age (Gladen and Rogan, 1991). Schantz et al. (1999) found no effect on visual-motor coordination or hand steadiness in a population of adults over 50 years of age exposed to PCBs and other contaminants through long-term consumption of large amounts of Great Lakes fish compared to those who consumed little or no Great Lakes fish. However, the same population showed a decrease in verbal memory in one of two standardized tests of memory and learning compared to controls (Schantz et al., 2001). No effects were seen on executive or visual-spatial function. In a study comparing women who had consumed more than 40 pounds of Great Lakes fish over their lifetimes with women who had never consumed Great Lakes fish, Stewart et al. (2000) found a significant linear relationship between highly chlorinated (C17-C19) PCB congeners in cord blood and decreased habituation and autonomic scores in the Neonatal Behavioral Assessment Scale. In a European cohort, Winneke et al. (1998) found the sum of PCBs 138, 153, and 180 in breast milk to be negatively associated with cognitive development, but not motor development or recognition memory in seven-month-old infants. These outcomes were not related to cord plasma PCBs. Neurological effects have also been observed in infants, children, and adults following PCB poisonings (ATSDR, 2000).

Recent data indicate that typical environmental levels of PCBs might affect the developing immune system in humans (Weisglas-Kuperus et al., 2000). Prenatal PCB exposure was positively associated with number of lymphocytes, T cells, and $CD3^{+}CD8^{+}$ (cytotoxic), $CD4^{+}$ $CD45RO^{+}$ (memory), $TcR\alpha\beta^{+}$, and $CD3^{+}$HLA-DR^{+} (activated) T cells and negatively associated with antibody levels to mumps and rubella in 42 month-old children. Current plasma PCB levels were positively associated with prevalence of chicken pox and recurrent middle ear infections, while negatively associated with prevalence of allergic reactions. Increased duration of breast feeding counteracted the negative effects of postnatal PCB exposure (Weisglas-Kuperus et al., 2000).

Human studies have shown inconsistent results with respect to adverse reproductive effects following PCB exposures (ATSDR, 2000). Menstrual cycles were slightly shorter and female fecundity was reduced in women consuming PCB-contaminated Great Lakes fish (Buck et al., 2000; Mendola et al. 1997). However, other studies have shown no adverse reproductive effects in women consuming high-PCB fish when examining endpoints such as increased time-to-pregnancy or risk of spontaneous fetal death (Buck et al., 1997; Courval et al., 1999; Mendola et al., 1995), although there was a small

association between sport-caught fish consumption and conception delay for men (Courval et al., 1999). Results of human studies on potential developmental effects of PCB exposure have also been mixed (ATSDR, 2000). Maternal PCB exposure via fish consumption has been reported to have a negative, positive, or no association with birth weight, head circumference, or gestation age (see, for example, Buck et al., 2003; Dar et al., 1992; Jacobson et al. 1990a, 1990b; Lonky et al., 1996; Rylander et al., 1995; Smith, 1984; ATSDR, 2000).

Most human epidemiological studies examining adverse effects of PCB exposure have been confounded by concomitant exposure to the trace contaminants PCDFs or other workplace chemicals such as solvents, benzene, and lead (Erickson, 2001; Persky, 2001), or have had other serious design or reporting flaws (Swanson et al., 1995). In fact, in a systematic critical evaluation of 72 occupational or environmental PCB exposure studies conducted prior to 1995, Swanson et al. (1995) found that only five of the occupational studies and none of the environmental studies provided either positive or suggestive evidence of a causal relationship between PCB exposure and adverse effects in humans. Most studies were deemed inconclusive. This is particularly true in studies of fish-eating populations as fish are often contaminated with multiple organochlorines and other neurological, developmental or reproductive toxins (Seegal, 1996; 1999). Although human epidemiological studies are quite limited in their ability to prove a causal relationship between PCB exposure and disease (Seegal, 1996), animal studies using controlled exposures to specific Aroclor mixtures do clearly demonstrate adverse effects on the hepatic, hematological, gastrointestinal, immunological, neurological, endocrine, and reproductive systems following oral PCB exposure (ATSDR, 2000). To date, the most sensitive effects of PCB toxicity have been identified in monkeys, including clinical signs showing developmental effects such as ocular exudate, inflamed Meibomian glands, and distorted growth of fingernails and toenails, as well as immunological effects such as decreased antibody response to sheep erythrocytes (IRIS, 1996). Studies showing specific effects are discussed in more detail below.

As has been the case with various non-cancer endpoints, epidemiological research in humans has also found an association between exposure to PCBs and mortality rates from cancers of the liver, gall bladder, biliary tract, and brain, as well as non-Hodgkin's lymphoma and malignant melanoma (see Cogliano, 1998 and ATDSR, 2000, for discussion). Additionally, male Yusho victims were noted to have an increase in mortality from liver cancer when compared to national death rates (Kuratsune et al., 1987); however, this may have resulted from PCDF contamination (Cogliano, 2001). While epidemiological studies cannot prove a causal relationship between exposure and health effects as noted above, numerous experimental investigations in rodents have clearly shown the ability of various commercial Aroclor mixtures to cause cancerous or pre-cancerous hepatic and gastrointestinal lesions (see Cogliano et al., 1998 and ATSDR, 2000, for discussion). IARC has listed PCBs as probable human carcinogens, based on limited evidence of hepatobiliary cancer in humans and sufficient evidence of malignant liver neoplasms in rodents (IARC, 1987). U.S. EPA also designates PCBs as probable human carcinogens based on tumors found in female mice exposed to Aroclors 1260,

1254, 1242, and 1016 and also in male rats exposed to Aroclor 1260 (IRIS, 1997). Based on these actions, OEHHA has administratively listed PCBs on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR PCBs

Studies to identify an RfD or CSF for PCBs have been conducted with the specific Aroclor mixtures that were prevalent as commercial products during the period that Aroclors were actively manufactured and used. However, as noted above, PCBs found in fish or other environmental media have undergone weathering that can selectively increase or decrease individual congeners, possibly increasing the overall toxicity of the mixture (Cogliano, 2001). U.S. EPA has adopted an approach that matches the expected environmental persistence and toxicity of congeners to the congener profile and toxicity of different Aroclors (Cogliano, 2001). Fish consumption is considered an exposure of high risk and persistence, so recommended health effects values are based on the cancer and non-cancer toxicities of Aroclors 1260 and 1254, which show the greatest toxicity and content of environmentally persistent chlorines (U.S. EPA, 1996).

Because PCB dose-response data for non-cancer endpoints in humans are inadequate, the U.S. EPA RfD for these compounds has been derived from animal data. The RfD for Aroclor 1254 of $2x10^{-5}$ mg/kg-day (IRIS, 1996) is based on a series of studies in adult female Rhesus monkeys (Arnold et al., 1993a, 1993b; Tryphonas et al., 1989, 1991a, 1991b) that were treated for 23 to 55 months. The critical effects noted in treated adults were ocular exudate, inflamed Meibomian (tarsal) glands, distorted fingernail and toenail growth, as well as a decreased antibody response to sheep erythrocytes, all of which occurred at the lowest tested dose of 0.005 mg/kg-day (IRIS, 1996). To this LOAEL, an uncertainty factor of three hundred (ten for sensitive individuals, three for extrapolation from rhesus monkey to humans, a partial factor[1] for the use of a minimal LOAEL [i.e., the effects were not severe], and three to convert from subchronic to chronic) was applied to develop the RfD (IRIS, 1996). OEHHA also used the LOAEL from Arnold et al. (1993a, 1993b) and a three hundred-fold uncertainty factor (ten for interindividual variability, ten for interspecies variation and three for mild and reversible effects at the LOAEL) to account for immunological effects of PCBs to derive a PHG (the concentration of a chemical in drinking water determined to present no significant risk to human health when consumed over a lifetime) (Avalos and Brodberg, 2004). Results of continuing studies in which these treated females were mated to untreated males have been published (Arnold et al. 1995; 1997) since the U.S. EPA derived its RfD. These studies present findings on effects on female reproduction and developmental effects in infants following intrauterine and post-parturition exposures (22 weeks via breast milk). Arnold et al. (1995) showed decreased conception rates at 0.02 mg/kg-day and above, but not at 0.005 mg/kg-day. Developmental effects such as inflammation or enlargement of the Meibomian (tarsal) glands, nail lesions and gum recession, as well as a decrease in

[1] IRIS did not stipulate what the "partial factor" was; however, by deduction, it must have been three.

titers to IgM sheep red blood cells and a dose-related decrease in head circumference were seen in infant rhesus monkeys whose mothers were exposed to 0.005 mg/kg-day Aroclor 1254. Studies with other Aroclor compounds (e.g., Aroclor 1016) have shown developmental and neurological effects in monkeys at slightly higher doses with minor morphological effects occurring at levels where no or minimal neurobehavioral effects were manifested (e.g., Shantz et al., 1989). Although the current RfD is derived from a LOAEL from a study in adult monkeys, similar morphological effects in offspring were reported at the same exposure level. Since morphological effects have been found to occur at or below the exposure levels causing developmental neurobehavioral effects (Schantz et al., 1989), the RfD is also expected to be protective of the developing fetus. This RfD of $2x10^{-5}$ mg/kg-day will be used to evaluate PCB non-cancer risk for OEHHA fish consumption guidelines.

Human cancer dose-response data for PCBs are also inadequate and, thus, the PCB CSF has been generated based on animal studies. Because of the differential ability of different PCB mixtures to cause cancer, U.S. EPA developed a range of CSFs based on Aroclors 1016, 1242, 1254, and 1260. These Aroclors include the range of typical congeners found in various environmental media such as water and fish (IRIS, 1997). For food chain exposure, such as fish consumption, where environmental processes increase risk, a "high-risk" cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$ is used based on the carcinogenic potential of Aroclors 1254 and 1260 (U.S. EPA, 1996). This value was derived from a study of male and female rats (Brunner et al., 1996; Norback and Weltman, 1985). A significant, dose-related increase in the number of liver adenomas or carcinomas was found in female rats exposed to all Aroclors and in male rats exposed to Aroclor 1260 (IRIS, 1997). Aroclors 1254 and 1260 are the most frequently detected Aroclors sampled in California fish (Brodberg and Pollock, 1999; LACSD, 2000). The CSF of 2.0 $(mg/kg\text{-}day)^{-1}$ will be used to evaluate PCB cancer risk for OEHHA fish consumption guidelines.

For fish consumption advisories, cancer and non-cancer health effects values are applied to the sum of detected Aroclors (generally 1248, 1254, and 1260) or a sum of congeners in fish tissue, as recommended by U.S. EPA (2000b).

In summary, the non-cancer and cancer critical values used to evaluate PCBs in fish for the development of consumption guidelines will be **$2x10^{-5}$ mg/kg-day** and **2.0 $(mg/kg\text{-}day)^{-1}$**, respectively.

SELENIUM

SELENIUM TOXICOLOGY

Selenium is a metalloid found naturally, but highly variably, throughout the environment (ATSDR, 1999; Reilly, 1996). Although toxic at relatively low levels, selenium is also a required nutrient that functions to protect against oxidative stress, regulate thyroid hormones, and in vitamin C metabolism (IOM, 2000). The current Recommended Dietary Allowance (RDA) for selenium is 55 µg/day for the general adult population, 60 µg/day for pregnant women, and 70 µg/day during lactation (IOM, 2000). Selenium is found in a variety of inorganic and organic forms (Haygarth, 1994); however, in animal tissues, most selenium occurs as the amino acids selenomethionine or selenocysteine (IOM, 2000). Fish and other food samples are analyzed for total selenium content, as nutritional and toxicity values have not been developed for specific chemical forms of the element.

Selenium is dispersed naturally in the environment by weathering of selenium-containing rocks and volcanic eruptions (ATSDR, 2003). Human activities can significantly redistribute environmental selenium; fossil fuel processing and combustion as well as irrigation of seleniferous soils are important origins of localized selenium contamination (Lemly, 1997). Because of the inherent variability in soil selenium concentrations, human and animal selenium exposures can fluctuate quite dramatically by geographic locale. Human selenium intakes in different regions of China known for endemic deficiency and toxicosis, for example, have been shown to range from seven to 38,000 µg/day, respectively (Levander, 1987).

Environmental conditions (e.g., pH and oxidation-reduction potential) dictate the chemical form in which selenium will be found, which, in turn, determines the biological fate of the element (ATSDR, 2003). Water and air selenium levels are generally low except in isolated areas; humans are exposed to selenium primarily through food. Cereals, grains, and forage crops are the largest contributors of selenium to the diet (ATSDR, 2003), although fish also can be a relatively rich source of the element (USDA, 2004). Freshwater fish in the United States have been found to contain a mean concentration of 0.56 ppm selenium, wet weight (May, 1981); however, in areas of California where high-selenium irrigation drainage water contaminated nearby waterways, selenium concentrations in whole body carp were reported up to 60 ppm (Fan, 1988). Brazil nuts, on average, contain the highest selenium concentration of any common food, ranging from 0.03 to 512 ppm, wet weight, depending on geographic location (Chang et al., 1995). Six to eight nuts (one ounce) typically supply approximately ten times (544 µg) the RDA for this nutrient (USDA, 2004).

Following ingestion, most forms of dietary selenium are well absorbed from the gastrointestinal tract (ATSDR, 2003; Barceloux, 1999; Thomson, 1998). Once absorbed, selenium is distributed to many tissues, reaching the highest concentrations in liver and kidney; selenium also crosses the placenta and is found in breast milk (ASTDR, 2003).

Excretion occurs primarily through urine and, to a lesser extent, feces. In cases of excess consumption, selenium is excreted in the breath and sweat as garlic-odored dimethylselenide (IOM, 2000; Klaassen and Watkins, 1999). The half-life of selenomethionine in the human body is 234 days (Klaassen and Watkins, 1999).

The toxicity of selenium was recognized many years before its role as an essential nutrient was discovered in the 1950s by Schwarz and Foltz (1957). Franke and Potter (1935) were the first to prove that selenium was the plant constituent responsible for signs of toxicosis such as hair and hoof loss reported in livestock grazing on the plains of Nebraska and South Dakota (Combs and Combs, 1986). Since that time, selenium toxicity has been well reviewed by many authors (e.g., ATSDR, 2003; Combs and Combs, 1986; Reilly, 1996; Barceloux, 1999; Schrauzer, 2000, 2003) and has been found to be dependent on chemical form and solubility (Klaassen and Watkins, 1999).

Acute, sometimes fatal, selenium toxicity only rarely has been reported in humans and has generally been the result of self-medication, accidental, suicidal, or occupational exposures (Civil and McDonald, 1978; Sioris et al., 1980; Gasmi et al., 1997; Schellmann et al., 1986). Gastrointestinal and neurological signs and symptoms, as well as hair and nail loss, predominate the clinical presentation (Combs and Combs, 1986). At least one case of acute selenium intoxication from a natural source has been noted in the literature. A 54-year-old Venezuelan man suffered anxiety, chills, diarrhea, fever, anorexia, and weakness after consuming 70 to 80 "Coco de Mono" (*Lecythis ollaria*) almonds. Eight days after consuming the nuts, he suffered extensive loss of scalp and body hair (Kerdel-Vegal, 1964). Subsequent studies identified the pharmacologically active agent as selenocystathionine (Aronow and Kerdel-Vegas, 1965; Kerdel-Vegas et al., 1965). Acute selenium poisoning was also reported in five individuals who consumed sodium selenate intended for use as a turkey diet supplement (dose not provided). Symptoms and signs, which resolved within 24 hours, included nausea, vomiting, diarrhea, abdominal pain, chills, and tremors (Sioris et al., 1980). Acute to sub-acute selenium toxicosis occurred in 13 individuals who consumed an improperly formulated over-the-counter selenium supplement (FDA Drug Bulletin, 1984; Jensen et al., 1984; Helzlsouer et al., 1984). Analysis of several tablets revealed that the selenium content was 182 times higher than labeled (approximately 27-30 mg per tablet, in the form of sodium selenate and elemental selenium). Estimates of ingested selenium dose ranged from 27 to 2310 mg (from a single tablet to 77 tablets taken over a 2 ½ month period). Signs and symptoms of toxicity included nausea, abdominal cramps, nail and hair changes (including total hair loss), peripheral neuropathy, garlic breath odor, fatigue, and irritability.

Chronic selenium toxicosis in humans has been well characterized as a result of endemic disease occurring in a seleniferous region of China (Yang et al., 1983, 1989a, 1989b). Excessive selenium intakes (a mean of 4,990 µg/day, versus 116 µg/day in a selenium adequate area) resulted from consumption of high-selenium corn and vegetables during a drought period. Affected individuals suffered nail and hair loss, dermal swelling, erythema and ulcerations, as well as paresthesias. Hair selenium levels were approximately 100 times higher than those found in selenium adequate areas (Yang et al.,

1983). Chronic human selenium toxicity as a consequence of environmental exposures has not been reported in the United States, although ranchers in a seleniferous area of South Dakota were found to consume as much as 724 µg selenium per day (Longnecker et al., 1991).

Although high levels of selenium have been shown to be teratogenic in birds (Ohlendorf, 1986; 1988), there is no evidence that selenium induces terata in humans or other mammals (ATSDR, 2003). Other developmental effects following *in utero* selenium exposure in mammals have only been conclusively demonstrated at doses that cause frank maternal toxicity (Willhite, 1993; ATSDR, 2003).

IARC and U.S. EPA have listed selenium compounds as not classifiable as to their carcinogenicity in humans because of inadequate evidence of carcinogenicity in humans or animals (IARC, 1975; IRIS, 1993). Selenium sulfide, an industrial chemical not present in food, is considered a probable human carcinogen by U.S. EPA (IRIS, 1993) and is listed by OEHHA on the Proposition 65 list of carcinogens.

DERIVATION OF A REFERENCE DOSE FOR SELENIUM

The current U.S. EPA RfD for selenium and selenium compounds was developed in 1991 and set at $5x10^{-3}$ mg/kg-day (IRIS, 1991), corresponding to 350 µg/day for a 70-kg adult or approximately six-fold higher than the RDA for the general adult population. This RfD was based on an epidemiological study of approximately 400 people residing in a seleniferous region of China noted above. Overt signs of clinical selenosis (e.g., garlic breath odor, nail changes, hair and nail loss, decreased hemoglobin, skin lesions, mottled teeth, and central nervous system effects) were reported at whole blood concentrations of 1.35 mg/L, corresponding to a daily selenium intake of 1.261 mg (Yang et al., 1989b; IRIS, 1991). A blood selenium level of 1.0 mg/L (equivalent to an intake of 0.853 mg selenium/day) did not elicit signs of selenium toxicity. Thus, a chronic oral NOAEL and LOAEL of 0.853 and 1.261 mg/day, respectively, were determined from this study and converted to a body weight basis using the average Chinese adult body weight of 55 kg (IRIS, 1991). U.S. EPA also cited a year-long study of individuals from high-selenium areas of South Dakota and Wyoming in support of the RfD (see above, Longnecker et al. 1991). Individuals consuming as much as 0.724 mg Se/day in these regions did not show signs or symptoms associated with selenium toxicity, thus confirming the NOAEL from the Yang et al. (1989b) study. To account for sensitive individuals, U.S. EPA applied a three-fold uncertainty factor to the NOAEL (0.015 mg/kg-day) to derive an RfD of $5x10^{-3}$ mg/kg-day. Because a similar NOAEL was observed in two moderate-sized populations exposed over a lifetime, a full 10-fold uncertainty factor was not considered necessary (IRIS, 1991). ATSDR (2003) also has developed a chronic oral MRL of $5x10^{-3}$ mg/kg-day, based on a follow-up study by Yang and Zhou (1994) that reexamined five individuals included in the original Yang et al. (1989b) paper. This study confirmed the original NOAEL used by U.S. EPA to set the RfD. OEHHA will use this RfD to evaluate selenium non-cancer risk for fish consumption guidelines.

In summary, the non-cancer critical value used to evaluate selenium in fish for the development of consumption guidelines will be **$5x10^{-3}$ mg/kg-day**.

TOXAPHENE

TOXAPHENE TOXICOLOGY

Toxaphene (camphechlor) is an organochlorine insecticide consisting of a mixture of over 670 chlorinated terpenes (ATSDR, 1996; U.S. EPA, 2000). The average chemical formula for toxaphene and related toxaphene-like pesticides is $C_{10}H_{10}C1_8$ (WHO, 1984; ATSDR, 1996; de Geus, 1999). Toxaphene was first produced in 1945, primarily as an insecticidal agent for cotton, but also for parasite control in livestock and to kill unwanted fish species in various water bodies (DHHS, 2002; de Geus, 1999). Once the most heavily used pesticide in the United States (Ribick et al., 1982), U.S. EPA restricted most applications of toxaphene in 1982 and banned it completely in 1990 (DHHS, 2002).

Because of its extensive use, volatility, and resistance to degradation, toxaphene is distributed throughout various environmental matrices worldwide, particularly in freshwater and marine fish (Alder, 1997; ATSDR, 1996; de Geus, 1999). Bioconcentration factors of persistent toxaphene congeners in fish and shellfish have been reported to reach as high as $3.5x10^6$ (Geyer et al., 1999). Biomagnification also occurs in the aquatic food chain (ATSDR, 1996). Fish toxaphene levels have been shown to be positively correlated with fish age and fat content (Alder, 1997). Similar to the case with PCBs, the composition of the toxaphene "technical" mixture is altered in the environment as a result of differential degradation of individual congeners (Stern et al., 1992). The number of congeners decreases with increasing trophic level; approximately twenty, eight and two primary congeners have been found in fish, marine mammals, and humans, respectively (Calciu et al., 1997).

Toxaphene is known to be absorbed from all absorption routes, although dermal absorption is comparatively low (ATSDR, 1996; WHO, 1984). Once absorbed, toxaphene is distributed primarily to fat, but also to liver, bone, kidney, brain, heart, muscle, lung, spleen, adrenal gland, and testis (ATSDR, 1996). Rat studies have shown that only a small percent of a maternal toxaphene dose is transferred to the fetus (Pollock and Hillstrand, 1982); however, toxaphene has been found in human breast milk, particularly in women residing in the Arctic region where dietary organochlorine levels can be very high (Dewailly et al., 1993; Chan and Yeboah, 2000; Newsome and Ryan, 1999; Walker et al., 2003; Vaz and Blomkvist, 1985). Breast milk from Inuit women in northern Quebec, for example, has been reported to contain toxaphene concentrations as high as 294 ng/g on a lipid weight basis (Newsome and Ryan, 1999; Stern et al., 1992). Toxaphene is excreted in both urine and feces with the majority of absorbed toxaphene undergoing metabolic transformation (ASTDR, 1996). The excretion half-life of radiolabeled toxaphene has been shown to be approximately nine days in rodents, with about twice as much excreted in feces as in urine over this time period (ATSDR, 1996). Even though the pesticide has been banned for many years, significant toxaphene residues have recently been found in adipose tissue of children in western Europe (Witt and Niessen, 2000).

The toxicity of toxaphene has been well reviewed by several authors (e.g., ASTDR, 1996; Pollock and Kilgore, 1978; WHO, 1984; Saleh, 1991). Like other cyclodiene insecticides, the mechanism of neurotoxic action is believed to be inhibition of chloride transport, resulting in only partial repolarization of neurons and uncontrolled central nervous system stimulation (Ecobichon, 2003; Klassen and Watkins, 1999). Following acute oral toxaphene intoxication in humans, signs and symptoms of central nervous system stimulation are seen such as hypersalivation, restlessness, muscle tremors, and convulsions (U.S. EPA, 1987). Signs often begin within two hours of ingestion; fatal doses generally cause death by respiratory failure within 24 hours (McGee et al., 1952; Wells and Milhorn, 1983). The human acute lethal dose has been estimated to range from 21-100 mg/kg body weight (U.S. EPA, 1987) or about 2 to 7 grams for an adult (WHO, 1984). In addition to nervous system and respiratory effects mentioned above, heart dilation, kidney swelling, and elevated liver enzymes have also been reported in humans following acute toxaphene ingestion (ATSDR, 1996; McGee et al., 1952; Wells and Milhorn, 1983).

In animals, neurological effects similar to those reported in humans have been reported following acute toxaphene toxicity (ATSDR, 1996). Intermediate or chronic toxaphene exposures in various animal species have been shown to cause hepatic and renal effects including increased liver and kidney weights, hepatic enzyme induction, and degenerative histopathological changes in both organs (ATSDR, 1996). Protein deficiency may significantly increase acute toxaphene toxicity (Boyd and Taylor, 1971).

Toxaphene has not been shown to cause reproductive harm in animals at levels that do not also cause parental toxicity. For example, decreased fetal weights, fetal death, or increased incidence of encephaloceles were reported in rats and mice exposed to toxaphene during the period of organogenesis, but only at doses that also caused maternal toxicity and death (Chernoff and Carver, 1976). In a three-generation study, rats fed 0, 25 or 100 ppm toxaphene showed no adverse effects on reproductive outcomes such as litter size, pup survival or weanling body weights; however, liver cytoplasmic vacuolization was seen in the majority of adults at the 100 ppm dose (Kennedy et al., 1973). Similarly, while dietary toxaphene concentrations of 20 ppm and above caused increased liver weights as well as histopathological changes in liver, thyroid and kidney in adults rats during a reproductive study, there were no effects on fertility, litter size, pup weight, or other indices of gestation or survival in rats fed dietary concentrations up to 500 ppm toxaphene (0.38 mg/kg-day) (Chu et al., 1988).

Developmental effects have been reported following toxaphene exposure in rats. Olson et al. (1980) found that juvenile rats exposed to 0.05 mg/kg-day toxaphene in the pre- and postnatal periods had decreased swimming and righting ability compared to controls, although differences in swimming ability between groups had disappeared by postnatal day 16. Time to master righting reflex was also prolonged in offspring of rats exposed to 6 mg/kg-day from gestation day 7 until parturition (Crowder et al., 1980).

A few studies have found immunotoxic effects resulting from toxaphene exposure. Adult mice fed 100 or 200 ppm dietary toxaphene for eight weeks showed a dose-dependent decrease in antibody response to bovine serum albumin (Allen et al., 1983). Liver-to-body weight ratios were also increased at both dose levels and histopathological changes were noted in livers. Immunological effects were more pronounced in offspring exposed *in utero* or during lactation (Allen et al., 1983). An immunotoxicity study in cynomolgus monkeys is described below (Tryphonas et al., 2001). *In vitro* human studies have confirmed that neutrophils are a significant immunologic target of toxaphene toxicity (Gauthier et al., 2001).

There are no data available to evaluate the carcinogenicity of toxaphene in humans; however, toxaphene has been found to be a liver carcinogen in mice and to cause thyroid cancer in rats (Litton Bionetics, 1978; Reuber, 1979; NCI, 1979). IARC has listed toxaphene as a possible human carcinogen, based on inadequate data in humans and sufficient evidence in experimental animals (IARC, 2001). U.S. EPA lists toxaphene as a probable human carcinogen, based on no data in humans and sufficient evidence of carcinogenicity in experimental animals (IRIS, 1991). OEHHA has administratively listed toxaphene on the Proposition 65 list of chemicals known to the State of California to cause cancer.

DERIVATION OF A REFERENCE DOSE AND CANCER SLOPE FACTOR FOR TOXAPHENE

U.S. EPA has not developed an RfD for toxaphene. However, in 2003, OEHHA published a PHG for toxaphene in drinking water, selecting a study by Chu et al. (1986) to determine the NOAEL for non-cancer effects (OEHHA, 2003). Rats fed diets containing 20 to 500 ppm toxaphene (corresponding to approximately 0.35 to 63 mg/kg-day) had biologically significant histopathological changes in liver, thyroid, and kidney at doses of approximately 1.8 mg/kg-day and above. Liver-to-body weight ratios and hepatic mixed function oxidase activities were also increased at the highest dose level. The NOAEL and LOAEL values in this study were determined to be 0.35 and 1.8 mg/kg-day, respectively. To the NOAEL, an uncertainty factor of 1000 (10 for interspecies extrapolation, 10 for sensitive individuals, and 10 for extrapolation from subchronic to chronic) can be applied to develop a reference dose of 3.5×10^{-4} mg/kg-day.

A more recent study in cynomolgus monkeys by Tryphonas et al. (2001) can also be used to support the RfD for toxaphene. Monkeys were fed 0, 0.1, 0.4, or 0.8 mg/kg-day toxaphene for 75 weeks. Doses of 0.4 and 0.8 mg/kg-day significantly reduced humoral immunity in female monkeys, as evidenced by decreased primary and secondary immune response to sheep erythrocytes. The NOAEL of 0.1 mg/kg-day in this study was similar to that derived by Chu (Chu et al., 1986). As the Chu et al. study produced the highest NOAEL below the lowest LOAEL, it will be used to set the reference dose to evaluate toxaphene non-cancer risk for fish consumption guidelines.

Human dose-response data for cancer are also inadequate; thus, the toxaphene CSF has been generated from animal studies. Two long-term rodent carcinogenicity assays have been published for toxaphene (Litton Bionetics, 1978; NCI, 1979). In their 1991 carcinogenicity assessment, U.S. EPA chose the Litton Bionetics study for determination of the toxaphene cancer slope factor. A significantly increased incidence of hepatocellular carcinomas was found in male B6C3F1 mice at a dietary dose of 50 ppm. Using a linearized multistage model, U.S. EPA determined the oral CSF for toxaphene in this study to be 1.1 $(mg/kg\text{-}day)^{-1}$ (IRIS, 1991). OEHHA (2003) employed a CSF of 1.2 $(mg/kg\text{-}day)^{-1}$ in their toxaphene PHG, using the same data set as U.S. EPA but making slightly different assumptions regarding the conversion of dietary toxaphene concentrations to mg/kg body weight doses. For the purpose of evaluating cancer risk for fish consumption guidelines, the CSF of 1.2 $(mg/kg\text{-}day)^{-1}$ will be used.

In summary, the non-cancer and cancer critical values used to evaluate toxaphene in fish for the development of consumption guidelines will be **$3.5x10^{-4}$ mg/kg-day** and **1.2 $(mg/kg\text{-}day)^{-1}$**, respectively.

FISH CONTAMINANT GOALS FOR CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

As is also the case for air, drinking water, or any other food, the ultimate goal of agencies responsible for the protection of public health is for fish to be devoid of biological or chemical contamination. FCGs can be derived for chemicals found in fish, comparable to PHGs for drinking water (Health and Safety Code, Section 116365). FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs were developed for chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. FCGs are based solely on public health considerations relating to exposure to each individual contaminant, without regard to economic considerations, feasibility, the counterbalancing benefits of fish consumption, or alternative risks of other protein sources that may be consumed in place of fish.

FCGs can be found in Table 1. OEHHA used the following assumptions in the development of FCGs for fish contaminants. Agencies developing fish tissue-based criteria may choose to alter one or more of these assumptions in order to meet their own specific goals or requirements:

Body Weight:

The default value for adult body weight for these calculations was assumed to be 70 kg, which is recommended in most risk assessment guidelines. While, at one time, 70 kg was the approximate combined average weight for adult males and females in the United States, it is now significantly less than the average weight for both adult females and males in this country (about 75 and 87 kg, respectively) (Ogden et al., 2004). The use of a lower default body weight for risk assessment calculations results in lower allowable contaminant concentrations in fish.

Serving Size and Consumption Rate:

Serving size assumptions vary considerably. The American Heart Association (AHA) recommends eating fish at least two times a week (AHA, 2006), and considers a single serving size to be four ounces (113.5 g) of fish prior to cooking (corresponding to three ounces [85 g] of cooked fish). The Institute of Medicine (IOM) also considers serving size to be three ounces of cooked fish, based on the National Health and Nutrition Examination Survey (NHANES) 1999-2002 data showing three ounces to be the average daily consumption rate for people who eat fish (IOM, 2007). In their 2006 food pyramid, the U.S. Department of Agriculture recommends five to six ounces, *total*, of meat, poultry, fish, dried beans or peas, eggs, nuts, and seeds *per day* for adult women and men,

suggesting that the typical serving size of a single animal protein source in a given day is three to four ounces (USDA, 2006). In contrast, U.S. EPA assumed a serving size of eight ounces of fish, prior to cooking, in their fish advisory guidance document (U.S. EPA, 2000b), as did both U.S. EPA and FDA in their joint national advisory for mercury in fish (U.S. EPA, 2004c). While OEHHA contemplated reducing serving sizes to four ounces, prior to cooking, to align with federal nutrition, IOM and AHA guidelines, focus groups interviewed by the California Department of Public Health indicated that sport fishers typically consume significantly larger portion sizes. Thus, an 8-ounce serving size was retained for use in fish advisories. OEHHA considers it to be a reasonable goal to provide recreational fish that, at a minimum, are safe to eat at the AHA recommended consumption rate for adults of at least eight ounces of fish per week, prior to cooking (an average of 32 g/day) and that this is an appropriate consumption rate for development of an FCG. Because of their smaller body weights, children will be advised to eat approximately one-half as much fish (in either quantity or frequency) as are women aged 18 to 45 years.

Hazard Quotient:

Standard risk assessment guidelines generally recommend limiting non-cancer exposures to no more than the RfD, which results in a hazard quotient (HQ; the ratio of exposure to the RfD) that does not exceed 1. FCGs were set using a maximum HQ of 1 at the consumption rate of 32 g/day.

Risk Level:

FCGs were developed using a maximum cancer risk level (RL) of $1x10^{-6}$, estimating that, at a given consumption rate, not more than one additional cancer case would be expected in a population of one million people consuming fish over a lifetime. This risk level is at the lower end of the acceptable range of risks ($1x10^{-4}$ to $1x10^{-6}$) used by U.S. EPA in regulatory criteria for drinking water (Fed. Reg., 1998) and is provided as an example of an acceptable risk level in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (U.S. EPA, 2000a,b). FCGs were set using a maximum RL of $1x10^{-6}$ at the consumption rate of 32 g/day.

Exposure Duration and Averaging Time:

For carcinogenic chemicals, the exposure duration and averaging time was assumed to be 30 years over a 70 year lifespan, based on the 95th percentile of U.S. residence time (U.S. EPA, 1997). This may be modified in cases where a carcinogenic contaminant is widespread throughout state water bodies and the source is relatively ubiquitous.

Cooking Reduction Factor:

OEHHA strongly recommends to all consumers that they skin and thoroughly cook their fish prior to eating. Skinning and cooking remove or reduce a variety of chemical and

biological hazards. FCGs take into account organochlorine contaminant loss during the cooking process. The concentration of PCBs and other organic contaminants in fish are generally reduced by at least 30 percent, depending on cooking method (Anderson et al., 1993; Sherer and Price, 1993; Santerre, 2000; Wilson et al., 1998; Zabik et al., 1996). As such, a cooking reduction factor of 0.7 was included in the FCG equation for organic compounds (allowing for 70 percent of the contaminant to remain after cooking). Although fish analytical data are generally provided to OEHHA as skin-off fillets, when contaminant levels are determined using skin-on fillets, a cooking and skinning reduction factor of 0.5 is used to account for organic chemical losses of approximately 50 percent that occur during both processes combined (Anderson et al., 1993). Mercury and selenium concentrations in fish are not reduced by cooking or cleaning techniques and, thus, no reduction factor has been applied for these chemicals.

Nutrients:

Unlike the case for other fish contaminants listed above, selenium is a required nutrient and fish are a major dietary source of selenium. Thus, it should be ensured that the FCGs for selenium do not unduly limit sport fish as a potential source of selenium and that they also take into account additional dietary exposures to this element. As reported above, the current RDA for selenium is 55 µg/day for the general adult population, 60 µg/day for pregnant women, and 70 µg/day during lactation (IOM, 2000). Data from NHANES III show that the mean selenium intake for all individuals from diet alone is 113.7 µg/day, while the mean intake from diet plus supplements is 116 µg/day (IOM, 2000). This indicates that most individuals in the United States easily meet their nutritional needs for selenium and do not consume selenium supplements. Thus, the mean selenium intake from diet alone (114 µg/day; IOM, 2000) will be used as the background dietary selenium consumption rate for developing FCGs for selenium. As in all cases of supplement intake, consumers who take selenium supplements should take them with caution and under the advisement of their physician.

Use/Application of FCGs:

OEHHA has developed FCGs, using standard exposure factors and a consumption rate of eight ounces prior to cooking (six ounces after cooking), to provide a starting point to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. Any agency using FCGs provided in this report to establish fish tissue-based criteria for their own purposes must accept the assumptions described herein.

Table 1. Fish Contaminant Goals (FCGs) for Selected Fish Contaminants Based on Cancer and Non-Cancer Risk* Using an 8-Ounce/Week (prior to cooking) Consumption Rate (32 g/day)**	
	FCGs (ppb, wet weight)
Contaminant Cancer Slope Factor $(mg/kg/day)^{-1}$	
Chlordane (1.3)	**5.6**
DDTs (0.34)	**21**
Dieldrin (16)	**0.46**
PCBs (2)	**3.6**
Toxaphene (1.2)	**6.1**
Contaminant Reference Dose (mg/kg-day)	
Chlordane ($3.3x10^{-5}$)	100
DDTs ($5x10^{-4}$)	1600
Dieldrin ($5x10^{-5}$)	160
Methylmercury ($1x10^{-4}$)[S]	**220**
PCBs ($2x10^{-5}$)	63
Selenium ($5x10^{-3}$)	**7400**
Toxaphene ($3.5x10^{-4}$)	1100

*The most health protective Fish Contaminant Goal for each chemical (cancer slope factor- versus reference dose-derived) for each meal category is bolded.
**g/day represents the average amount of fish consumed daily, distributed over a 7-day period, using an 8-ounce serving size, prior to cooking.
[S]Fish Contaminant Goal for sensitive populations (i.e., women aged 18 to 45 years and children aged 1 to 17 years.)

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

EQUATIONS USED TO CALCULATE FISH CONTAMINANT GOALS

The following general equations were used to calculate Fish Contaminant Goals for chemicals at the consumption rates listed in Table 1, using an 8-ounce (prior to cooking) serving size. Separate equations are used for carcinogenic effects, non-carcinogenic effects, and nutrients with non-carcinogenic effects.

The following general equation can be used to calculate Fish Contaminant Goals (in µg/kg) at which the consumption exposure from a chemical with a ***carcinogenic*** effect is equal to the risk level for that chemical at any consumption level:

$$\text{Tissue concentration (ppb)} = \frac{\text{(Risk Level)(kg BW)(1000 µg/mg)}}{\text{[CSF (mg/kg/day)}^{-1}\text{] (CR kg/day)(ED/AT)(CRF)}}$$

As an example, for dieldrin, the Fish Contaminant Goal using a risk level of $1x10^{-6}$ and a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{(1x10^{-6})(70\text{ kg})(1000\text{ µg/mg})}{[16\text{ (mg/kg/day)}^{-1}](0.032\text{ kg/day})(30/70)(0.7)} = 0.46\text{ ppb}$$

The following general equation can be used to calculate Fish Contaminant Goals (in µg/kg) at which the consumption exposure from a chemical with a ***non-carcinogenic effect*** is equal to the reference level for that chemical at any consumption level:

$$\text{Tissue concentration (ppb)} = \frac{\text{(RfD mg/kg-day)(kg BW)(1000 µg/mg)}}{\text{(CR kg/day)(CRF)}}$$

As an example, for mercury, the Fish Contaminant Goal using a consumption rate of one, 8-ounce serving per week (32.0 g/day) for women aged 18 to 45 years and children aged 1 to 17 years would be calculated as follows:

$$\frac{(1x10^{-4}\text{ mg/kg-day})(70\text{ kg BW})(1000\text{ µg/mg})}{(0.032\text{ kg/day})(1)} = 219\text{ ppb}$$

The following general equation can be used to calculate the Fish Contaminant Goals (in mg/kg) at which consumption exposure from a ***nutrient with a non-carcinogenic effect*** is equal to the reference level for that chemical at any consumption level:

Tissue Concentration (ppb) =

$$\frac{\text{[(RfD mg/kg-day)(kg BW) – mg/day Background Dietary Level](1000 µg/mg)}}{\text{(CR kg/day)}}$$

As an example, for selenium, the Fish Contaminant Goal using a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{[(5\times10^{-3}\ \text{mg/kg-day})(70\ \text{kg}) - 0.114\ \text{mg/day}](1000\ \mu\text{g/mg})}{0.032\ \text{kg/day}} = 7{,}375\ \text{ppb}$$

Where,
Risk Level = 1×10^{-6}
BW = Body weight of consumer (70 kg default)
CSF = Cancer Slope Factor
CR = Consumption Rate as the daily amount of fish consumed
CRF = Cooking Reduction Factor (0.7 for organic contaminants in skin-off fillet)
ED/AT = Exposure Duration/Averaging Time (30 yr exposure/70 yr lifetime)
RfD = Chemical specific reference dose or other reference level

POTENTIAL BENEFITS OF FISH CONSUMPTION

Fish consumption advice is generally provided to the public from disparate arms of the biomedical community: physicians and nutritionists, who focus on the health benefits of eating fish, and toxicologists, who concentrate on the risks from exposure to contaminants that may be found in fish. The conflicting messages that often result likely confuse the consumer, who may then ignore recommendations to limit consumption of contaminated fish or, alternatively, avoid eating fish altogether (see, e.g., Oken et al., 2003). Only recently has there been a more focused attempt to craft unified guidance that addresses benefits and risks of fish consumption, although beneficial aspects are generally only discussed qualitatively.

With the discovery in the 1970s that, despite their high fat diet, Greenlandic Eskimos were virtually devoid of ischemic heart disease and diabetes mellitus, came the earliest recognition that fatty acids found in fish and marine mammals may have particular benefits to human health (Bang and Dyerberg, 1972; Dyerberg et al., 1975; Bang et al., 1976; Dyerberg et al., 1978; Dyerberg and Bang, 1979; Bang et al., 1980). The diet and blood lipid profile of the Eskimos were found to be very high in omega-3 fatty acids and very low in omega-6 fatty acids, in direct contrast to a typical "Western" diet in which the reverse is true (Dyerberg et al., 1975; Bang et al., 1980).

Omega-3 fatty acids, such as α-linolenic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are long-chain polyunsaturated fatty acids (PUFAs) with the first double bond inserted at the *third* carbon atom from the methyl end, while omega-6 fatty acids, such as linoleic acid, γ-linolenic acid and arachidonic acid, have the first double bond inserted at the *sixth* carbon atom from the methyl end (IOM, 2005). Fatty acids are designated by their number of carbon atoms, followed by the number of double bonds and the placement of the first double bond. For example, linoleic acid is denoted as 18:2n-6 because it has 18 carbons and two double bonds, with the first double bond located six carbons from the methyl end (the "n" or "omega" position). α-Linolenic (18:3n-3) and linoleic acids cannot be synthesized by humans and are thus required in the diet (IOM, 2005). α-Linolenic acid's only known function is as the precursor to the very long chain PUFAs EPA (20:5n-3) and DHA (22:6n-3), omega-3 fatty acids that are also consumed directly from fish (IOM, 2005). Because the conversion of α-linolenic acid to EPA and DHA is so inefficient (estimated at less than 5 percent) (Wang et al., 2006), and DHA and EPA levels are so low in other foods, fish or fish oil consumption is by far the most important dietary source of these fatty acids (Marszalek and Lodish, 2005). DHA serves as an important structural lipid in nervous tissue, spermatozoa, and the retina, and may be retroconverted to EPA; linoleic acid (18:2n-6), the most common dietary PUFA, is the precursor to arachidonic acid (20:4n-6) (IOM, 2005; Kris-Etherton et al., 2000). Arachidonic acid is also consumed directly from dietary sources such as meat, egg yolk and dairy (Calder, 2006; Richardson, 2006).

Once dietary omega-3 and omega-6 fatty acid precursors are converted *in vivo* to EPA or arachidonic acid, respectively, they can then be metabolized to produce different

eicosanoids, including various prostaglandins, thromboxanes, and leukotrienes, which, in turn, have contravening physiological actions (Robinson and Stone, 2006; Calder, 2006). The omega-3 derived eicosanoids, such as thromboxane A_3 and B_3, prostaglandins PGI_3 and PGE_3, and leukotriene B_5, induce vasodilation, inhibit arrhythmia, decrease platelet aggregation, and are anti-inflammatory. In contrast, eicosanoids derived from omega-6 fatty acids, such as thromboxane A_2 and B_2, prostaglandins PGI_2 and PGE_2, and leukotriene B_4, cause vasoconstriction, are pro-arrhythmic, and increase platelet aggregation and inflammation (Robinson and Stone, 2006; Simopoulos, 1999; DeFilippis and Sperling, 2006). A proper ratio of dietary omega-6 to omega-3 fatty acids is thus imperative to protect health (Simopoulos, 1999; 2002), particularly since high dietary omega-6 levels inhibit the *in vivo* conversion of α-linolenic acid to DHA and EPA (Kris-Etherton et al., 2000). Similarly, high dietary omega-3 fatty acid levels reduce the formation of 2-series eicosanoids from arachidonic acid (IOM, 2005). It has been speculated that conflicting results in clinical trials on the benefits of dietary omega-3 fatty acids may have resulted from failure to take into account background dietary omega-6 fatty acid consumption, high levels of which may inhibit the production of anti-aggregatory eicosanoids and thus undermine the effectiveness of omega-3 fatty acids in disease prevention (Hibbeln et al., 2006).

Humans evolved consuming a diet that was largely equivalent in omega-6 and omega-3 fatty acids. In the 1960s, however, a dramatic shift in the level and composition of dietary fat occurred following the recommendation that saturated fats in the diet be replaced with vegetable oils, such as corn oil and safflower oil, which contain omega-6 to omega-3 ratios greater than 60:1 (Simopoulos, 2001). At the same time, the proportion of farm-raised to wild fish consumption increased (DeFilippis and Sperling, 2006). Farm-raised fish, like farm-raised cows, pigs, and chickens, are often fed diets rich in omega-6 fatty acids and many have tissue omega-6 to omega-3 ratios considerably higher than wild fish of the same species (Hamilton et al., 2005; DeFilippis and Sperling, 2006; Kris-Etherton et al., 2002; Foran et al., 2005; Marszalek and Lodish, 2005). The typical "Western" diet has been estimated to have an omega-6 to omega-3 ratio of 10:1 to 20:1 (Simopoulos, 2003), with a total omega-3 fatty acid consumption of approximately 1.6 g/day (Johnson and Schaefer, 2006). Of that, mean consumption of EPA + DHA is about 0.1 g/day (IOM, 2007). In NHANES 1999-2002, all age/sex population groups were reported to consume an average of less than 0.2 g/day EPA + DHA (IOM, 2007).

Since the Greenlandic Eskimo studies in the 1970s, an explosion of research has examined potential health benefits of fish consumption, with a particular emphasis on omega-3 fatty acids. In 1996, the AHA published their first statement on fish consumption, fish oils, lipids, and coronary heart disease (Stone, 1996). While considering it "premature" at that time to recommend the use of fish oil supplements for the prevention of cardiovascular disease by the general public, the AHA did nonetheless recognize that consumption of marine sources of omega-3 fatty acids seemed "reasonable" because of the low content of saturated fat in fish compared to other meat products and the potential for cardiovascular benefits that might be borne out by future research (Stone, 1996). Subsequently, the most recent AHA statement on the subject

(Kris-Etherton et al., 2002) was strengthened significantly from its original version, as additional research since 1996 has provided even more compelling evidence of the benefits of fish and fish oil consumption.

Currently, the AHA recommends that *individuals without documented coronary heart disease* "eat a variety of (preferably fatty) fish at least twice a week," *individuals with documented coronary heart disease* "consume about 1 g of EPA + DHA per day, preferably from fatty fish (EPA + DHA from capsule form could be considered in consultation with the physician)," and *individuals who need to reduce triglycerides* should consume "two to four grams of EPA + DHA per day provided as capsules under a physician's care" (AHA, 2006). The AHA considers a serving size to be four ounces of fish prior to cooking, or three ounces after cooking, one-half of the serving size typically assumed in fish consumption advisories. The WHO also recommends consumption of 1-2 servings of fish per week (to provide 200-500 mg of EPA + DHA per serving) to protect against coronary heart disease and ischemic stroke (WHO, 2003), while the 2005 Dietary Guidelines Advisory Committee (DGAC) Report concludes that "consumption of two servings (approximately eight ounces) per week of fish high in EPA and DHA is associated with reduced risk of both sudden death and CHD (coronary heart disease) death in adults." The Committee further states that "to benefit from the potential cardioprotective effects of EPA and DHA, the weekly consumption of two serving of fish, particularly fish rich in EPA and DHA, is suggested" (DGAC, 2005). In their report assessing the risks and benefits of fish consumption, the Scientific Advisory Committee on Nutrition (SACN) of the Food Standards Agency and Department of Health in the United Kingdom recommends that all individuals, including pregnant women, "eat at least two portions of fish per week, of which one should be oily," providing approximately 450 mg/day long chain omega-3 fatty acids (SACN, 2004; see also IOM, 2007, for additional discussion).

Presented below is a brief summary of many of the potential benefits of fish or fish oil consumption, given the current state of scientific knowledge. This review is not intended as an exhaustive evaluation of the merits and weaknesses of the vast number of articles on this subject, but merely to be illustrative of significant, and generally recent, research or review articles in the field. Many studies are observational, as is also commonly the case with human toxicity studies on fish contaminants, and cannot prove cause and effect relationships with certainty. Even randomized controlled trials (RCTs), the gold standard of human medical experimentation, may suffer in the case of fish or fish oil studies from the inability to blind the subject to the treatment. Although current scientific consensus recommends fish consumption as a likely way to prevent specific chronic disease conditions, it is unclear to what extent potential benefits from fish or fish oil consumption listed below may be realized through the following mechanisms: increased consumption of omega-3 fatty acids, decreased dietary omega-6 to omega-3 fatty acid ratio (as generally occurs to a lesser extent with fish oil supplementation and to a greater extent with fish consumption), simple replacement of other high fat dietary protein sources with fish, or other nutritive or non-nutritive factors that may covary with fish consumption

(e.g., an overall healthy lifestyle). Many of these issues are discussed in the recent IOM report on balancing the risks and benefits of seafood consumption (IOM, 2007).

Cardiovascular Disease and Total Mortality:

The most thoroughly evaluated potential beneficial effect of fish or fish oil consumption has been on the prevention and treatment of cardiovascular disease. In a recent meta-analysis, Hooper et al. (2006) concluded that evidence to date does not support the position that short or long chain omega-3 fatty acids have a clear effect on this condition. Numerous researchers criticized this review, however, particularly with respect to inappropriate pooling of study participants, outcomes, and marine- and plant-based omega-3 fatty acids, as well as the inclusion of a "methodologically poor" study, which, in and of itself, "changed the conclusion of the meta-analysis from clear benefit to no benefit" (Deckelbaum and Akabas, 2006; Geleijnse et al., 2006; He and Song, 2006; Twisselmann, 2006; von Schacky et al., 2006). A subsequent systematic review of the literature addressed some of these shortcomings (Deckelbaum and Akabas, 2006). After evaluating 46 studies meeting strict selection criteria, Wang et al. (2006) found that omega-3 fatty acids from fish or fish oil supplements, but not α-linolenic acid, appeared to reduce the risk of all-cause mortality, cardiac and sudden death, and stroke. Because RCTs on the effects of omega-3 fatty acids in individuals already suffering from cardiovascular disease (secondary prevention) have been conducted, the strength of the evidence for that outcome is greater than that for prevention of cardiovascular disease in healthy individuals (primary prevention), for which only cohort studies are available (Wang et al., 2006). Mozaffarian and Rimm (2006) also reported that evidence generated from pooling published prospective or randomized primary and secondary prevention trials indicated that consumption of 250 to 500 mg/d of EPA + DHA reduced the relative risk of coronary heart disease death by 36 percent compared to little or no EPA + DHA intake. Additional intake did not appear to confer additional benefits; risk reduction was most closely linked to consumption of fatty fish, not lean fish. Other recent meta-analyses or systematic literature reviews have supported the conclusion that omega-3 fatty acid consumption has a significant beneficial effect on cardiovascular disease (He et al., 2004a; Bucher et al., 2002; Jacobson, 2006; Whelton et al., 2004; Konig et al., 2005; Harper et al., 2005).

Several studies have suggested that mercury may attenuate cardioprotective effects of omega-3 fatty acids in fish (e.g., Salonen et al., 1995; Rissanen et al., 2000; Guallar et al., 2002; Virtanen et al., 2005), particularly in Finnish men, although at least one study did not find such an association (Yoshizawa et al., 2002). Current evidence suggests that fish or fish oils provide more health benefits to those individuals who also have low methylmercury body burdens (IOM, 2007).

Stroke:

Early research on the potentially protective effects of omega-3 fatty acid and/or fish consumption and stroke showed conflicting results (see, for example, Gillum et al., 1996;

Keli et al., 1994; Orencia et al., 1996). This may have occurred, in part, because of a failure to differentiate ischemic and hemorrhagic strokes in study populations (He et al., 2004b), which are caused by opposing mechanisms. A recent meta-analysis of nine cohorts suggested that fish consumption and ischemic stroke were inversely related, with the possibility that as few as one to three fish meals a month might significantly reduce the incidence of this disorder (He et al., 2004b). In a study of 79,839 women, Iso et al. (2001) found that risk of thrombotic infarction was decreased 48 percent for women who ate fish two to four times per week compared to those who ate fish less than once per month. In another analysis of published studies, Bouzan et al. (2005) found that any fish consumption provided significant reduction in stroke risk compared to no fish consumption. The authors noted that an incremental increase in fish consumption may reduce stroke risk even further. In a review of the literature, Wang et al. (2006) found that studies on the effect of marine-based omega-3 fatty acids on stroke were not consistent, but suggested a possible role of fish or fish oils in the prevention of stroke.

Cognitive Function:

Brain tissue is highly enriched in DHA, which is considered essential for the functional development of neural tissues. Much of DHA and other long chain PUFA content of fetal brain is obtained from the maternal blood supply, as *in vivo* synthesis from shorter chain PUFAs is minimal during this period (Cheruku et al., 2002; Marszalek and Lodish, 2005; Uauy and Dangour, 2006). Studies have suggested that fish consumption by the mother during pregnancy or by the young child may improve several neurological outcomes during early development (Mozaffarian and Rim, 2006). Language and social skills, for example, were higher in 6- and 12-month-old infants who ate fish once or more per week compared to those who rarely or never ate fish (Daniels et al., 2004). Maternal fish intake was also positively associated with infant cognitive scores in this study. Sleep-state patterns indicative of greater cognitive maturity were seen in infants whose mothers had higher plasma phospholipid DHA levels compared to those whose mothers had lower plasma phospholipid DHA levels (Cheruku et al., 2002). Oken et al. (2005) showed that infant cognitive scores were positively correlated with fish consumption, but inversely related to maternal hair mercury concentrations. Scores were highest among infants whose mothers had hair mercury concentrations of 1.2 ppm or less and consumed two or more fish meals per week. Conversely, scores were lowest among infants whose mothers had hair mercury concentrations greater than 1.2 ppm and ate two or fewer fish meals per week. Hibbeln et al. (2007) found that, after adjusting for 28 potentially confounding variables, the risk of suboptimal scores for verbal intelligence, prosocial behavior, fine motor, communication, and social development in children six months to eight years old was greater when maternal fish consumption was less than 340 g per week compared to when maternal fish consumption was greater than 340 g per week.

Several studies have shown that DHA levels are reduced in brain and plasma of patients with Alzheimer disease (AD) or other forms of dementia (Johnson and Schaefer, 2006). Potential mechanisms by which these fatty acids may modify the risk for dementia include the prevention or reduction of atherosclerosis, thrombosis, and inflammation

(Barberger-Gateau et al., 2002). In one of the first studies to investigate the potential relationship between fish consumption and dementia, Kalmijn et al. (1997) found that the incident risk of developing all forms of dementia was reduced 60 percent in people 55 years or older who consumed 18.5 or more g/day of fish compared to those consuming 3.0 or fewer g/day fish. The risk for developing AD without cerebrovascular disease in these respective populations was reduced 70 percent. Similarly, Morris et al. (2003) found that people who ate fish at least once per week reduced their risk of incident AD by 60 percent compared to those who rarely or never ate fish. In a subsequent study using the same population group, fish consumption was also found to be significantly inversely related to expected cognitive decline in individuals 65 years and older over a six year period (Morris et al., 2005). Fatty fish consumption and EPA + DHA consumption were also inversely related to mild cognitive decline in a cross-sectional study of middle-aged males and females (Kalmijn et al., 2004). Huang et al. (2005) specifically showed that fatty fish consumption, but not consumption of lean or fried fish, decreased the risk of dementia in a dose-dependent fashion in individuals who did not carry the *APOE* ε4 allele (a risk factor for AD). Fatty fish consumption more than twice per week decreased the risk of incident dementia and AD by 28 and 41 percent, respectively, compared to those eating fish less than once per month. Using a more accurate estimate of omega-3 fatty acid exposure, Heude et al. (2003) found that omega-3 fatty acid concentration and omega-3 to omega-6 ratio of erythrocyte membranes was inversely related to cognitive decline in 63-74 year-old men and women over a four year period.

Although omega-3 fatty acids are often considered the physiologically active agents responsible for positive health effects of fish, some research indicates that other components may have benefits as well. For example, fish, but not omega-3 fatty acid, consumption was inversely associated with a reduced rate of cognitive deterioration over a six-year period in a study of 6,158 males and females, aged 65 or older (Morris et al., 2005). Consumers who ate fish once a week or more maintained the mental status of a person three to four years younger compared to those who ate fish less than once a week.

Preliminary studies have found that omega-3 fatty acids mitigate symptoms in some children with attention-deficit/hyperactivity disorder; however, other studies have not supported these results (Richardson, 2006; Young and Conquer, 2005). Additionally, several epidemiological studies and intervention trials have shown that fish or omega-3 fatty acid consumption may be useful for the prevention or treatment of depression or other mood disorders, which may reflect the well-recognized link between depression and cardiovascular disease (see Parker et al., 2006; Nemets et al., 2006). Numerous authors have reported decreased blood omega-3 fatty acid levels in patients with psychiatric disorders (Tiemeier et al., 2003; Peet and Stokes, 2005; Sublette et al., 2006; Young and Conquer, 2005; Richardson, 2006). Additional research is needed to elucidate the potential role of fish or fish oils in the treatment of neuropsychiatric disorders (Parker et al., 2006; Richardson, 2006; Young and Conquer, 2005).

Visual Function:

DHA is found in very high concentrations in the retina and has a functional role in visual development (Connor et al., 1992; Neuringer, 2000; Cho et al., 2001; Uauy and Dangour, 2006; Johnson and Schaefer, 2006). As noted above, fetal DHA is largely obtained through the maternal blood supply and, postnatally, through breast milk (Marszalek and Lodish, 2005). The degree to which DHA supplementation of infant formulas is necessary or beneficial is not known (Mozaffarian and Rimm, 2006), although the evidence supporting its benefit for preterm infants is more persuasive than it is for term infants (Heird and Lapillonne, 2005; Cheatham et al., 2006). A recent meta-analysis of 14 controlled trials of DHA supplementation of infant formulas showed a strong positive relationship between DHA dose and visual acuity measurements in four-month-old infants (Uauy et al., 2003). Some studies show that the relationship between low dietary omega-3 fatty acids and slowed development of visual acuity may be transitory; however, long-term sequelae of early visual impairments that may occur with low-DHA diets have not been studied and could be significant (Neuringer, 2000).

Numerous studies have also shown that fish and/or omega-3 fatty acid consumption provides benefits to the aging eye and may protect against retinal pathologies associated with ischemia, light, oxygen, inflammation, and age (SanGiovanni and Chew, 2005). Age-related macular degeneration (AMD) is the primary cause of visual disability and blindness in older Americans (Chua et al. 2006; Seddon et al., 2006). In a cross-sectional population-based study, Smith et al. (2000) reported that individuals consuming fish more than once per week were at significantly lower risk of developing late AMD than individuals consuming fish less than once per month. Similarly, in two large prospective cohort studies, fish consumption was inversely related to AMD development; consumption of four or more servings per week reduced the risk of AMD 35 percent compared to eating fish three or fewer times per week. DHA consumption had a smaller, but still significant, inverse relation with AMD development, indicating that substances in fish other than fatty acids may also decrease AMD risk (Cho et al., 2001). In prospective cohort and case control studies, Seddon et al. (2001; 2003; 2006) showed that the risk for development and progression of AMD was significantly reduced or slowed, respectively, with increasing fish or omega-3 fatty acid consumption. In two of the three studies, however, this relationship existed only if consumption of linoleic acid was also low, indicating that the omega-6 to omega-3 ratio may be an important component to the protective effect of omega-3 fatty acids in the development and progression of this disease (Seddon et al., 2006). Chua et al. (2006) found that weekly fish consumption reduced the 5-year incidence of early AMD about 40 percent, while eating fish three times per week or more reduced the 5-year incidence of late AMD about 75 percent. In a review of published studies, Hodge et al. (2006) found that, while there is evidence to suggest that omega-3 fatty acids may play a role in prevention of AMD, variability among studies and the lack of a RCT prevent clinical conclusions from being drawn.

Inflammatory Diseases:

The effect of omega-3 fatty acids on inflammation and inflammatory diseases has been recently reviewed (Ariza-Ariza et al., 1998; Calder, 2006; Cleland et al., 2005; Simopoulos, 2002). Omega-3 fatty acids have been theorized to be useful as anti-inflammatory agents because they generate anti-inflammatory mediators, decrease production of arachidonic acid-derived pro-inflammatory eicosanoids, and modify the expression of inflammatory genes (Calder, 2006). Research has strongly supported the role of long-chain omega-3 fatty acids in the treatment of rheumatoid arthritis (Calder, 2006), including the reduced need for traditional non-steroidal anti-inflammatory drugs (NSAIDS) in patients taking sufficient doses of fish oils (Ariza-Ariza et al., 1998; Cleland, 2005; 2006). However, the data are less robust for the use of long chain omega-3 fatty acids in the treatment of other inflammatory diseases, such as inflammatory bowel disease or asthma, and additional clinical trials are recommended to further define their potential role in the treatment of these conditions (Calder, 2006). Currently, the effective dose for anti-inflammatory effect in rheumatoid arthritis is estimated to be 2.7 g/day EPA + DHA (Cleland, 2005), a dose not easily obtainable through fish consumption alone. It is recommended that this dose not be achieved through the use of cod liver oil supplementation because of the high vitamin A concentration of this product (Cleland, 2005). The shorter chain α-linolenic acid has not been shown to possess anti-inflammatory properties at practical intakes (Calder, 2006).

CONSIDERATION OF THE RISKS AND BENEFITS OF FISH CONSUMPTION

Since the recognition in the 1960s and 1970s that dietary fish might play a significant role in both health and disease, a vast number of studies have been conducted on the benefits and risks of fish consumption. As noted above, though, these areas of research are typically evaluated independently. Risk assessments on contaminants found in fish are occasionally published in the peer-reviewed literature (e.g., Hites et al., 2004; Mahaffey et al., 2004; Knobeloch et al., 2006); a recent risk assessment of organic contaminants in wild and farmed salmon (Hites et al., 2004) sparked intense controversy over whether the known benefits of fish consumption had been adequately considered in comparison to the relatively small lifetime cancer risks associated with organochlorine compounds (Stokstad, 2004; Rembold, 2004; Tuomisto et al., 2004; Lund et al., 2004; Foran et al., 2006; Willett, 2005; 2006). Recently, a few authors have published risk-benefit analyses for fish consumption that considered one or more contaminants and incorporated a quantitative estimate of benefit (Anderson and Wiener, 1995; Foran et al. 2005; Cohen et al., 2005; Gochfeld and Burger, 2005; Ponce et al., 2000; Sidhu, 2003). Using one method of calculating the combined risks and benefits of fish consumption, for example, Foran et al. (2005) found that consumption of farmed salmon was estimated to prevent nearly 300 times more cardiac-related deaths than it potentially caused from PCB-associated cancer. In most assessments, the comparative risks of alternate foods are not taken into account. Other sources of animal protein that may be consumed in place of fish, such as beef, pork, or chicken, also contain undesirable components (e.g., PCBs, dioxins, saturated fat, and hormone or antibiotic residues) whose risk has not been characterized or estimated in a fashion similar to that of fish.

As early as 1986, OEHHA held a workshop on balancing the risks and benefits of fish consumption (CDHS, 1988). In more recent years, OEHHA, and similar agencies from other states, have incorporated benefit statements into their fish consumption advisories that assure the public that fish should be part of a healthy diet. In a technical memorandum describing the derivation of a noncommercial fish consumption recommendation for women who may become pregnant, pregnant women, nursing mothers, and young children, U.S. EPA and FDA noted that their advice "balances the risk from mercury with the benefits of fish" (U.S. EPA, 2004).

Conclusions:

OEHHA determines that there is a significant body of evidence and general scientific consensus that eating fish at dietary levels that are easily achievable, but well above national average consumption rates, appears to promote significant health benefits, including decreased mortality**.** As is the case with all foods, fish contain constituents that may be harmful when consumed in unrestricted quantities. However, because of the unique health benefits associated with fish consumption, the advisory process should be

expanded beyond a simple risk paradigm in order to best promote the overall health of the fish consumer.

ADVISORY TISSUE LEVELS FOR CHLORDANE, DDTs, DIELDRIN, METHYLMERCURY, PCBs, SELENIUM, AND TOXAPHENE

To include the benefits of fish consumption in the advisory process, ATLs were calculated for each of the contaminants for which FCGs were derived. In comparison to FCGs, which were based on a single meal frequency, ATLs were calculated for several meal frequency categories that are used to provide advice to the consumer that balances the benefits and risks of fish consumption. This yields a range of corresponding contaminant concentrations in fish within categories as shown in Table 2. ATLs were calculated using the same general formulas as those used to calculate FCGs, with some adjustments in order to incorporate the benefits of fish consumption. Because benefits are integrated differently into ATL equations for cancer and non-cancer risk, these methods are discussed separately. All factors and assumptions not specifically addressed are the same as those used to develop FCGs.

Cancer Risk:

$$\text{Tissue concentration (ppb)} = \frac{\text{(Risk Level)(kg BW)(1000 µg/mg)}}{\text{[CSF (mg/kg/day)}^{-1}\text{] (CR kg/day)(ED/AT)(CRF)}}$$

Risk Level:

For FCGs, the maximum risk level was set at $1x10^{-6}$, estimating that, at the given consumption rate, not more than one additional cancer case would be expected in a population of one million people consuming fish over a lifetime. OEHHA acknowledges that, while it should be a goal to maintain a risk level of $1x10^{-6}$ for fish and other foods, the counterbalancing nutritional benefits of foods, particularly the unique benefits of fish, must be considered. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued through fish consumption.

Thus, OEHHA concludes that, for the purposes of developing fish consumption advisories, ATLs should be calculated using a maximum risk level of $1x10^{-4}$, estimating that, at the given consumption rate, not more than one additional cancer case would be expected in a population of 10,000 people consuming fish over a lifetime. This risk level is within the acceptable range of risks ($1x10^{-4}$ to $1x10^{-6}$) used by U.S. EPA in regulatory criteria for drinking water (Fed. Reg., 1998) and is provided as an example of a maximum acceptable risk level in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (U.S. EPA, 2000a). OEHHA considers that a maximum risk level of $1x10^{-4}$ appropriately balances the cancer risk associated with fish consumption with the numerous known health benefits that can be accrued from eating fish. Because each meal frequency category encompasses a range of fish

contaminant levels (see consumption rate discussion and ATL table below), fishers, over time, will be exposed to a range of risk levels as they catch and eat different fish. Thus, when the *maximum* risk level is set at $1x10^{-4}$ for each meal frequency category, the actual *average* cancer risk for fish consumers over their lifetime is less than $1x10^{-4}$ (ranging from approximately $5x10^{-5}$ to $1x10^{-4}$), when consumption advisories are based on carcinogens detected in fish.

Consumption Rate (CR):

FCGs were calculated using a single consumption rate (32 g/day, or a single serving of eight ounces of fish, prior to cooking, per week) aligning with the AHA's minimum recommended fish consumption rate for adults and exceeding the typical consumption rate for the vast majority of sport fishers (see, for example, SFEI, 2000). This consumption rate is also used to begin issuing fish consumption advisories that are based on cancer risk using the ATLs and other considerations. Because OEHHA also considers it important to offer advice for the small segment of fishers who choose to consume fish more frequently than one 8-ounce serving per week, ATLs for two and three 8-ounce servings per week, prior to cooking (64 and 96 g/day, respectively), were also calculated based on cancer risk.

Example Calculation:

Using a risk level of $1x10^{-4}$, the slope factor for each chemical, and consumption rates of 32, 64, and 96 g of fish/day in the above equation will yield three numbers that are the cutoff values for one, two, and three servings per week, respectively, for cancer risk.

As an example, for dieldrin, the ATL using a risk level of $1x10^{-4}$ and a consumption rate of one, 8-ounce serving per week (32.0 g/day) would be calculated as follows:

$$\frac{(1x10^{-4})(70\text{ kg})(1000\ \mu g/mg)}{[16\ (mg/kg/day)^{-1}](0.032\text{ kg/day})(30/70)(0.7)} = 46\text{ ppb}$$

Thus, fish containing 46 ppb dieldrin, or less, can be consumed in the amount of at least one, 8-ounce serving per week.

Non-Cancer Risk:

$$\text{Tissue concentration (ppb)} = \frac{(\text{RfD mg/kg-day})(\text{kg BW})(1000\ \mu g/mg)}{(\text{CR kg/day})(\text{CRF})}$$

Hazard Quotient and Consumption Rate:

For FCGs, the maximum HQ was set at 1, indicating that the *maximum* exposure (based on CR in the equation) is equivalent to the RfD. In order to balance the risks and benefits

of fish consumption when considering non-cancer risk, however, OEHHA determined that the *average* exposure should be equivalent to the RfD. With the ATLs, each meal frequency category (one, two and three servings per week) encompasses a range of fish contaminant levels, as noted above. Thus, fishers over time will be exposed to a range of HQs as they catch and eat different fish. When the *maximum* HQ for each meal consumption frequency is set at 1, using the maximum consumption rate in the equation (32, 64, and 96 g/day for one, two, and three servings per week, respectively) to set the cutoff for each meal frequency leads to an actual *average* HQ for fish consumers, over a multiple week basis, of less than 1. This is because the majority of fish caught in each meal frequency category will have a lower contaminant level than the maximum contaminant level used to set the cutoff. However, if the cutoffs are adjusted slightly so that the *average* rather than the maximum HQ is 1, over a multiple week basis, and an acceptable maximum HQ is still maintained, fishers who follow the advice will be able to consume a greater amount of fish and consequently enjoy a higher level of health benefits without incurring significant non-cancer risks from contaminants in fish.

U.S. EPA adjusted a meal frequency cutoff to establish its national advisory for mercury of one serving per week of sport fish from untested water bodies. They combined several meal categories (two, three and four servings per month), as do many states, in order to balance the risks and benefits of fish consumption and simplify communication (U.S. EPA, 2004). U.S. EPA used the contaminant concentration that would otherwise be associated with a recommendation of two servings per month as the cutoff for the one serving per week advice. Although this results in an HQ higher than 1 for some fish that fall into the 1 serving per week category, this advice is still health protective because, on average, fishers will be consuming fish with lower mercury levels than those used to establish the one serving per week cutoff.

OEHHA incorporated an "average HQ" concept into the ATLs by modifying the fish consumption rate used in the ATL equation. As explained above, one, 8-ounce serving of fish per week is equivalent to a consumption rate of 32 g/day. Consumption of two servings of fish per month would be equivalent to 0.5 servings per week, or 16 g/day. Following the example of U.S. EPA in their national advisory (see above), OEHHA also used a 16 g/d consumption rate to calculate the cutoff for the one serving per week category when considering non-cancer risk for the ATLs. As can be seen in the sample calculation below, this allows for greater consumption of fish (and a better balancing of risks and benefits) than if a consumption rate of 32 g/day were used. In a similar fashion, OEHHA used a consumption rate of 48 g/day (approximately 1.5 servings per week) to compute the ATLs for the two servings per week category for non-cancer risk. A consumption rate of 96 g/day was used, as it was for cancer risk, to determine the ATLs for three servings per week. As a consequence of making these adjustments, the *average* HQ, over the entire range of potential exposures, is approximately 1. OEHHA considers this average HQ appropriate to balance the risk and benefits of fish consumption when considering non-cancer risk.

Example Calculation:

Using the RfD for each chemical, and consumption rates of 16, 48, and 96 g/day, in the above equation will yield three numbers that are the cutoff values for one, two, and three servings per week, respectively, for non-cancer risk.

As an example, for mercury, the ATL for one, 8-ounce serving per week for women aged 18-45 years would be calculated as follows:

$$\frac{(1\times10^{-4}\ \text{mg/kg-day})(70\ \text{kg BW})(1000\ \mu\text{g/mg})}{(0.016\ \text{kg/day})(1)} = 440\ \text{ppb}$$

Thus, fish containing 440 ppb mercury, or less, can be consumed in the amount of at least one, 8-ounce serving per week.

Final ATL Calculations:

For each chemical, ATLs were calculated separately for cancer and non-cancer risk, if appropriate, for consumption frequency categories of one, two, and three 8-ounce servings per week. Values for cancer and non-cancer risk were then compared to determine whether the cancer or non-cancer value was the most health-protective. For all chemicals except DDTs, either cancer or non-cancer risk determined the ATL for each consumption frequency category. For DDTs, consumption advice for one serving per week was based on cancer risk, while consumption advice for two and three servings per week was based on non-cancer risk.

OTHER CONSIDERATIONS USED IN THE DEVELOPMENT OF FISH CONSUMPTION ADVISORIES AND SAFE EATING GUIDELINES

ATLs are used as part of the process to develop traditional health advisories (which focus on fish whose consumption should be restricted or avoided altogether) as well as the newer "safe eating guidelines," which inform consumers of fish with low contaminant levels considered safe to eat frequently. Other factors, including the following, will also be used by OEHHA to develop advisories and safe eating guidelines, as appropriate.

Omega-3 Fatty Acid Levels:

The fatty acid content of fish is highly variable within and among species; fish diet, sex, age, and reproductive status, as well as location and season all affect the total concentration and composition of tissue fat (Nettleton, 1995). At the present time, omega-3 fatty acids levels are not available specifically for California sport fish, although applicable national averages have been published for some species. If acceptable surrogate or actual omega-3 fatty acid data exist for California sport fish, this information may be used to alter fish consumption advice. For example, OEHHA may recommend higher consumption of fish with high omega-3 levels than fish with identical levels of contaminants but lower omega-3 levels.

Contaminant Data:

Once the consumption frequency categories and ATLs are established, the data must then be carefully examined to determine what contaminant values will be compared to the ATLs. Fish contaminant data collected from a water body are often highly variable, reflecting environmental factors such as seasonal effects and localized sources or sediment methylation processes. Evaluating these data prior to developing site-specific (water body) or regional consumption advice is a complex process that may involve one or more approaches. The most common and simplest method of interpreting fish contaminant data collected from a site is to calculate a value of central tendency such as the geometric mean, arithmetic mean, median or mode. OEHHA often uses the arithmetic mean for developing safe eating guidelines; however, each of these measurements is helpful in interpreting the distribution of the data. Another method of interpreting a data set is to examine the regression line between species length and chemical contaminant level. Consumption guidance can then be tailored to different fish size classes or to the predicted contaminant concentration of the most typical length of fish consumed, provided adequate creel data are available to make this determination. This method is most useful for contaminants, such as mercury, where the concentration is largely dependent on fish size in specific fish species.

After careful selection of an appropriate contaminant concentration for each species at a site (e.g., an arithmetic mean, mode or a regression analysis), that value or values can then be compared to the range of concentrations presented in the ATL table (Table 2).

Risk Communication:

After thorough evaluation of fish contaminant data for a site and comparison of appropriate contaminant values to the ATLs, OEHHA may determine that strict adherence to established consumption frequency categories results in consumption advice that is too complex for the fisher to follow, particular for large water bodies. In these cases, OEHHA may make minor adjustments to recommended consumption limits for a species in order to best facilitate communication. For example, if contaminant levels in a species vary along a discreet coastal region, OEHHA may choose the most restrictive or most common advice for that species for the entire region, depending on circumstances and communication considerations. Additionally, in safe eating guidelines, fishers who do not skin or cook their fish may be advised to consume less fish than guidelines recommend for their population group, if organochlorine contaminants are present in quantities that affect consumption guidelines. Skinning and cooking do not reduce methylmercury concentrations in fish tissue. Serving sizes are based on fish consumption by an average 160 pound person. Individuals weighing less than 160 pounds will be encouraged to eat proportionately smaller amounts. As noted previously, because of their smaller body weights, children will be advised to eat approximately one-half as much fish (in either quantity or frequency) as are women of childbearing age.

Conclusions:

The ATLs described in this report should not be misinterpreted as static “bright lines” that others can use to duplicate state fish consumption advisories. As noted, ATLs are but one component of a complex process of data evaluation and interpretation used by OEHHA in the assessment and communication of fish consumption risks. The nature of the contaminant data or omega-3 fatty acid concentrations in a given species in a water body, as well as risk communication needs, may alter strict application of ATLs when developing site-specific advisories. For example, OEHHA may recommend that consumers eat fish containing low levels of omega-3 fatty acids less often than the ATL table would suggest based solely on contaminant concentrations. OEHHA will use the guidelines set forth in this report as a framework, along with best professional judgment, to provide fish consumption guidance on an *ad hoc* basis that best combines the needs for health protection and ease of communication for each site.

Table 2. Advisory Tissue Levels (ATLs) for Selected Fish Contaminants Based on Cancer or Non-Cancer Risk Using an 8-Ounce Serving Size (Prior to Cooking) (ppb, wet weight)				
Contaminant	**Three 8-ounce Servings* a Week**	**Two 8-ounce Servings* a Week**	**One 8-ounce Servings* a Week**	**No Consumption**
Chlordane[c]	≤190	>190-280	>280-560	>560
DDTs[nc**]	≤520	>520-1,000	>1,000-2,100	>2,100
Dieldrin[c]	≤15	>15-23	>23-46	>46
Methylmercury (Women aged 18-45 years and children aged 1-17 years)[nc]	≤70	>70-150	>150-440	>440
Methylmercury (Women over 45 years and men)[nc]	≤220	>220-440	>440-1,310	>1,310
PCBs[nc]	≤21	>21-42	>42-120	>120
Selenium[nc]	≤2500	>2500-4,900	>4,900-15,000	>15,000
Toxaphene[c]	≤200	>200-300	>300-610	>610

[c]ATLs are based on cancer risk
[nc]ATLs are based on non-cancer risk
*Serving sizes are based on an average 160 pound person. Individuals weighing less than 160 pounds should eat proportionately smaller amounts (for example, individuals weighing 80 pounds should eat one 4-ounce serving a week when the table recommends eating one 8-ounce serving a week).
**ATLS for DDTs are based on non-cancer risk for two and three servings per week and cancer risk for one serving per week.

Tabled values are rounded based on laboratory reporting of three significant digits in results, where the third reported digit is uncertain (estimated). Tabled values are rounded to the second digit, which is certain. When data are compared to this table they should also first be rounded to the second significant digit as in this table.

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APPENDIX 1: RESPONSE TO COMMENTS

Comments and Responses to the Original Draft Document:
Development of Guidance Tissue Levels and Screening Values for Common Contaminants in California Sport Fish:
Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene.

Commenter 1:
Sheila Hamilton
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Comment 1.1
Because the final guidance tissue levels and screening values will, no doubt, play a significant role in future regulatory decisions throughout the state, we urge OEHHA to be more specific on the proper and improper use of these proposed thresholds. For example, the State Water Resources Control Board recently misinterpreted OEHHA's screening values (SVs) as thresholds defining impaired water quality. The report does not caution against using the screening values as informal Water Quality Objectives or Maximum Contaminant Levels.

Response 1.1
OEHHA has reconsidered the usefulness of establishing SVs as part of our protocol to develop fish consumption recommendations and determined that the SVs should be removed from the final document. We are providing Fish Contaminant Goals that can be used as a starting point for agencies to develop fish tissue-based criteria. Agencies that require screening criteria for mandated activities may still seek OEHHA's advice for their development. Any screening criteria employ numerous assumptions, particularly the consumption rate and risk level, and may be targeted to different population groups. These issues must be considered and agreed upon as relevant to the purpose of the criteria prior to their development and use by any agency.

Comment 1.2
The draft document was developed using a wide variety of assumptions. We recommend that these assumptions be summarized in a single table.

Response 1.2
The assumptions are explained carefully and individually in the text where they are used, which is considered most appropriate.

Comment 1.3
Table 1 shows a range of recommended GTLs that vary in relation to the average amount of fish consumed in a month. The presentation should be expanded to show how changes in other key assumptions will cause the GTL or SV to increase or decrease.

Response 1.3
While Fish Contaminant Goals (FCGs) and GTLs (now the Advisory Tissue Levels, or ATLs) will change if the assumptions change, the assumptions made by OEHHA in development of this document are fairly standard in risk assessment and have been clearly described in the document. As OEHHA is responsible for issuing sport fish consumption guidelines in the state of California, there is no reason to present alternative assumptions that will not be used to issue fish consumption advice.

Comment 1.4:
We recommend that OEHHA develop a simple spreadsheet tool, based on the equations shown on page 39-40 (now page 43-44) of the draft report, that allow end users to modify the underlying assumption and graph the range of recommended values. With minor modifications, that tool could be adapted for general use by other state agencies.

Response 1.4:
As noted previously, it is OEHHA's mandate to issue health advisories for sport fish consumption in the State of California. As such, OEHHA is the only "end user" of the GTLs (now ATLs), although the ATLs may be used by counties to issue interim advice in consultation with OEHHA. The sole purpose of releasing the document was to improve transparency of the fish advisory process, not to provide other agencies with a tool to provide their own fish consumption advice to the public. To prevent such confusion in the future, OEHHA will rename the final document: Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, selenium, and toxaphene. OEHHA recognizes that use of the word "guidance" in Guidance Tissue Level has led some to think that this is a "guidance document" to be used by other agencies in developing their own advisories. We are making the change to correct this misinterpretation.

Comment 1.5:
The draft document does not describe what constitutes "sufficient fish tissue data" (p. 2) nor does it provide an explanation as to how to perform the highly-specialized risk analyses recommended.

Response 1.5:
The GTL (now ATL) document is not intended as a guidance document to be used by other agencies (see response to comments above) to develop their own advisories. OEHHA performs the risk analyses; recommendations provided to other agencies responsible for data collection and analyses are provided in another document (Gassel and Brodberg, 2006; General Protocol for Sport Fish Sampling and Analysis). Because each water body is unique, agencies should consult OEHHA prior to collecting fish from

California water bodies so that OEHHA can direct sampling and analysis to collect data sufficient to adequately estimate human health risks. The discussion of sampling and analysis has been removed from the document.

Comment 1.6:
We are concerned that OEHHA elected to make very large adjustments to the estimated reference dose to account for various "uncertainty factors." The published GTLs and SVs should be presented with and without such adjustments so that it is clear to other state agencies that a safety factor has already been applied. Otherwise, it is likely that other agencies will incorrectly assume that the GTL or SV represents the No-Observed-Effect-Threshold and seek to add on their own safety factors. It would be useful to explain that the magnitude of adjustment applied was somewhat arbitrary. Higher or lower multipliers may be equally well justified.

Response 1.6:

Uncertainty factors (UFs) are always included in the development of an RfD. After evaluating the original toxicity data, toxicologists apply uncertainty factors to the point of departure value (e.g., the NOAEL or LOAEL), taking into account any deficiencies in the data (such as short-term exposure, the use of an animal model, or lack of a reproductive study) in order to arrive at the RfD. UFs are not arbitrary but are routinely and rather consistently applied using accepted risk assessment principles. With the exception of toxaphene and chlordane, the UFs and RfDs used for each chemical in this document were originally developed by U.S. EPA and are in general use by the risk assessment community. After reviewing the most current literature, OEHHA has chosen to maintain these RfDs. Again, other agencies should not attempt to modify OEHHA advisories by manipulating any of the parameters used by OEHHA in developing the advisories.

Comment 1.7:
It is unclear if OEHHA considered the published recommendation of other federal agencies (e.g., FDA's less restrictive "Action Levels") and, if so, why those recommendations were rejected. Nor is it clear why OEHHA declined to use EPA's more stringent recommendations.

Response 1.7:

OEHHA conducted a thorough evaluation of federal and other state's methods of providing fish consumption recommendations and selected methods that appropriately balanced benefits and risks. FDA action levels are not appropriate for setting sport fish consumption guidelines. In their guidance document, U.S. EPA does not propose a single, specific method of providing fish consumption recommendations but, instead, illustrates one possible scenario using only the RfD and a risk level of 1×10^{-5}. The U.S. EPA acknowledges that states and tribes may modify this method in multiple ways to make it more or less conservative as they see fit. Examples of RLs from 10^{-4} to 10^{-7} are also included in their guidance document. OEHHA uses the most up-to-date data and

methodology and considers sensitive populations. OEHHA's advisories are within the range of guidance provided by U.S. EPA but, in several cases, are more conservative.

Commenter 2:
Alyce Ujihara
Diana Lee
Sharon Lee
Elana Silver
California Department of Health Services
Environmental Health Investigations Branch
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Comment 2.1
Clarification of the reduction factor for organic chemicals for skinning of fillets is needed. You have applied a reduction factor to your GTL calculations that assumes people consume fish as skin-off fillets. Since you assume a 30% reduction due to contaminant loss during cooking and you assume a 50% loss due to cooking and skinning combined, skinning alone appears to account for about a 20% reduction in contaminants in your calculations. This reduction factor for skinning should be explicitly stated.

Response 2.1
Data on the contaminant reduction achieved by various trimming and cooking techniques are variable. It is known that removing the skin and associated fat as well as cooking remove a significant amount of organic contaminants. The general cooking reduction factors of 50% and 30% are typical values that have been generated with experiments using either skin-on or skin-off fillets, respectively. Therefore, there is no explicit reduction factor for skinning alone. The 30% and 50% reduction factors are used, for example, by the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory and by other states in their fish consumption advisories.

Comment 2.2
Incorporating an assumption that people eat skin-off fillets results in GTLs that are not adequately health protective for a significant number of people. In a survey of San Francisco Bay anglers (SFEI 2001), DHS found that significant numbers of anglers report eating the skin of fish. Specifically, we found that 21% of striped bass consumers and 38% of white croaker consumers reported eating the skin more than half of the time. Generally, among anglers who reported eating skin, there were more non-white anglers, particularly African Americans and Asians. Thus, using a skin-off fillet as the default to develop GTLs for organic chemicals will disproportionately affect these groups.

Response 2.2
OEHHA recommends fish preparation methods, such as skinning, that allow anglers to safely eat more fish. In order to protect anglers who choose not to follow these guidelines, however, OEHHA may provide separate advice, as part of risk

communication, to fishers who do not skin or otherwise trim fish or cook it by methods recommended to reduce contaminant levels when guidance is based on chlorinated hydrocarbon contaminants.

Comment 2.3
The draft document states that "if fishers choose not to follow this advice and cook fish as skin-on fillets, they should reduce their consumption by approximately one-fourth…to achieve and equivalent exposure." From a practical perspective, it does not make sense to base the GTLs on a consumption pattern that people "should" follow, rather than what they already do. The GTLs should not assume that a significant proportion of people will take additional measures in order for the advisory to be adequately health protective. Furthermore, advisory messages need to be as simple as possible. Adding another qualifier to the advisory message (e.g., this advice will only be health protective if you remove the skin) complicates the message.

Response 2.3
Based on the study cited, the majority of anglers *do* skin fish, whether doing this of their own accord or following recommendations that OEHHA provides. OEHHA does not issue consumption and cleaning/cooking advice only to protect the most exposed individual but makes recommendations that all fishers can choose to follow – or not – to lower their exposure to contaminants. Fishers who do not follow advice to skin and/or cook their fish also may not follow advice to limit fish consumption. In the case of mercury, separate advice is provided for two populations groups so that less sensitive individuals (women beyond childbearing age and men) do not have their fish consumption unduly restricted by the needs of the other group (women of childbearing age and children). So it should be with cooking and cleaning methods, i.e., the majority of fishers who do consume/prepare fish in the safest manner should be offered advice that allows them to consume the most fish safely while fishers who choose to eat the skin or prepare fish in a way that does not reduce contaminant loads should be offered separate advice tailored to their needs. This is particularly important in the case of subsistence fishers, for example, where unwarranted fish consumption restrictions may impose an economic burden. The draft report recommended that fishers who do not follow advice to skin fish should reduce their consumption by approximately one-fourth. However, newer data indicate that the amount of contaminants found in skin may be more variable (and ultimately higher) that previously thought. In some cases, fish that could be eaten once or twice a week without skin will fall into the "do not consume" category with skin. For additional consideration in the final report and in future advisories for chlorinated hydrocarbons, OEHHA will consider site- or species-specific advice to reduce consumption if fishers do not cook or clean their fish in the safest manner.

Comment 2.4
Additionally, the decision to use skin-off fillets for scaled fish is not consistent with U.S. EPA guidance for fish advisories. U.S. EPA recommends that contaminant concentrations be measured using skin-on fillets for scaled fish species and skinless fillets for scaleless fish species (e.g., catfish).

Response 2.4
Historically, fish monitoring programs in California have analyzed skinless fillets of fish. See response 2.3 for further discussion. Analyzing skin-on fillets actually dilutes the measured mercury concentrations, making the advice less conservative. As mercury is the predominant fish contaminant in California, OEHHA recommends measuring contaminant concentrations in skin-off fillets.

Comment 2.5
On page 39, a correction to the example equation for dieldrin is needed; 1000 µg/kg should be 1000 µg/mg.

Response 2.5
Corrected. The mistake was the result of a typographical error. Calculated values were correct in the original version.

Commenter 3:
Roberta Blank
Chief, Site Cleanup Section 1, Superfund Division
U.S. EPA
Region IX
75 Hawthorne Street
San Francisco, CA 94105

Comment 3.1
A major component of the EPA Institutional Controls Program for the Palos Verdes Shelf site is educating the public on the current state sport fish consumption guidelines. The current state fish advisory for DDTs uses an excess cancer risk of 10^{-5}. The proposed GTLs use a 10^{-4} level. The GTLs guidance cites that other states (e.g., Georgia and West Virginia) use the risk level of 10^{-4} in fish consumption advisories. However, these states have not used a risk level of 10^{-5} before, while California has been using 10^{-5} cancer risk endpoint for at least 15 years. No rationale for this change is provided.

Response 3.1
The rationale for the current protocol was discussed in the draft document. The 10^{-5} risk level was not consistently used for all chemicals in the Southern California sport fish consumption guidelines and has not been the basis for other advisories. Over the last 15 years, a tremendous amount of data has been published on the benefits of fish consumption – information that was not available when the 10^{-5} risk level was initially used. As scientific knowledge and protocols continue to expand or develop, our understanding of the risk and benefits of fish consumption have increased. The revised document has greatly expanded the discussion of the benefits of fish consumption and the reasoning behind the choice of the 10^{-4} risk level. In their fish advisory guidance document, U.S. EPA allows states to choose risk levels ranging from 10^{-4} to 10^{-7}. OEHHA concludes that, while it should be a goal to maintain a risk level of $1x10^{-6}$, when considering the counterbalancing benefits of fish consumption, a risk level of $1x10^{-4}$ is

appropriate. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption.

Comment 3.2
The draft GTLs are consistent with the FDA cancer risk level used for establishing tolerance levels in fish. However, the underlying assumptions used in the FDA methodology were not intended to be protective of recreational, ethnic, and subsistence fishers who typically consume larger quantities of fish than the general population and often harvest the fish and shellfish they consume from the same local water bodies repeatedly over many years, such as in the case for PV Shelf. The EPA national guidance states that "the FDA action levels and tolerances are indicators of chemical residue levels in fish and shellfish typically purchased in supermarkets or fish markets that sell products that are harvested from a wide geographic area, including imported fish and shellfish products."

Response 3.2
The reference to the FDA tolerance level for PCBs has been removed.

Comment 3.3
Using a cooking reduction of 30% in volume of fish consumed would increase the allowable contaminant intake in the screening value. Using this factor is inconsistent with the EPA national guidance for fish advisories. In addition, the assumption of skin-off fillet is not protective of sensitive populations such as ethnic populations who often eat whole fish, and fish stew and/or soup.

Response 3.3
Appendix C in U.S. EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol. 2, discusses dose modifications that may be used to adjust for food preparation and cooking. Various surveys in California have shown that the majority of fishers eat skin-off, cooked fish. OEHHA will provide differential advice for those that prepare and cook fish in the safest manner as well as those that do not (see 2.3 above).

Comment 3.4
For chlordane, DDT and PCBs, the noncancer endpoint is not protective of effects for children. The 10^{-5} indirectly provides protection to these sensitive populations as the 10^{-5} value is the more conservative value. However, the use of 10^{-4} risk level does not provide this indirect buffer.

Response 3.4
OEHHA is not aware of any compelling evidence that children have increased susceptibility to DDTs that is not accounted for by the current RfD. OEHHA is currently assessing whether children may have increased susceptibility to PCBs under our SB 25 toxic air contaminants program. RfDs are generated taking into account the most

sensitive population; in particular, the RfD for PCBs is deemed protective of neurodevelopmental effects in fetuses and children as those occurred at a higher dose than the critical effect. The RfDs for DDTs and PCBs have uncertainty factors of 100 and 300, respectively, which should offer ample protection should additional adverse effects of these contaminants be determined later. If new research allows development of a childhood-specific RfD, like that for mercury or chlordane, OEHHA will reevaluate fish consumption guidelines at that time.

Comment 3.5
The draft GTLs guidance states that "Even if fishers fish the same location for 70 years, their exposure to such chemicals will undoubtedly decline significantly over this period" due to decline in levels in the environment. When the duration of exposure increases, even if there is a decline in contaminant levels, it is possible that the increase in the exposure time outweighs the decline in contaminant levels. At this time, we have not fully evaluated the existing and current data to corroborate the assumption that the levels of these contaminants are declining in the environment.

Response 3.5
The assumption of a 30 year exposure from fish consumption for a particular water body is a reasonable high-end health protective assumption for assessing risk from carcinogens, given current knowledge about population mobility from various studies. This assumption may need further consideration for bioaccumulating, carcinogenic contaminants ubiquitously present in water bodies.

Commenter 4
Mark Gold, D. Env.
Director
Kirsten James, MESM
Staff Scientist
Heal the Bay
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Santa Monica, CA 90401

Comment 4.1
OEHHA should decrease the allowed cancer risk level in calculating GTLs and SVs to maintain the 10^{-5} end point for carcinogens to adequately protect sensitive subpopulations such as ethnic subsistence fishers, pregnant women and children. The lines of reasoning provided by OEHHA for the 10^{-4} risk level are not sufficient to justify the increase in allowed cancer risk. The FDA methodology used to calculate their level of acceptable risk cited in the draft report assumes that the population consumes a smaller number of fish from multiple sources; in this case, the draft report calculations are intended to protect people who consume fish from *local* water bodies. Finally, the draft report implies that consuming a certain amount of fish may be more important than avoiding contaminant exposure. Not only does this conclusion appear to be outside the purview of OEHHA, it is not well justified in the draft report. In sum, there is no appropriate

rationale provided in the Draft Report to justify the change to a less protective endpoint. OEHHA should use an allowed cancer risk level of 10^{-5} in calculating GTLs and SVs to be sufficiently protective of human health particularly under circumstances that occur in California. This lower value would serve as a "buffer" for other non-conservative assumptions relied upon by OEHHA as discussed below.

Reponse 4.1
OEHHA has removed the SVs from the draft report; see additional discussion below. Instead, OEHHA has provided Fish Contaminant Goals (FCGs) that maintain very conservative assumptions and may be used by other agencies as a starting point for developing fish tissue-based criteria.

The reference to the FDA tolerance limit for PCBs has been removed.

OEHHA (formerly of the Department of Health Services) has discussed balancing the risk and benefits of fish consumption since as early as 1986 (California Department of Health Services. Balancing the scales: Weighing the benefits and risks of fish consumption. Proceedings of a workshop held in Concord, California, October 20, 1988.). With the vast amount of data that has become available on the benefits of fish consumption in the last few years, OEHHA determined that this section should be significantly expanded in the final report. OEHHA believes that using a 10^{-4} risk level best balances known health benefits with cancer risks of fish consumption. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption.

Comment 4.2
OEHHA should ensure that GTLs and SVs are protective of the entire population including several sensitive subpopulations. The GTLs and SVs are not protective of certain highly relevant population groups, including children, pregnant women, and ethnic subsistence fishers. For example, the authors make various assumptions about the consumer in developing the GTLs and SVs, such as assuming a body weight of 160 pounds and a normal meal size of 6 ounces after cooking. While these assumptions are accounted for somewhat in the Draft Report by including recommendations to adjust the amount of fish consumed based on the weight of the consumer, OEHHA is also proposing to base the screening values upon the same characteristics of an average adult, thus failing to account for other routinely exposed groups of the population. In addition, under this assumption, OEHHA appears to recommend that children under 40 pounds should not eat any fish at all and kids under 80 pounds should not eat a tuna fish sandwich (based on a 2 oz serving size). This is not realistic. There is ample evidence that children in California consume local fish regularly and often, and thus are exposed to these contaminants. To adequately protect all consumers, OEHHA should use a much more conservative (lower) body weight in calculating the GTLs and SVs.

Response 4.2
The assumption of a 70 kg adult body weight is standard risk assessment protocol and six ounces after cooking is considered a standard fish meal size. Because there is a strong positive correlation between food consumption and body weight, particularly when averaged over a lifetime as the risks and hazards are, most risk assessments simply assume the concomitantly reduced consumption rate for lower body weights rather than stating it explicitly. In the final document, simplified instructions will be added to reduce meal sizes proportionately to body weight. Additionally, 70 kg is currently well below the average adult body weight for males and females, making the use of this default value a conservative assumption.

Comment 4.3
The cooking reduction factor of 30 percent and skin-on reduction factor of 20 percent should be removed from the calculations of GTLs and SVs. The GTL calculations also incorporate a cooking reduction factor of 30 percent and a skin-on reduction factor of 20 percent based on a theory that the process of heating the fish will break down organic contaminants and most consumers do not eat skin-on fish. This may be appropriate under some circumstances, but not in *all* cases. First, the specific method of cooking may determine the extent of breakdown of these organic constituents. For instance, searing the fish or cooking the fish in a stew may lead to a reduction in organic contaminants that is much lower than 30 percent. Second, methylmercury will not likely breakdown during the cooking process. Third, ethnic subsistence fishermen are put at additional risk under this assumption because they often use the whole fish (not a fillet) with skin-on. For instance, a fish consumption study found that of Asian anglers surveyed, 50 percent consume the whole fish. In fact, white croaker, a popular fish in Asian communities, is *rarely* eaten as a fillet. Thus, as just one example, Asian populations are not properly protected using these reduction factor assumptions. And again, while the draft report recommends reducing consumption if skin-on fillets are used, the screening values do not take this variable into account. Plainly, the reduction factors increase the allowable contaminated fish consumption in the screening values and will lead to fewer fish advisories and thus less protection for all groups of consumers. OEHHA should remove the 30 percent cooking reduction factor and 20 percent skin-on reduction factor in calculating the GTLs and SVs.

Response 4.3
See response to comments 2.2, 2.3, and 3.3. As noted in the draft document, the cooking and skinning reduction factors are not applied to mercury data. Mercury analysis of skin-off fillets provides more conservative fish consumption advice than analysis of skin-on fillets would (see response 2.4).

Comment 4.4
OEHHA should consider the policy implications of the draft report. There are additional water quality policy issues tied to the finalization of this draft report. Currently, California's Clean Water Act 303(d) list relies heavily on OEHHA Screening Values to determine fish tissue impairment. In fact, the *Water Quality Control Policy for*

Developing California's Clean Water Act 303(d) List ("Listing Policy") specifies that evaluation guidelines for protection from the consumption of fish and shellfish published by OEHHA can be used in evaluating fish tissue data for 303(d) listing and de-listing purposes. (Listing Policy at 20.) As a result, various listings and delistings in the Draft 2006 303(d) List are based upon the current OEHHA SVs or "benchmarks." In addition, the Listing Policy specifies that a waterbody "…shall be placed on the section 303(d) list if a health advisory against the consumption of edible resident organisms, or a shellfish harvesting ban has been issued by the Office of Environmental Health Hazard Assessment (OEHHA)." (Listing Policy at 5.) Further, numeric targets in certain TMDLs are derived from these screening values.

As discussed above, the Draft Report uses a risk level of 10^{-4}. In contrast, water quality standards, such as CTR standards, were set using the 10^{-6} risk level. Thus, there may be conflict between the protection offered through the Clean Water Act and policy decisions based upon the GTLs and SVs that are calculated using the 10^{-4} risk levels. In addition, the SVs included in the Draft Report are as much as 6 times higher than the 1999 OEHHA SVs. This may result in many inappropriate de-listings from the 303(d) list, resulting, in turn, in a failure to address the underlying problem at the source. Given the seriousness of the risks here, this is entirely inappropriate.

Response 4.4
As noted above, the SVs have been removed from the final document. Fish Contaminant Goals (FCGs), developed in this final report, use a 10^{-6} risk level. Agencies can use these values as a starting point to develop fish tissue-based criteria. GTLs (now ATLs) are not regulatory standards. OEHHA does not determine policies developed by other state programs. However, if other state programs choose to consider or use values that OEHHA has developed for some other purpose, then it is advisable that they consult with OEHHA to avoid any misuse or misinterpretation. (See response 1.1).

Comment 4.5
In general, OEHHA will be taking a step backward in terms of protecting public health if it adopts the non-conservative assumptions proposed in this Draft Report. As discussed above, there are major implications for sensitive subpopulations – particularly children and ethnic Asian subpopulations. An allowable cancer risk level of one in 10,000 is just not acceptable given these variable consumption patterns and practices. Therefore, we *strongly* urge OEHHA to maintain the 10^{-5} endpoint, as well as to use more conservative assumptions in calculating the GTLs and SVs.

Response 4.5
OEHHA has addressed the "non-conservative" assumptions in prior responses to comments. OEHHA has determined that highly conservative assumptions, as used in traditional risk assessment paradigms, are not protective of overall health when considering fish consumption. However, in response to comments regarding the cooking reduction factor, separate advice may be tailored to those who do not cook or clean according to OEHHA recommendations. OEHHA maintains that using a 10^{-4} risk level

best balances the cancer risks and benefits (health and economic) of sport fish consumption as well as the risks of alternate protein sources that might be consumed in place of sport fish. Setting the risk level at $1x10^{-5}$ or $1x10^{-6}$ would restrict fish consumption to the extent that it could largely deny fishers the numerous health benefits that can be accrued by fish consumption. OEHHA does not agree with the premise that "sensitive subpopulations" are not accounted for in the advisory process. All consumers who follow the advice are equally protected based on known sensitivities. When there is compelling evidence that women or children are more susceptible to a contaminant (e.g., mercury), the advisories provide separate advice for their protection.

Commenter 5
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Clean Water Act Biologist
Environmental Contaminants Branch
Division of Environmental Quality
U.S. Fish and Wildlife Service
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Arlington, VA 22203

Comment 5.1
This is a wonderfully well done report that should be viewed as "state of the art" in its niche.

Comment 5.2
"Avians" is not an accepted noun.

Response 5.2
Changed "avians" to birds.

Comment 5.3
It would be helpful to provide the reference dose as µg/day, in addition to mg/kg-day, to facilitate comparison to the RDA.

Response 5.3
Additional units included.

Comment 5.4
Is the advice for reducing consumption by approximately one-fourth for skin-on fillets really applicable to selenium?

Response 5.4
Language altered to indicate that, of the chemicals evaluated, reduction of contaminant levels by cooking and skinning is only applicable to chlorinated hydrocarbons, rather than "organics" as stated.

Comment 5.5
The equations presented on page 39 result in calculated outcomes expressed on a ppm (mg/kg) basis, yet the summary table of outcomes, Table 1, presents everything on a ppb basis. It would be an improvement to make the equations and outcomes table internally consistent.

Response 5.5
The equations include mg/kg units because the reference doses and cancer slope factors are presented in those units. Conversion factors were included in the equations to change the outcome units to ppb (µg/kg), to coincide with the most convenient way of expressing fish contaminant levels as presented in Table 1 and Table 2.

Comment 5.6
The selenium screening value is expressed on a wet weight basis. Many historic fish tissue databases are expressed on a dry weight basis without corresponding percent moistures and, thus, there is no way to convert the values to a wet weight basis. EPAs new tissue-based chronic criterion value for selenium will be issued on a dry weight basis. It would be useful to provide a conversion to dry weight basis for a range of fish species.

Response 5.6
Screening values have been eliminated from the document. However, fish collected for human health assessments must be based on wet weight analysis; dry weight data for individual or composite fish samples are not consistently available. OEHHA will leave developing national conversion factors for multiple species to other agencies.

Commenter 6
David McBride
Office of Environmental Health Assessments
Division of Environmental Health
Washington State Department of Health
P.O. Box 47846
Olympia, WA 94504

Comment 6.1
Overall the document read well and its purpose was clearly stated. Calculations of GTLs and screening level values were checked and consistent with our calculations. Appropriate studies are cited to support your selection of toxicity criteria.

Comment 6.2
Within the introduction, it may be useful to give subheadings to the sections dealing with the development of screening level values and for establishing GTLs. A brief description of the equation for deriving GTLs for cancer endpoints similar to the noncancer equation would be useful. The differences in the two equations could be explained, briefly describing the differences in averaging times used in the two calculations.

Response 6.2
An equation for deriving GTLs (now ATLs) for cancer endpoints was included. The SVs are no longer included in the final document.

Comment 6.3
Within the introduction, it would be helpful to list major data sources and give a brief description of the programs that they are collected under. Fish tissue collection and analysis is often conducted for reasons other than to evaluate human health concerns. Therefore, the adequacy of the database should first be determined.

Response 6.3
This information is outside the scope of this document. It is presented in the Health Advisory and Safe Eating Guidelines for each water body. Recommendations for sampling are included in the report "General Protocol for Sport Fish Sampling and Analysis," by Gassel and Brodberg, 2006.

Comment 6.4
A summary table should be included with the contaminants of concern and their corresponding cancer and noncancer values separate from the GTL calculated concentrations.

Response 6.4
Cancer and noncancer values are presented in at least two places in the document, including Table 1. OEHHA feels that including another separate table of these values is not necessary, given that they are clearly presented in the toxicology profiles and in the derivation of the ATLs.

Comment 6.5
A brief discussion on the consumption rate used to establish screening level values. What are they based on and what populations do they protect or not protect?

Response 6.5
The screening values have been removed from the final document.

Comment 6.6
The discussion of the Guidance Tissue Levels for the various contaminants is easy to follow and provides appropriate background on use of various parameters considered.

Comment 6.7
Consider graphing contaminant meal recommendations with contaminant concentrations.

Response 6.7
Graphs were presented by the commenter as another way of looking at GTLs (now ATLs). We didn't find that these added to the clarity or usefulness of the document.

Comment 6.8
We find that people often get hung up on the numbers such as GTLs but are unaware that these values are generally a starting point in determining what the recommended meal limits should be. Left out of the discussion is the risk management and risk communication aspects in evaluating fish.

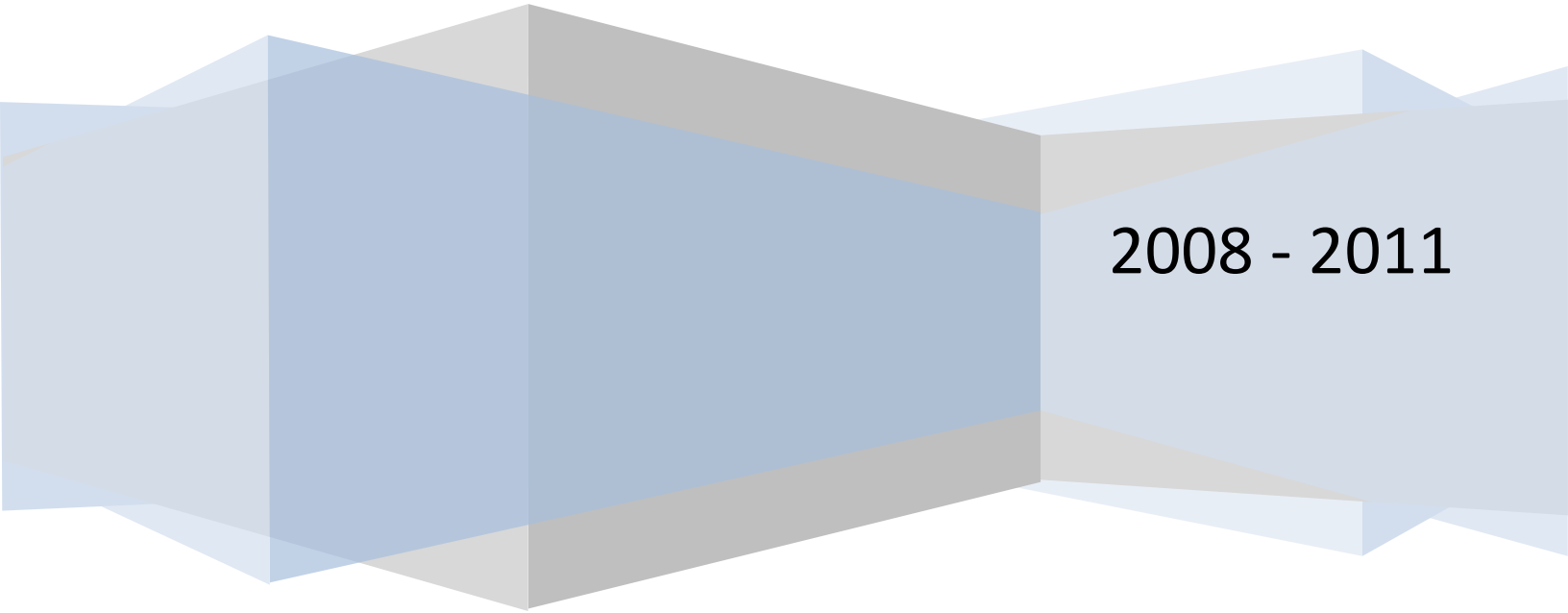
Response 6.8
OEHHA agrees that the ATLs are just a starting point for developing fish consumption guidelines. We have attempted to strengthen the language in the document to make that point. A brief discussion of risk communication has been added to the document, but risk communication details are developed as part of individual safe eating guidelines for specific water bodies.

State of Oregon Department of Environmental Quality

Human Health Criteria Issue Paper

Toxics Rulemaking

Prepared by: Andrea Matzke, Debra Sturdevant, and Jennifer Wigal



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Human Health Criteria Issue Paper

Toxics Rulemaking

A. Introduction

Purpose of this issue paper

DEQ's currently effective human health toxics criteria are based on a fish consumption rate (FCR) that does not adequately protect Oregonians based on the amount of fish and shellfish they are known to consume. On June 1, 2010, EPA disapproved Oregon's human health toxics criteria that were submitted for approval in 2004 and were based on a fish consumption rate of 17.5 grams per day (g/d). EPA disapproved the human health toxics criteria because the fish consumption rate used to calculate the criteria does not protect Oregonians based on the amount of fish and shellfish they are known to consume. DEQ is addressing EPA's disapproval by proposing to use a higher, more protective fish consumption rate of 175 g/d in its calculation of revised human health toxics criteria. If DEQ does not promulgate revised standards in a timely manner addressing EPA's disapproval, EPA must conduct rulemaking to promulgate human health toxics criteria for Oregon.

This issue paper includes information relevant to DEQ's development of proposed human health toxics criteria based on a higher fish consumption rate. It also describes the human health toxics criteria methodology used to calculate criteria. Proposed changes will affect the criteria values contained in Tables 20, 33A, and 33B, as well as the narrative toxics provision in OAR 340-041-0033 (Toxic Substances).

B. Background

B.1. Brief History of EPA's Recommended Human Health Toxics Criteria

The Clean Water Act requires EPA to publish recommended water quality criteria based upon the most recent science. States typically use these values in developing their own water quality standards regulations. In 1986, EPA published a compilation of these values in the Quality Criteria for Water 1986[1], also known as the "Gold Book." In 1992, EPA promulgated water quality criteria for toxic pollutants for 14 States. These updated criteria became known as the National Toxics Rule[2] and differed substantially from the EPA Gold Book. In 1995, EPA applied the methodology and data used in the Great Lakes Water Quality Initiative[3] to derive new national aquatic life criteria for 15 toxic pollutants in freshwater. In 1999, EPA published the next major update of water quality criteria[4]. In 2000, EPA promulgated water

[1] EPA. Quality Criteria for Water, 1986 (Gold Book). EPA 440/5-86-001

[2] EPA. Federal Register, Volume: 57, Issue: 246, Page: 60848 (57 FR 60848), Tuesday, December 22, 1992.

[3] EPA. Federal Register, Volume: 60, Number 56, Page: 15365, March 23, 1995.

[4] EPA. National Recommended Water Quality Criteria—Correction. EPA 822-Z-99-001.

quality criteria for toxic pollutants for California known as the California Toxics Rule[5] and also in that same year published a revised methodology[6] for deriving human health criteria. EPA did not publish a summary criteria table to accompany the revised methodology. Since 2000, EPA has updated the human health criteria for some individual compounds as well (e.g. cadmium). In late 2002, EPA published another major update[7] of criteria values using the EPA revised human health methodology, which included more extensive criteria revisions for 15 other toxic pollutants.

B.2. Oregon 2004 Submission of Water Quality Standards

In 1999, DEQ initiated a Water Quality Standards Review (triennial review) to update DEQ toxics criteria based on the 1986 EPA Gold Book (contained in Table 20 of Oregon's water quality standards). This review was completed in 2003. During this review, DEQ made significant revisions to both the aquatic life and human health criteria based on the updated EPA methodologies and science for deriving aquatic life and human health criteria (as described above) that had occurred since the Gold Book had been published. DEQ's criteria that it adopted in 2004 reflected an increase in the fish consumption rate from 6.5 g/d to 17.5 g/d, based on the rate used EPA's national criteria recommendations. However, despite being based on this higher fish consumption rate, some of the 2004 criteria were actually less stringent than Oregon's previous criteria due to updated scientific information affecting other factors that go into calculating human health criteria. To be consistent with the federal requirements, DEQ specified that the criteria that were less stringent than the older Table 20 criteria were not effective for Clean Water Act purposes until after EPA approval.

The Environmental Quality Commission (commission) adopted these new and revised water quality standards on May 20, 2004. Upon adoption, DEQ submitted these criteria changes along with revisions to the narrative toxics provision to EPA on July 8, 2004.

EPA did not act on these revised water quality standards, and a lawsuit was filed on April 7, 2006 noting EPA's failure to act on Oregon's revised human health water quality criteria among other revisions. On May 29, 2008, a U.S. District Court in the District of Oregon issued a consent decree setting forth deadlines by which EPA must take action on Oregon's 2004 water quality standards submission, under Section 303(c) of the CWA (*Northwest Environmental Advocates v. U.S. EPA,* No. 06-479-HA (D. Or. 2006)). The court subsequently issued several extensions of the applicable deadlines for action. The consent decree's applicable deadline for EPA action on the human health criteria was ultimately extended to June 1, 2010.

[5] EPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California. Federal Register, Volume: 65, Number 97, Page: 31682, May 18, 2000.
[6] EPA. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). EPA-822-B-00-004, October 2000.
[7] EPA. Revision of National Recommended Water Quality Criteria. Federal Register, Volume: 67, Number 249, Page 79091-79095, December 27, 2002.

B.3. EPA Action on Oregon's 2004 Submission of Human Health Toxics Criteria

B.3.1. Disapproved Human Health Criteria

On June 1, 2010, EPA concluded that human health criteria based on a fish consumption rate of 17.5 g/d were not protective of Oregon's designated use of fishing, and thus, did not protect Oregonians who consume higher levels of fish. Consequently, EPA disapproved the majority of the human health criteria that were based on 17.5 g/d (i.e. 48 non-carcinogens and 55 carcinogens). Accompanying footnotes to the disapproved criteria were subsequently disapproved as well. For specific details on EPA's actions, refer to EPA's Technical Support Document[8] accompanying its action.

Oregon's water quality standards included a provision specifying that if a value in Table 33A was disapproved by EPA, the corresponding value in Table 20 would become effective immediately. Values that were the same in Tables 20 and 33A would remain in effect. Consequently, as a result of EPA's disapproval, DEQ's human health toxics criteria reverted back to Table 20 values which are largely based on a fish consumption rate of 6.5 g/d. The few exceptions where EPA did approve criteria from DEQ's 2004 adoption are noted below in the "Approved Human Health Criteria" section.

Under CWA Section 303(c)(3) and EPA's regulations at 40 CFR Parts 131.21 and 131.22, if EPA disapproves a state's new or revised water quality standards, it must "specify the changes" necessary to meet the applicable requirements of the Act and EPA's regulations. If the state does not adopt necessary changes, EPA must propose and promulgate appropriate changes. In the EPA letter[9] disapproving DEQ's 2004 submission, EPA indicated that revising the human health toxics criteria based on a higher fish consumption rate of 175 g/d will address the EPA's disapproval. This rate represents the value that DEQ recommended to the commissioners at the October 23, 2008 Environmental Quality Commission meeting and that they subsequently directed DEQ to use in its revisions. For more information on DEQ's recommended fish consumption rate, see section C.

B.3.2. Approved Human Health Criteria

The human health criteria identified in this section that EPA approved on June 1, 2010, will be included in the new Table 40 along with the proposed human health criteria.

1. **Human health criteria for copper and asbestos**

   Copper

   The "water + organism" criterion of 1300 ug/L is consistent with EPA's 304(a) recommendation and was therefore approved by EPA. Since human health risks from copper are primarily from

[8] EPA. Technical Support Document for Action on the State of Oregon's New and Revised Human Health Water Quality Criteria for Toxics and Revisions to Narrative Toxics Provisions Submitted on July 8, 2004. June 1, 2010.
[9] EPA. Mike Bussell, EPA Region 10 Division Director to Neil Mullane, DEQ Water Quality Division Administrator. EPA's Action on New and Revised Human Health Water Quality Criteria for Toxics and Revisions to Narrative Toxics Provisions in Oregon's Water Quality Standards. June 1, 2010

drinking water and not fish consumption, the lower fish consumption rate of 17.5 g/d was not relevant to EPA's decision.

Asbestos
The "water + organism" criterion of 7,000,000 fibers/L is consistent with EPA's 304(a) recommendation and was therefore approved by EPA. Since human health risks from copper are primarily from drinking water and not fish consumption, the lower fish consumption rate of 17.5 g/d was not relevant to EPA's decision.

2. Footnote K insofar as it applies to the "water + organism" human health criteria for iron and manganese

Footnote K states: "Human Health criterion is for "dissolved" concentration based on the 1976 EPA Red Book conclusion that adverse effects from exposure at this level are aesthetic rather than toxic." EPA approved this footnote for the "water + organism" criteria for both iron and manganese, but disapproved the footnote for the manganese "organism only" criterion because EPA could not ensure the protectiveness of using the dissolved form of manganese. In a separate rulemaking for manganese, DEQ therefore, expressed the criterion as an "organism only" total manganese criterion for marine waters. The criterion is based on human health toxicity endpoints related to the consumption of marine mollusks.

In same rulemaking, DEQ withdrew the "water + organism" iron and manganese human health criteria and the "organism only" manganese criterion for fresh waters. The criteria were not based on levels needed to protect human health. Rather, the primary effects considered were aesthetic (e.g., taste and laundry staining). Iron and manganese are a naturally occurring earth metals that sometimes exceeded the previous criteria due to natural background levels.

The Environmental Quality Commission adopted the revisions to the iron and manganese criteria on December 9, 2010. The revisions are reflected in the new Table 40 and will become applicable upon EPA approval.

3. Withdrawal of the human health criteria for eight toxic pollutants

Consistent with EPA's action under the National Toxics Rule, Oregon withdrew its human health criteria for the following toxic pollutants and was approved by EPA:

- Beryllium
- Cadmium
- Chromium III
- Chromium VI
- Lead
- Mercury
- Silver

- Trichloroethane 1, 1, 1

4. Revisions to the narrative toxic provisions at OAR 340-041-0033(1) and (2).

Revisions to OAR 340-041-0033(1) were approved by EPA as minor editorial changes. Revisions to (2) describe effective dates for human health and aquatic life toxics criteria in Tables 20, 33A and 33B.

B.4. Applicability of EPA's June 2010 Action to 2011 Proposed Human Health Criteria Revisions

In the current effort to develop the human health criteria proposed revisions, DEQ generally relied on the scientific information, policy decisions, and subsequent recommendations from the 1999 triennial review and 2004 submission as the basis for these human health criteria revisions. The major difference between criteria that were submitted in 2004 and the proposed 2011 criteria is the fish consumption rate (i.e. 175 g/d versus 17.5 g/d). In addition, DEQ is not proposing any revisions to the aquatic life criteria. These criteria were adopted and submitted to EPA in 2004 and are still undergoing Endangered Species Act consultation by EPA, the U.S. Fish and Wildlife Service, and NOAA's National Marine Fisheries Service and are not the subject of this review.

C. Development of a Fish Consumption Rate

C.1. Background

DEQ's water quality standards play an important role in maintaining and restoring the environmental quality and quality of life that Oregonians value. Human health criteria are used to limit the amount of toxic pollutants that enter Oregon's waterways and accumulate in the fish and shellfish consumed by many Oregonians as a traditional and/or healthful lifestyle. Human health criteria help to ensure that people may eat fish and shellfish (from here forward referred to as "fish") from local waters without incurring unacceptable health risks.

In 2004, the commission, at DEQ's recommendation, adopted water quality criteria based on EPA's 2002 recommended toxic pollutants criteria for aquatic life and for human health. The human health criteria were based on a fish consumption rate of 17.5 g/d, which represents the 90th percentile of consumption among consumers and non-consumers of fish nationwide. Prior to adopting the 2004 revisions, DEQ's human health criteria were based on EPA's 1986 recommended criteria and a fish consumption rate of 6.5 g/d. A fish consumption rate of 17.5 g/d equals about 0.6 ounces per day or three 6-ounce meals per month. Based on concerns that the fish consumption rate used in the EPA criteria may not accurately represent Oregonian's consumption patterns, the commission requested that DEQ seek resources to conduct a fish consumption rates study in Oregon.

Following DEQ's 2004 adoption of EPA's recommended criteria, concerns about Oregon's human health criteria heightened. Native American tribal governments objected to the criteria, stating that the criteria

did not protect tribal members who eat much greater amounts of fish and for whom fish consumption is a critical part of their cultural tradition and religion. Tribes have rights to catch fish in Oregon waters and EPA has a trust responsibility to protect the interests of the tribes. The Oregon tribes who were most involved in the fish consumption rate workshops and discussions and the subsequent rulemaking process include the Umatilla, Warm Springs, Klamath, Siletz and Grand Ronde tribes.

Although DEQ's 2004 human health criteria reflected EPA's guidance contained in the Human Health Methodology including use of 17.5 g/d as a default value, the guidance also recommends using local fish consumption data when it is available. In this circumstance, local data was available from a study conducted by the Columbia River Inter-Tribal Fish Commission [10] or "CRITFC Study", which included surveys of four Columbia River Tribes, two of whom reside in Oregon, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Confederated Tribes of the Warms Springs Reservation.

C.2. Fish Consumption Rate Review Project

For the above reasons and with the recognition that many Oregonians eat more than 17.5 g/d of fish and shellfish, DEQ embarked on a project to review the fish consumption rate and subsequently revise the human health water quality criteria for Oregon. DEQ was not able to obtain funding for a study of Oregon fish consumption rates, so the review was based on available literature and data.

DEQ launched the fish consumption rate review project in the fall of 2006 and conducted seven workshops in cooperation with the EPA and the Confederated Tribes of the Umatilla Indian Reservation. The objective for these workshops was to allow any member of the public to receive and provide input on the information being gathered and evaluated, and express views on the policy issues inherent in choosing a fish consumption rate.

DEQ also formed two workgroups, the Human Health Focus Group (HHFG), to assist with gathering and evaluating relevant information. The Human Health Focus Group, made up of public health professionals and toxicologists, reviewed the available data on fish consumption patterns in the Pacific Northwest and elsewhere. The group wrote a report[11] summarizing the science and made recommendations about the quality and appropriate use of the available information. DEQ considered the HHFG's analysis in its selection of a fish consumption rate. The report, materials and agendas from the HHFG process, are contained on DEQ's website.

C.3. Choosing an Appropriate Fish Consumption Rate

Oregon's existing human health criteria are based either on a defined acceptable level of cancer risk (1 in 1,000,000 additional incidents of cancer) or a reference dose beyond which effects in test populations begin to be observed. People who eat more fish have a greater probability of incurring a health effect

[10] Columbia River Inter-Tribal Fish Commission. October 1994. A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin. Technical Report 94.3.
[11] Human Health Focus Group Report. Oregon Fish and Shellfish Consumption Rate Project. June 2008.

from this exposure to contaminants and those who eat less fish will have less risk. As the fish consumption rate increases, the water quality criteria values will decrease and the costs to meet requirements associated with the revised criteria may rise. How much the criterion for any given pollutant will change with a change in the fish consumption rate also depends on the degree to which that pollutant accumulates in fish tissue. Therefore, a ten-fold increase in the fish consumption rate will not necessarily result in a ten-fold decrease for all criteria; the change in the criteria will vary by pollutant.

A major policy decision inherent in developing human health criteria is whether to base the criteria on a fish consumption rate that includes Oregonians who eat large amounts of fish and shellfish for cultural, economic, health or other reasons, or whether to use a fish consumption rate reflective of Oregon's total population, including people who do not eat fish or eat it rarely. A related decision is what proportion or percentile of the population(s) to base the fish consumption rate on. Within any group, whether Native-Americans, Asian-Americans or commercial fishermen, there will be some individuals who eat more than any chosen rate and some who eat less than that rate.

An additional issue discussed during this process was whether to include salmon (an anadromous fish) and/or marine fish in the consumption rate. The Human Health Focus Group recommended that DEQ include salmon and marine fish in the fish consumption rate because these fish are an important part of the fish diet in the Northwest and represent a potential source of exposure to contaminants. In addition, they found that for non-carcinogens, given the status of the relative source contribution (RSC) approach and values, it would be more accurate to account for the consumption of marine fish in the consumption rate than to use the RSCs in deriving criteria for non-carcinogens. Counter arguments to including (or fully counting) salmon and marine fish in the fish consumption rate assert that these fish accumulate most of their contaminant body burden in ocean waters, outside the influence of Oregon's water quality standards and pollution controls. In addition, salmon tend to contain lower levels of contaminants than resident fish. DEQ ultimately recommended that salmon be included in the rate given the large number of Oregonians who traditionally consume large amounts of salmon and noted that they represent a potential path of exposure to toxic pollutants. Consequently, the recommended rate reflects consumption of salmon and lamprey relative to rates documented in the CRITFC study (to protect at least 95% of fish consumers in Oregon), as well as marine fish and shellfish relative to the rates documented in the Puget Sound studies (to protect at least 90% of fish consumers in Oregon).

C.4. DEQ Recommendation on Selecting a Fish Consumption Rate

DEQ determined that a fish consumption rate of 175 g/d is a reasonable and protective fish consumption rate to use as the basis for Oregon's human health criteria. A fish consumption rate of 175 g/d equals approximately 6.2 ounces per day (or approximately 23 8-oz fish or shellfish meals per month). This rate represents the 95th percentile value from the Columbia River Inter-Tribal Fish Commission study and is within the range of the 90th percentile values from various studies from the Northwest assembled by the HHFG. The 175 g/d rate is consistent with the HHFG recommendation to use 90th or 95th percentile values to represent the proportion of the population the criteria should be

designed to protect. It is also consistent with HHFG recommendations to use a fish consumption rate that represents fish consumers only, rather than a rate derived from the overall population including both consumers and non-consumers of fish, and to include salmon and other marine species in the rate.

Another question raised during the 2004 water quality standards review was whether Oregon should use different fish consumption rates for basins or water bodies that reflect consumption patterns in those areas. Although the Technical Advisory Committee proposed applying different consumption rates for different geographic areas within the state, DEQ did not recommend this option based on the following considerations:

- While there is data only for the Umatilla and Warm Springs Tribes in Oregon, studies from the Pacific Northwest and elsewhere show that many Tribes and other groups (e.g. Asian Americans) eat moderate to large amounts of fish. Input at public workshops indicates that there may be other groups that eat large amounts of fish as well, such as commercial or sport fishermen.
- Nearly all the major river basins in Oregon are usual and accustomed fishing areas for an Oregon Tribe.
- People may catch fish in many locations around the state, not just in the river basin in which they live.
- Having different criteria in different basins would create complexities in the regulations and their implementation.

The EPA, CTUIR, and DEQ collaborated on this project throughout the process and issued a joint recommendation[12] to the Environmental Quality Commission on October 23, 2008, to revise Oregon's toxics criteria for human health based on a FCR of 175 g/d. The commission agreed with this recommendation and directed DEQ to proceed with this fish consumption rate as a basis for revising human health criteria.

D. New and Revised Human Health Water Quality Criteria

D.1. Technical Review Process for 2004 Submission

During the development of the 2004 water quality standards revisions, the Technical Advisory Committee (TAC) reviewed EPA's 2000 Methodology in comparison to the 1980 methodology used to derive Table 20 toxics criteria.

The formulae in the 2000 EPA Methodology used to calculate the criteria values differed from those in the 1980 EPA methodology by:

[12] DEQ. October 6, 2008 Memo from Dick Peterson, Director DEQ, to the Environmental Quality Commission. Agenda Item G, Action Item: Oregon's Fish Consumption Rate – For Use in Setting Water Quality Standards for Toxic Pollutants October 23, 2008 commission Meeting.

1) the addition of a new formula to calculate criteria for compounds where the mode of carcinogenicity shows a non-linear relationship between dose and effect;
2) the use of a bioaccumulation factor rather than bioconcentration factor (bioconcentration refers to the uptake and retention of a chemical from the water only; bioaccumulation refers to the uptake and retention of a chemical from all the surrounding environment, e.g. water, food, and sediment); and
3) the use of a new fish consumption rate.

Unless otherwise specified, DEQ relied on the review and decisions made during the development of the 2004 water quality standards to form the technical basis of revising criteria for this rulemaking. The major difference is the use of a higher fish consumption rate of 175 g/d.

D.2. Applicability of "water + organism" and "organism only" Criteria

The criteria calculations for both carcinogens and non-carcinogens differ depending upon the exposure scenario for which the criteria are derived. Oregon's criteria were developed to protect human health from long term exposure to toxic pollutants in drinking water and through eating fish and shellfish contaminated with toxics. The "water + organism" criteria refer to values that if met, ensure exposure through the consumption of drinking water and fish, including shellfish does not result in adverse health effects. The "organism only" criteria refer to values that if met, ensure exposure through the consumption of fish and shellfish only does not result in adverse health effects. These criteria apply where Oregon has designated waters as either a public or private domestic water supply, or as a fishing beneficial use. Generally, the majority of Oregon's waterbodies have been designated as both a domestic or private domestic water supply and as a fishing beneficial use. Therefore, human health toxics criteria will be widely applicable across the state. Table 1 indicates where the "organism only" criteria are the only human health criteria applicable, since a drinking water use has not been designated in these waters (e.g. non-potable estuarine waters).

TABLE 1: Waters Where "Organism Only" Criteria are Solely Applicable: Waters designated as having a fishing use, but not a domestic or private water supply

Table Reference Number	Basin	Segment Name
140A	Goose and Summer Lakes Basin	Goose Lake; and Highly Alkaline and Saline Lakes
190A	Malheur Lake Basin	Natural Lakes
220A	Mid Coast Basin	Estuaries and Adjacent Marine Waters
230A	North Coast Basin	Estuaries and Adjacent Marine Waters
271A	Rogue Basin	Rogue River Estuary and Adjacent Marine Waters; and Bear Creek Main Stem
286A	Sandy Basin	Streams Forming Waterfalls Near Columbia River Highway
300A	South Coast Basin	Estuaries and Adjacent Marine Waters
320A	Umpqua Basin	Umpqua River Estuary to Head of Tidewater and Adjacent Marine Waters

D.3. Criteria Derivation

The methodology for calculating human health toxics criteria takes into consideration three major factors: risk assessment, exposure, and to what degree the pollutant accumulates in fish tissue. Risk assessment includes the potency of the compound to cause a toxic effect that is either cancerous or noncancerous, and for cancer causing compounds, the level of risk that is acceptable for society (e.g. one additional cancer per million people). Exposure includes consideration of body weight, water intake, and fish intake. Bioconcentration is the degree to which an organism accumulates the contaminant from water only, while bioaccumulation describes the net accumulation of a contaminant from all sources.

D.3.1. Non-Carcinogens

DEQ utilized the 2000 Methodology to derive ambient water quality criteria for pollutants. This section describes how DEQ used the methodology as it applies to non-carcinogens.

Equation for Non-Carcinogens:

$$AWQC = RfD \times RSC \times \frac{(BW)}{[DI + (FCR \times BAF)]}$$

where:

AWQC = Ambient Water Quality Criterion (mg/L)

RfD = Reference dose for noncancer effects (mg/kg-day)

RSC = Relative source contribution factor to account for non-water sources of exposure

BW = Human body weight (kg) =70 kg

DI = Drinking water intake (L/day) = 2 L/day

FCR = Fish consumption rate (kg/d) = 175 g/d

BAF = Bioaccumulation factor (L/kg)

Body Weight and Drinking Water Intake

DEQ used EPA's national default values for body weight (70 kilograms or 154 lbs) and drinking water intake (2 L/day). DEQ also relied on EPA's reference doses used as part of its nationally recommended criteria[13]. A reference dose is defined[14] as an estimate (with uncertainty spanning approximately an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects over a lifetime.

[13] EPA. 2002. Nationally Recommended Water Quality Criteria 2002 – Human Health Criteria Calculation Matrix. USEPA, Office of Water, Washington, DC. EPA 822-R-02012.

[14] EPA. 1993. Reference Dose (RfD): Description and Use in Health Risk Assessments. Integrated Risk Information System (IRIS). Intra-Agency Reference Dose (RfD) Work Group, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, USEPA, Cincinnati, OH.

Bioconcentration Factors (BCF) Versus Bioaccumulation Factors (BAF)

Water quality criteria for the protection of human health are derived, in part, by considering human exposure to pollutants that have been stored within fish after that fish has been exposed to a toxic pollutant. A BCF accounts for the uptake of a pollutant by a fish from the surrounding water, while a BAF accounts for the uptake of a pollutant from all sources (including the surrounding water, food, and sediment). While the consideration of a BAF in EPA's 2000 Methodology was considered an improvement over BCFs, developing BAFs is a complex process and can vary from site to site. EPA has not yet developed a national list of BAFs for its nationally recommended criteria. Consequently, EPA recommends criteria be developed using BCFs until such time local or regional BAFs that would be applicable to Oregon are developed. As a result, proposed criteria for this rulemaking reflect EPA recommended BCF values.

Reference Dose (RfD)

A reference dose is an estimate (with uncertainty spanning approximately an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects over a lifetime[15]. Proposed criteria for this rulemaking reflect EPA recommended RfD values. Reference Dose values are based on real studies that reflect health effects from these pollutants at specific levels.

Relative Source Contribution

Criteria for pollutants that are non-carcinogens are based on a total cumulative dose over time that causes an observable effect. Because the human health water quality criteria address exposure only through drinking water and eating fish, a relative source contribution (RSC) factor is used to calculate the criteria. The RSC identifies or estimates the portion of total exposure attributed to water and fish consumption, and therefore, accounts for potential exposure from other sources, such as skin absorption, inhalation, other foods and occupational exposures. The RSC value is either multiplied by the reference dose or subtracted from the reference dose, depending on the chemical and known exposure sources of contaminants. Table 2 identifies the pollutants for which DEQ applied RSC values to the revised human health water quality criteria. For all of the pollutants but Endrin, DEQ used EPA's recommended RSC value. The other non-carcinogen pollutants used a RSC of 1, which indicates that all of the exposure to that pollutant is assumed to come from water and fish ingestion. In some cases, EPA does not have enough data to establish RSC values for other chemicals.

TABLE 2: Criteria Where Relative Source Contribution Values Were Applied

1) Antimony (40%)	9) Thallium (20%)
2) Chlorobenzene (20%)	10) Toluene (20%)
3) Chlorodibromomethane (80%)	11) 1,1,2-Trichloroethane (20%)

[15] EPA. Reference dose (RfD): Description and use in health risk assessments. Integrated Risk Information System (IRIS). Online. Intra-Agency Reference Dose (RfD) Work Group, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office. Cincinnati, OH. March 15, 1993.

4) Cyanide (20%)	12) 1,1-Dichloroethylene (20%)
5) Endrin (80%)	13) 1,2,4-Trichlorobenzene (20%)
6) Ethylbenzene (20%)	14) 1,2-Dichlorobenzene(o) (20%)
7) gamma-BHC (Lindane) (20%)	15) 1,2-trans-Dichloroethylene (20%)
8) Hexachlorocyclopentadiene (20%)	16) 1,4-Dichlorobenzene(p) (20%)

RSC for Methylmercury

EPA established a RSC value that is subtracted from the reference dose to derive the tissue based methyl mercury criterion. EPA's recommended criterion uses a RSC because EPA's national default fish consumption rate does not include the consumption of marine species of fish (including Pacific salmon), which are a significant potential exposure route for methylmercury. Because the primary human route of exposure to methylmercury comes from ingestion of fish and shellfish, and because DEQ included marine species in the development of its fish consumption rate, it would be "double counting" the exposure if DEQ incorporated the same RSC value used in EPA's recommended methylmercury criterion. Methylmercury is unique in that it is a fish tissue criterion and the primary route of exposure to humans is through the consumption of fish and shellfish. The other criteria where RSC values have been established have other contributing sources of pollutant (e.g., consumption of food or other exposure routes), so removing the RSC would not be appropriate in those circumstances.

RSC for Endrin

EPA used a default RSC value of 20% for Endrin based on a recommendation from EPA's drinking water program. DEQ's final proposed criteria for Endrin use a RSC value of 80%. The primary reason DEQ proposes using an alternate default value is because DEQ does not anticipate exposure to this chemical outside of water and fish ingestion. This is consistent with EPA guidance for use of default RSC values:

> Default RSC Percentage Values: Floor of 20%, Ceiling of 80% (65 FR 66472)
> - EPA has recommended using the 20% RSC default when routes of water exposures other than oral or sources of exposure other than fish and water are anticipated, but adequate data are lacking to quantify those exposures.
> - Utilize local data to quantify exposures from other routes where available: When data are adequate to quantify exposures to other sources (oral or exposure to fish and water), EPA recommends that they be used instead of the default 20% RSC value.
> - If it can be demonstrated that other sources and routes of exposure are not anticipated for the chemical in question (based on information about its known/anticipated uses and chemical/physical properties), then the 80% ceiling is recommended. This 80% ceiling is a way to provide adequate protection for those who experience exposures (from any or several sources) higher than available data may indicate.

Due to the properties of this chemical and the fact that it has not been in use for about 25 years, it is highly unlikely that people in Oregon would gain only 20% of their exposure to Endrin from water and fish and 80% of their exposure from other sources. Endrin bioconcentrates in aquatic organisms, but is not very soluble in water. The bioconcentration factor used to derive the human health criteria is 3970,

resulting in the same criteria value (when rounded to significant digits) for water + organism and for organism only ingestion.

The following information from the US Department of Health and Human Services Toxicological Profile for Endrin (1996, Chapter 5) supports DEQ's decision to use an RSC of 80% rather than 20% to derive Oregon's water quality criteria:

- The use of Endrin ended in the mid-1980s and "consequently, there are no longer any significant releases of Endrin to the environment in the United States."
- "Information on current levels of Endrin in the environment is limited; however, the available data indicate that concentrations in all environmental media are generally negligible or below levels of concern. "
- "The FDA has concluded that Endrin is no longer present in the environment to the extent that it may be contaminating food or feed at levels of regulatory concern (USDA 1995)."
- Endrin tends to persist in the environment mainly in forms sorbed to sediments and soil particles. A conservative estimate of its half-disappearance time in sandy loam soils is approximately 14 years. "Therefore, the exposure risks from Endrin to the general population of the United States are likely to steadily decrease over time."
- Limited information on the physical and/or chemical properties of Endrin aldehyde indicates that it is highly insoluble in water (EPA 1981a), highly immobile in soil, and will not volatilize significantly from water or soil.
- Endrin has been found to volatilize significantly (20-30%) from soils within days after application (Nash 1983). Because Endrin has not been in use for many years, this exposure route no longer occurs in Oregon.
- The main sources for potential human exposure to Endrin are residues on imported food items, unused stocks, unregistered use, inappropriate disposal, and hazardous waste sites; however, there is no current evidence of significant exposures from any of these sources. Furthermore, it should be noted that in environmental media, especially in contaminated soils and sediments, the amount of Endrin chemically identified by analysis is not necessarily the amount that is toxicologically available.
- Endrin was identified at 102 and Endrin ketone was identified at 37 of 1430 current or former hazardous waste sites in the United States. None of these sites were in Oregon (Figures 5-1 and 5-2).

D.3.2. Carcinogens

DEQ utilized the 2000 Methodology to derive ambient water quality criteria for pollutants that are carcinogens.

Equation for linear dose-response carcinogens:

$$AWQC = \frac{(Risk\ Level \times BW)}{[CSF \times (DI + (FCR \times BAF))]}$$

where:

AWQC = Ambient Water Quality Criterion (mg/L)

Risk Level = Risk Level (unitless)

CSF = Cancer slope factor (mg/kg-day)

BW = Human body weight (kg) =70 kg

DI = Drinking water intake (L/day) = 2 L/day

FCR = Fish consumption rate (kg/d) = 175 g/d

BAF = Bioaccumulation factor (L/kg)

The equation to derive ambient water quality criteria for pollutants that are carcinogens (i.e. cancer-causing pollutants) uses many of the same variables as the equation for non-carcinogens (i.e. body weight, drinking water intake, fish consumption rate, and bioaccumulation factor). The main difference is that a risk level and a cancer slope factor are used, and a relative source concentration is not used.

Cancer Slope Factor and Risk Level

The cancer slope factor is a measure of chemical potency. For most cancer-causing chemicals there is no toxicity threshold or reference dose. Because carcinogenic chemicals are thought to initiate the cancer process at almost any concentration, a dose-response parameter referred to as the cancer slope factor is used for chemicals that display toxic behavior such that the carcinogenic risk increases linearly as the chemical dose increases. Cancer slope factors are specific to individual pollutants. DEQ utilized EPA's nationally recommended slope factors to calculate criteria for carcinogens. Cancer slope factors are based on real studies that reflect health effects from carcinogenic pollutants at specific levels.

Risk estimates for carcinogens are expressed as the incremental probability of developing cancer (e.g., an additional one in one million chance of developing cancer) over a lifetime of exposure to potential carcinogens. EPA has identified a risk level range of 1×10^{-6} (1 in 1,000,000) to 1×10^{-5} (1 in 100,000) to be an appropriate risk management goal for the general population, as long as the most sensitive population is protected at 1×10^{-4} (1 in 10,000). As a matter of policy, DEQ has historically chosen to protect Oregonians at a risk level of 1×10^{-6} and will continue with this recommendation for the proposed human health toxics criteria. As a result, the proposed criteria will protect highly exposed populations in Oregon consuming up to 175 g/d of fish at a risk level of 1×10^{-6}.

D.3.3. Criteria Not Dependent on a Fish Consumption Rate

Although the majority of DEQ's proposed human health criteria are affected by the fish consumption rate, several of Oregon's existing criteria are not based on a fish consumption rate. For these criteria,

human health risks are primarily from drinking water and the existing criteria are based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act. Therefore, DEQ has not developed any "organism only" criteria. As a result, DEQ is not proposing to change the existing human health criteria identified in Table 3.

TABLE 3: Human health toxics criteria not dependent on a fish consumption rate

Asbestos	Methoxychlor
Barium	Nitrates
Chlorophenoxy Herbicide (2,4,5,-TP)	Copper
Chlorophenoxy Herbicide (2,4,-D)	Manganese

D.3.4. Toxics Criteria DEQ is Proposing to Withdraw

The following toxics pollutants have currently effective human health criteria, however, there are no longer EPA criteria for these pollutants. In some cases, like PAHs, the revised criteria include individual species of the more toxic forms of PAH, rather than a single criterion for a chemical family. Therefore, DEQ's proposed final rule withdraws the human health criteria for these pollutants.

TABLE 4: Pollutants for which DEQ Proposes to Withdraw Criteria

Dinitrotoluene
Dinitro-o-Cresol 2,4
Diphenylhydrazine
Halomethanes
Monochlorobenzene
Polynuclear Aromatic Hydrocarbons (PAHs)
Endosulfan

Based on information gathered during the public comment period, DEQ learned it had inadvertently included a "benzene range" as part of Table 40. In addition, DEQ included revisions to the "benzene" criteria that are single values. In investigating the basis for the "benzene range" DEQ identified that EPA does not have any recommended criteria for a "benzene range" and noted that DEQ has no precedent for expressing criteria as a range of values. Further investigations show there is a range of values presented in EPA's IRIS database for the cancer slope factor associated with benzene associated with the use of different modeling methods for the data. The cancer slope factor used for the development of the benzene criteria is consistent with the factor EPA used in deriving the national benzene criterion. Given this information, including both the "benzene range" criteria in addition to the benzene criteria is duplicative. As a result, DEQ removed the benzene range criteria from Table 40.

D.3.5. Proposed Toxics Criteria Additions

DEQ's final proposed rules add criteria for 39 toxic pollutants to the human health criteria table. DEQ included criteria for these pollutants in its 2004 water quality standards based on updated EPA criteria,

but EPA subsequently disapproved those criteria on June 1, 2010, because of an inadequate fish consumption rate. Revised criteria for these pollutants now reflect a fish consumption rate of 175 g/d.

TABLE 5: Pollutants for Which DEQ Proposes to Add Criteria

Acenapthene	Dimethyl phenol 2,4
Anthracene	Dinitrophenol 2,4
Benzene [represents range]	Dinitrophenols
Benz(a)anthracene	Diphenylhydrazine 1,2
Benzo(a)pyrene	Endosulfan alpha
Benzo(b)fluoranthene 3,4	Endosulfan beta
Benzo(k)fluoranthene	Endosulfan sulfate
Bromoform	Endrin aldehyde
Butylbenzyl phthalate	Fluorene
Chlorodibromomethane	Heptachlor epoxide
Chloronaphthalene 2	Indeno(1,2,3-cd)pyrene
Chlorophenol 2	Methyl bromide
Chrysene	Methyl-4,6-dinitrophenol 2
DDD 4, 4'	Methylene chloride
DDE 4, 4'	Methylmercury (mg/kg)
Dibenz(a,h)anthracene	Nitrosodi-n-propylamine, n
Dichlorobenzene(p) 1,4	Pyrene
Dichlorobromomethane	Trichlorobenzene 1,2,4
Dichloroethylene trans 1,2	Zinc
Dichloropropane	

D.3.6. Less Stringent Toxics Criteria

Although the majority of proposed toxics criteria are more stringent than the currently effective values based on a higher fish consumption rate, several of the criteria values became less stringent. As new risk-based data and studies become available, EPA updates risk values (e.g. cancer slopes, reference doses, bioconcentration factors) associated with exposure to environmental contaminants in EPA's IRIS (Integrated Risk Information System) database. DEQ, unless otherwise specified, used EPA's default values in IRIS as the basis for revising criteria. For the pollutants identified in Table 6, changes to values other than the fish consumption rate resulted in proposed criteria that were less stringent than current criteria despite utilizing a higher fish consumption rate.

TABLE 6: Less Stringent Toxics Criteria

Chloroform
Nickel
Phenol
Selenium

E. New, Revised, and Removed Footnotes

DEQ included new or removed footnotes for some human health criteria in Table 40. The majority of these footnotes clarify the source of information upon which the proposed criteria are based. Several of these footnotes with similar language were proposed as part of the 2004 water quality standards submittal, but were subsequently disapproved in conjunction with EPA's disapproval of the associated criteria.

TABLE 7: New Footnotes

Toxic Pollutant	New Footnote
1. Arsenic	This footnote was not included as part of the separate rulemaking for arsenic which was adopted by the EQC on April 21, 2011. A new footnote is now proposed to clarify how arsenic is expressed, as well as the associated risk level the criteria are based upon. *The arsenic criteria are expressed as total inorganic arsenic. The "organism only" criteria are based on a risk level of approximately of 1.1 x 10^{-5}, and the "water + organism" criterion is based on a risk level of 1 x 10^{-4}*
2. Asbestos	*The human health risks from asbestos are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*
3. Barium	*The human health criterion for barium is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*
4. Chlorophenoxy Herbicide (2,4,5,-TP)	*The Chlorophenoxy Herbicide (2,4,5,-TP) criterion is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*
5. Chlorophenoxy Herbicide (2,4-D)	*The Chlorophenoxy Herbicide (2,4-D) criterion is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also*

Toxic Pollutant	New Footnote
	published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.
6. Cyanide	*The cyanide criterion is expressed as total cyanide (CN)/L.*
7. Di-2-ethylhexyl Phthalate	*Di-2-ethylhexyl Phthalate was previously known as Bis-2-ethylhexyl phthalate*
8. Methoxychlor	*The human health criterion for methoxychlor is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*
9. Methylmercury	*This value is expressed as the fish tissue concentration of methylmercury. Contaminated fish and shellfish is the primary human route of exposure to methylmercury*
10. PCBs	*This criterion applies to total PCBs (e.g. determined by Aroclors or congeners)*

TABLE 5: Revised Footnotes

Toxic Pollutant	Current Footnote	Revised Footnote
1. Copper	*This value is based on a Drinking Water regulation.*	*Human health risks from copper are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*

Toxic Pollutant	Current Footnote	Revised Footnote
2. Nitrates	*No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.*	*The human health criterion for nitrates is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*

TABLE 6: Footnotes Removed

Bioconcentration factors for the three toxic pollutants in Table 6 are now available and were used to calculate criteria. For this reason, DEQ removed the footnotes because they are no longer applicable.

Toxic Pollutant	Current Footnote To Be Removed
1. Hexachlorocyclo-hexane-Technical	*No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.*
2. Nitrosamines	*No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.*
3. N-Nitrosodiethylamine	*No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.*

F. Proposed Redline/Strikethrough Revisions to the Toxic Substances Rule

DEQ proposed several changes to 340-041-0033 in the rules DEQ published for public comment. The proposed revisions addressed the separation of the aquatic life criteria and the human health criteria in different tables. In addition, DEQ proposed a "Background Pollutant Allowance" for public comment.

In the revisions shown below, DEQ reorganized provisions relating to the aquatic life criteria and the human health criteria as separate sections. In addition, DEQ added a new section (1) specifying that the 112 toxics human health criteria revised by this rule are not applicable for purposes of the Clean Water Act until they are approved by EPA. This section also applies to the revised iron, manganese, and arsenic criteria the commission adopted in December 2010 and April 2011, respectively.

The provisions addressing background pollutants (now termed "Site-Specific Background Pollutant Criteria") remain in OAR 340-041-0033(6). These revisions are discussed in the *Implementing Water*

Quality Standards in NPDES Permits issue paper, and therefore, are not included in the revisions shown below.

In April 2011, EQC also adopted the arsenic reduction policy as OAR 340-041-0033(3). To accommodate revisions associated with this rulemaking, DEQ reorganized the rule to move the arsenic reduction policy section further back in this rule to OAR 340-041-0033(7), but did not revise any of the rule as adopted by the commission.

340-041-0033

Toxic Substances

(1) Amendments to sections (4) and (6) of this rule (OAR 340-041-0033) and associated revisions to Tables 20, 33A, 33B and 40 do not become applicable for purposes of ORS chapter 468B or the federal Clean Water Act unless and until they are approved by EPA pursuant to 40 CFR 131.21 (4/27/2000).

(~~1~~2) Toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare or aquatic life, wildlife, or other designated beneficial uses.

(~~2~~3) Aquatic Life Criteria. Levels of toxic substances in waters of the state may not exceed the applicable aquatic life criteria listed in Tables 20, 33A, and 33B. Tables 33A and 33B, adopted on May 20, 2004, update Table 20 as described in this section.

(a) Each value for criteria in Table 20 is effective until the corresponding value in Tables 33A or 33B becomes effective.

(A) Each value in Table 33A is effective on February 15, 2005, unless EPA has disapproved the value before that date. If a value is subsequently disapproved, any corresponding value in Table 20 becomes effective immediately. Values that are the same in Tables 20 and 33A remain in effect.

(B) Each value in Table 33B is effective upon EPA approval.

~~(b) The arsenic criteria in Table 20 established by this rule do not become applicable for purposes of ORS chapter 468B or the federal Clean Water Act unless and until they are approved by EPA pursuant to 40 CFR 131.21 (4/27/2000).~~

(~~c~~b) The department will note the effective date for each value in Tables 20, 33A, and 33B as described in this section.

~~(3) To establish permit or other regulatory limits for toxic substances for which criteria are not included in Tables 20, 33A, or 33B, the department may use the guidance values in Table 33C, public health advisories, and other published scientific literature. The department may also require or conduct bio-~~

assessment studies to monitor the toxicity to aquatic life of complex effluents, other suspected discharges, or chemical substances without numeric criteria.

(4) Arsenic Reduction Policy: The inorganic arsenic criterion for the protection of human health from the combined consumption of organisms and drinking water is 2.1 micrograms per liter. While this criterion is protective of human health and more stringent than the federal maximum contaminant level (MCL) for arsenic in drinking water, which is 10 micrograms per liter, it nonetheless is based on a higher risk level than the Commission has used to establish other human health criteria. This higher risk level recognizes that much of the risk is due to naturally high levels of inorganic arsenic in Oregon's waterbodies. In order to maintain the lowest human health risk from inorganic arsenic in drinking water, the Commission has determined that it is appropriate to adopt the following policy to limit the human contribution to that risk.

(a) The arsenic reduction policy established by this rule section does not become applicable for purposes of ORS chapter 468B or the federal Clean Water Act unless and until the numeric arsenic criteria established by this rule are approved by EPA pursuant to 40 CFR 131.21 (4/27/2000).

(b) It is the policy of the Commission that the addition of inorganic arsenic from new or existing anthropogenic sources to waters of the state within a surface water drinking water protection area be reduced the maximum amount feasible. The requirements of this rule section [OAR 340-041-0033(4)] apply to sources that discharge to surface waters of the state with an ambient inorganic arsenic concentration equal to or lower than the applicable numeric inorganic arsenic criteria for the protection of human health.

(c) The following definitions apply to this section [OAR 340-041-0033(4)]:

(A) "Add inorganic arsenic" means to discharge a net mass of inorganic arsenic from a point source (the mass of inorganic arsenic discharged minus the mass of inorganic arsenic taken into the facility from a surface water source).

(B) A "surface water drinking water protection area," for the purpose of this section, means an area delineated as such by DEQ under the source water assessment program of the federal Safe Drinking Water Act, 42 U.S.C. § 300j-13. The areas are delineated for the purpose of protecting public or community drinking water supplies that use surface water sources. These delineations can be found at DEQ's drinking water program website.

(C) "Potential to significantly increase inorganic arsenic concentrations in the public drinking water supply source water" means:

(i) to increase the concentration of inorganic arsenic in the receiving water for a discharge by 10 percent or more after mixing with the harmonic mean flow of the receiving water; or

(ii) as an alternative, if sufficient data are available, the discharge will increase the concentration of inorganic arsenic in the surface water intake water of a public water system by 0.021 micrograms per liter or more based on a mass balance calculation.

~~*(d) Following the effective date of this rule, applications for an individual NPDES permit or permit renewal received from industrial dischargers located in a surface water drinking water protection area and identified by DEQ as likely to add inorganic arsenic to the receiving water must include sufficient data to enable DEQ to determine whether:*~~

~~*(A) The discharge in fact adds inorganic arsenic; and*~~

~~*(B) The discharge has the potential to significantly increase inorganic arsenic concentrations in the public drinking water supply source water.*~~

~~*(e) Where DEQ determines that both conditions in subsection (d) of this section (4) are true, the industrial discharger must develop an inorganic arsenic reduction plan and propose all feasible measures to reduce its inorganic arsenic loading to the receiving water. The proposed plan, including proposed measures, monitoring and reporting requirements, and a schedule for those actions, will be described in the fact sheet and incorporated into the source's NPDES permit after public comment and DEQ review and approval. In developing the plan, the source must:*~~

~~*(A) Identify how much it can minimize its inorganic arsenic discharge through pollution prevention measures, process changes, wastewater treatment, alternative water supply (for groundwater users) or other possible pollution prevention and/or control measures;*~~

~~*(B) Evaluate the costs, feasibility and environmental impacts of the potential inorganic arsenic reduction and control measures;*~~

~~*(C) Estimate the predicted reduction in inorganic arsenic and the reduced human health risk expected to result from the control measures;*~~

~~*(D) Propose specific inorganic arsenic reduction or control measures, if feasible, and an implementation schedule; and*~~

~~*(E) Propose monitoring and reporting requirements to document progress in plan implementation and the inorganic arsenic load reductions.*~~

~~*(f) In order to implement this section, DEQ will develop the following information and guidance within 120 days of the effective date of this rule and periodically update it as warranted by new information:*~~

~~*(A) A list of industrial sources or source categories, including industrial stormwater and sources covered by general permits, that are likely to add inorganic arsenic to surface waters of the State.*~~

~~*(i) For industrial sources or source categories permitted under a general permit that have been identified by DEQ as likely sources of inorganic arsenic, DEQ will evaluate options for reducing inorganic arsenic during permit renewal or evaluation of Stormwater Pollution Control Plans.*~~

~~*(B) Quantitation limits for monitoring inorganic arsenic concentrations.*~~

~~*(C) Information and guidance to assist sources in estimating, pursuant to paragraph (d) (C) of this section, the reduced human health risk expected to result from inorganic arsenic control measures based on the most current EPA risk assessment.*~~

~~*(g) It is the policy of the Commission that landowners engaged in agricultural or development practices on land where pesticides, fertilizers, or soil amendments containing arsenic are currently being or have previously been applied, implement conservation practices to minimize the erosion and runoff of inorganic arsenic to waters of the State or to a location where such material could readily migrate into waters of the State.*~~

(4) Human Health Criteria. The criteria for waters of the state listed in Table 40 are established to protect Oregonians from potential adverse health effects associated with long-term exposure to toxic substances associated with consumption of fish, shellfish, and water.

(~~3~~5) To establish permit or other regulatory limits for toxic substances for which criteria are not included in Tables 20, 33A, or 33B, the department may use the guidance values in Table 33C, public health advisories, and other published scientific literature. The department may also require or conduct bio-assessment studies to monitor the toxicity to aquatic life of complex effluents, other suspected discharges, or chemical substances without numeric criteria.

(6) Establishing Site-Specific Background Pollutant Criteria: ….

(4~~7~~) Arsenic Reduction Policy: …

[ED. NOTE: Tables referenced are available from the agency.]

Stat. Auth.: ORS 468.020, 468B.030, 468B.035 & 468B.048
Stats. Implemented: ORS 468B.030, 468B.035 & 468B.048
Hist.: DEQ 17-2003, f. & cert. ef. 12-9-03; DEQ 3-2004, f. & cert. ef. 5-28-04; DEQ 17-2010, f. & cert. ef. 12-21-10

G. Implementation

G.1. Effective Dates

DEQ is proposing that the human health criteria revisions established by OAR 340-041-0033 and shown in Table 40 do not become applicable for purposes of ORS chapter 468B or the federal Clean Water Act until approved by EPA pursuant to 40 CFR 131.21 (4/27/2000).

In contrast, for DEQ's 2004 water quality standards submission, the revised toxics criteria became effective for NPDES purposes nine months following the date of commission adoption. DEQ also specified that if the values were subsequently disapproved after that date, any corresponding value in Table 20 would become effective. EPA disapproved the majority of DEQ's 2004 human health criteria on June 1, 2010, nearly six years after the effective date. As a result, many of the criteria adopted in 2004 that had become effective subsequently reverted back to human health criteria based on a FCR of 6.5 g/day. Given the potential ramifications of criteria becoming effective in advance of EPA's action, DEQ is proposing that the human health criteria only become applicable for CWA programs upon EPA approval, rather than at the time of commission adoption.

G.2. NPDES Compliance

Dischargers will not need to modify existing permits to immediately incorporate new limits or requirements associated with the revised criteria at the time of EPA approval if that approval occurs during their permit cycle. However, at the time of permit renewal, permits will be evaluated and water quality-based effluent limitations (WQBELs) will be developed or revised in the renewed permit, if needed, to meet revised water quality criteria.

G.3. Methylmercury

In January 2001, EPA published a new water quality criterion for methylmercury that, for the first time, expresses a human health criterion as a concentration in fish and shellfish tissue rather than in the water. In 2004, the EQC adopted a tissue-based methylmercury criterion to replace its previous mercury water column criteria, but it was subsequently disapproved by EPA based on a fish consumption rate that was too low (i.e. 17.5 g/day). DEQ's final proposed rules includes a revised methylmercury fish tissue criterion based on a fish consumption rate of 175 g/day. Because the adoption of tissue-based criteria can pose challenges in implementing the criteria, DEQ has begun exploring options for incorporating the new criteria into various DEQ programs. Generally, DEQ intends to develop implementation procedures similar to EPA's *Guidance for Implementing the January 2001 Methylmercury Criterion*.

G.3.1. NPDES Permitting

DEQ intends to develop implementation procedures based on EPA's *Guidance for Implementing the January 2001 Methylmercury Criterion*. A variety of situations exist throughout Oregon that are addressed in EPA's implementation guidance, including waterbodies with mercury TMDLs, waters listed as impaired without TMDLs, and other waters with insufficient methylmercury data. DEQ will use the options as described in EPA's guidance to develop additional detail regarding how DEQ will implement the new criterion in various circumstances, once adopted by the Environmental Quality Commission and approved by EPA.

G.3.1.2. TMDLs

DEQ intends to make use of EPA's guidance in developing TMDLs and notes that it is fairly flexible and provides DEQ with several options. However, the guidance is written to address waterbodies that are dominated by direct air deposition of mercury, as found in the mid-west and east coast states. In contrast, Oregon is not dominated by direct air deposition of mercury.

In addition to EPA's Guidance, DEQ may also utilize EPA Region 10's Mercury Reduction Strategy in implementing a methylmercury criterion of which DEQ was a key stakeholder in the development of this strategy. Additionally, implementation may include the results of Region 10's *"Development of a Monitoring Guide to Support Water-Resource Assessments for Mercury within EPA Region X"*. This work may help answer questions related to mercury methylation and bioaccumulation in fish tissue.

Oregon's methylmercury criterion implementation strategy from a TMDL perspective would:

- Utilize an environmentally relevant analytical approach that could be conducted on a seasonal basis and include general water and sediment quality parameters that are known to methylate mercury, which could allow for a spatially appropriate bioaccumulation factor to be calculated.
- Focus either on a regional or grouped (likely basin scale) spatial approach that would evaluate both mercury loading and methylmercury methylation.
- Spatially detailed models could be used that are dynamic for modeling fate and transport of both mercury and methylmercury, or a simplified regression model depending on the amount of data available for the analytical area.
- A linked model approach may be likely, especially in data rich areas such as the Willamette Basin. This method would include the use of EPA models: GBMM, WASP, and / or BASS
- Fish tissue could be monitored at a frequency of every 5 years at a minimum(DEQ is already developing a statewide baseline with the Toxics Monitoring Program).
- Relative source contribution analysis would include REMSAD air modeling from EPA for both far field (Asia) and near-field (in-basin sources) analysis.

Further discussion with EPA and DEQ staff in implementing the methylmercury criterion will occur following the commission's adoption of the rules.

G.4. Quantitation Limits

Approximately 48 percent of the proposed human health criteria have Quantification Limits (QLs) that are higher than the criterion. For that reason, pollutants may occur in Oregon's waterbodies at concentrations greater than the proposed criteria that cannot be measured given limitations in analytical methods. As a point of reference, approximately 40 percent of the currently effective criteria have QLs that are higher than the criterion. For permitting purposes, the QL becomes the compliance point for dischargers. Consequently, if the criterion for a particular pollutant becomes more stringent, but the QL remains higher than the criterion, there would be no effective change in the point of compliance until and unless analytical methods improve. Historically, the pace of change in laboratory methods has not been rapid. However, when methods do improve, there will likely be additional toxics impairment listings and more stringent water quality based effluent limits (WQBELs) for permit holders.

G.5. Effective Toxics Criteria Tables

DEQ is proposing a new Table 40 which will only contain criteria applicable to human health. Human health criteria will be deleted from Table 20, Table 33A, and Table 33B. These tables will remain a part of Oregon's water quality standards and only contain the aquatic life criteria. Once EPA takes action on the aquatic life criteria, DEQ will take action to combine the aquatic life criteria in Tables 20, 33A, and Table 33B into one table containing all of the aquatic life criteria.

Appendix A. Table 20 Redline/Strikethrough

TABLE 20

AQUATIC LIFE WATER QUALITY CRITERIA SUMMARY[1]

The concentration for each compound listed in Table 20 is a criterion not to be exceeded in waters of the state in order to protect aquatic life ~~and human health~~. All values are expressed as micrograms per liter (µg/L) except where noted. Compounds are listed in alphabetical order with the corresponding designations as to whether EPA has identified it as a priority pollutant and a carcinogen, aquatic life freshwater acute and chronic criteria, and aquatic life marine acute and chronic criteria, ~~human health water & organism and fish consumption only criteria, and Drinking Water Maximum Contaminant Level (MCL)~~. The acute criteria refer to the average concentration for one (1) hour and the chronic criteria refer to the average concentration for 96 hours (4 days), and that these criteria should not be exceeded more than once every three (3) years.

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
ACENAPTHENE	Y	~~N~~							
ACROLEIN	Y	~~N~~					~~320ug~~	~~780ug~~	

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
ACRYLONITRILE	Y	~~Y~~					~~0.058ug**~~	~~0.65ug**~~	
ALDRIN	Y	~~Y~~	3		1.3		~~0.074ng**~~	~~0.079ng**~~	
ALKALINITY	N	~~N~~		20,000					
AMMONIA	N	~~N~~	CRITERIA ARE pH AND TEMPERATURE DEPENDENT—SEE DOCUMENT USEPA JANUARY 1985 (Fresh Water) CRITERIA ARE pH AND TEMPERATURE DEPENDENT—SEE DOCUMENT USEPA APRIL 1989 (Marine Water)						
ANTIMONY	Y	~~N~~					~~146ug~~	~~45,000ug~~	
ARSENIC	Y	~~Y~~					~~2.2ng**~~	~~17.5ng**~~	~~0.05mg~~
ARSENIC (PENT)	Y	~~Y~~							
ARSENIC (TRI)	Y	~~Y~~	360	190	69	36			
ASBESTOS	Y	~~Y~~					~~30K f/L**~~		
BARIUM	N	~~N~~					~~1mg~~		~~1.0mg~~
BENZENE	Y	~~Y~~					~~0.66ug**~~	~~40 ug**~~	
BENZIDINE	Y	~~Y~~					~~0.12ng~~	~~0.53ng**~~	
BERYLLIUM	Y	~~Y~~					~~6.8ng**~~	~~117ng**~~	
BHC	Y	~~N~~							

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
CADMIUM	Y	~~N~~	3.9+	1.1+	43	9.3	~~10ug~~		~~0.010mg~~
CARBON TETRACHLORIDE	Y	~~Y~~					~~0.4ug**~~	~~6.94ug**~~	
CHLORDANE	Y	~~Y~~	2.4	0.0043	0.09	0.004	~~0.46ng**~~	~~0.48ng**~~	
CHLORIDE	N	~~N~~	860 mg/L	230 mg/L					
CHLORINATED BENZENES	Y	~~Y~~					~~488 ug~~		
CHLORINATED NAPHTHALENES	Y	~~N~~							
CHLORINE	N	~~N~~	19	11	13	7.5			
CHLOROALKYL ETHERS	Y	~~N~~							
CHLOROETHYL ETHER (BIS-2)	Y	~~Y~~					~~0.03 ug~~	~~1.36 ug**~~	
CHLOROFORM	Y	~~Y~~					~~0.19ug**~~	~~15.7ug**~~	
CHLOROISOPROPYL ETHER (BIS-2)	Y	~~N~~					~~34.7ug~~	~~4.36mg~~	
CHLOROMETHYL ETHER (BIS)	N	~~Y~~					~~0.00000376ng**~~	~~0.00184ug**~~	
CHLOROPHENOL 2	Y	~~N~~							
CHLOROPHENOL 4	N	~~N~~							

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
CHLOROPHENOXY HERBICIDES (2,4,5,-TP)	N	~~N~~					~~10ug~~		
CHLOROPHENOXY HERBICIDES (2,4-D)	N	~~N~~					~~100ug~~		
CHLORPYRIFOS	N	~~N~~	0.083	0.041	0.011	0.0056			
CHLORO-4 METHYL-3 PHENOL	N	~~N~~							
CHROMIUM (HEX)	Y	~~N~~	16	11	1,100	50	~~50ug~~		~~0.05mg~~
CHROMIUM (TRI)	N	~~N~~	1,700.+	210.+			~~170mg~~	~~3,433mg~~	~~0.05mg~~
COPPER	Y	~~N~~	18.+	12.+	2.9	2.9			
CYANIDE	Y	~~N~~	22	5.2	1	1	~~200ug~~		
DDT	Y	~~Y~~	1.1	0.001	0.13	0.001	~~0.024ng**~~	~~0.024ng**~~	
(TDE) DDT METABOLITE	Y	~~Y~~							
(DDE) DDT METABOLITE	Y	~~Y~~							
DEMETON	Y	~~N~~		0.1		0.1			
DIBUTYLPHTHALATE	Y	~~N~~					~~35mg~~	~~154mg~~	

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
DICHLOROBENZENES	Y	~~N~~					~~400ug~~	~~2.6mg~~	
DICHLOROBENZIDINE	Y	~~Y~~					~~0.01ug**~~	~~0.020ug**~~	
DICHLOROETHANE 1,2	Y	~~Y~~					~~0.94ug**~~	~~243ug**~~	
DICHLOROETHYLENES	Y	~~Y~~					~~0.033ug**~~	~~1.85ug**~~	
DICHLOROPHENOL 2,4	N	~~N~~					~~3.09mg~~		
DICHLOROPROPANE	Y	~~N~~							
DICHLOROPROPENE	Y	~~N~~					~~87ug~~	~~14.1mg~~	
DIELDRIN	Y	~~Y~~	2.5	0.0019	0.71	0.0019	~~0.071ng**~~	~~0.076ng**~~	
DIETHYLPHTHALATE	Y	~~N~~					~~350mg~~	~~1.8g~~	
DIMETHYL PHENOL 2,4	Y	~~N~~							
DIMETHYL PHTHALATE	Y	~~N~~					~~313mg~~	~~2.9g~~	
DINITROTOLUENE 2,4	N	~~Y~~					~~0.11ug**~~	~~9.1ug**~~	
DINITROTOLUENE	Y	~~N~~					~~70ug~~	~~14.3mg~~	
DINITROTOLUENE	N	~~Y~~							
DINITRO-O-CRESOL 2,4	Y	~~N~~					~~13.4~~	~~765ug~~	
DIOXIN (2,3,7,8-TCDD)	Y	~~Y~~					~~0.000013ng**~~	~~0.000014ng**~~	

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
DIPHENYLHYDRAZINE	Y	~~N~~					~~42ng**~~	~~0.56ug**~~	
DIPHENYLHYDRAZINE 1,2	Y	~~N~~							
DI-2-ETHYLHEXYL PHTHALATE	Y	~~N~~					~~15mg~~	~~50mg~~	
ENDOSULFAN	Y	~~N~~	0.22	0.056	0.034	0.0087	~~74ug~~	~~159ug~~	
ENDRIN	Y	~~N~~	0.18	0.0023	0.037	0.0023	~~1ug~~		~~0.0002mg~~
ETHYLBENZENE	Y	~~N~~					~~1.4mg~~	~~3.28mg~~	
FLUORANTHENE	Y	~~N~~					~~42ug~~	~~54ug~~	
GUTHION	N	~~N~~		0.01		0.01			
HALOETHERS	Y	~~N~~							
HALOMETHANES	Y	~~Y~~					~~0.19ug**~~	~~15.7ug**~~	
HEPTACHLOR	Y	~~Y~~	0.52	0.0038	0.053	0.0036	~~0.28ng**~~	~~0.29ng**~~	
HEXACHLOROETHANE	N	~~Y~~					~~1.9ug~~	~~8.74ug~~	
HEXACHLOROBENZENE	Y	~~N~~					~~0.72ng**~~	~~0.74ng**~~	
HEXACHLOROBUTADIENE	Y	~~Y~~					~~0.45ug**~~	~~50ug**~~	
HEXACHLOROCYCLOHEXANE (LINDANE)	Y	~~Y~~	2	0.08	0.16				~~0.004mg~~

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
HEXACHLOROCYCLOHEXANE-ALPHA	Y	~~Y~~					~~9.2ng**~~	~~31ng**~~	
HEXACHLOROCYCLOHEXANE-BETA	Y	~~Y~~					~~16.3ng**~~	~~54.7ng**~~	
HEXACHLOROCYCLOHEXANE-GAMA	Y	~~Y~~					~~18.6ng**~~	~~62.5ng**~~	
HEXACHLOROCYCLOHEXANE-TECHNICAL	Y	~~Y~~					~~12.3ng**~~	~~41.4ng**~~	
HEXACHLOROCYCLOPENTADIENE	Y	~~N~~					~~206ug~~		
IRON	N	~~N~~		1,000			~~0.3mg~~		
ISOPHORONE	Y	~~N~~					~~5.2mg~~	~~520mg~~	
LEAD	Y	~~N~~	82.+	3.2+	140	5.6	~~50ug~~		~~0.05mg~~
MALATHION	N	~~N~~		0.1		0.1			
MANGANESE	N	~~N~~					~~50ug~~	~~100ug~~	
MERCURY	Y	~~N~~	2.4	0.012	2.1	0.025	~~144ng~~	~~146ng~~	~~0.002mg~~
METHOXYCHLOR	N	~~N~~		0.03		0.03	~~100ug~~		~~0.1mg~~
MIREX	N	~~N~~		0.001		0.001			
MONOCHLOROBENZENE	Y	~~N~~					~~488ug~~		
NAPHTHALENE	Y	~~N~~							

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
NICKEL	Y	~~N~~	1,400.+	160+	75	8.3	~~13.4ug~~	~~100ug~~	
NITRATES	N	~~N~~					~~10mg~~		~~10mg~~
NITROBENZENE	Y	~~N~~					~~19.8mg~~		
NITROPHENOLS	Y	~~N~~							
NITROSAMINES	Y	~~Y~~					~~0.8ng**~~	~~1,240ng**~~	
NITROSODIBUTYLAMINE N	Y	~~Y~~					~~6.4ng**~~	~~587ng**~~	
NITROSODIETHYLAMINE N	Y	~~Y~~					~~0.8ng**~~	~~1,240ng**~~	
NITROSODIMETHYLAMINE N	Y	~~Y~~					~~1.4ng**~~	~~16,000ng**~~	
NITROSODIPHENYLAMINE N	Y	~~Y~~					~~4,900ng**~~	~~16,100ng**~~	
NITROSOPYRROLIDINE N	Y	~~Y~~					~~16ng**~~	~~91,900ng**~~	
PARATHION	N	~~N~~	0.065	0.013					
PCB's	Y	~~Y~~	2	0.014	10	0.03	~~0.079ng**~~	~~0.079ng**~~	
PENTACHLORINATED ETHANES	N	~~N~~							
PENTACHLOROBENZENE	N	~~N~~					~~74ug~~	~~85ug~~	
PENTACHLOROPHENOL	Y	~~N~~	***20	***13	13		~~1.01mg~~		

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
PHENOL	Y	~~N~~					~~3.5mg~~		
PHOSPHORUS ELEMENTAL	N	~~N~~				0.1			
PHTHALATE ESTERS	Y	~~N~~							
POLYNUCLEAR AROMATIC HYDROCARBONS	Y	~~Y~~					~~2.8ng**~~	~~31.1ng**~~	
SELENIUM	Y	~~N~~	260	35	410	54	~~10ug~~		~~0.01mg~~
SILVER	Y	~~N~~	4.1+	0.12	2.3		~~50ug~~		~~0.05mg~~
SULFIDE HYDROGEN SULFIDE	N	~~N~~		2		2			
TETRACHLORINATED ETHANES	Y	~~N~~							
TETRACHLOROBENZENE 1,2,4,5	Y	~~N~~					~~38ug~~	~~48ug~~	
TETRACHLOROETHANE 1,1,2,2	Y	~~Y~~					~~0.17ug**~~	~~10.7ug**~~	
TETRACHLOROETHANES	Y	~~N~~							
TETRACHLOROETHYLENE	Y	~~Y~~					~~0.8ug**~~	~~8.85ug**~~	
TETRACHLOROPHENOL 2,3,5,6	Y	~~N~~							
THALLIUM	Y	~~N~~					~~13ug~~	~~48ug~~	
TOLUENE	Y	~~N~~					~~14.3mg~~	~~424mg~~	

Compound Name (or Class)	Priority Pollutant	~~Carcinogen~~	Concentration in Micrograms Per Liter for Protection of Aquatic Life				~~Concentration in Units Per Liter for Protection of Human Health~~		
			Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	~~Water and Fish Ingestion~~	~~Fish Consumption Only~~	~~Drinking Water M.C.L.~~
TOXAPHENE	Y	~~Y~~	0.73	0.0002	0.21	0.0002	~~0.71ng**~~	~~0.73ng**~~	~~0.005mg~~
TRICHLORINATED EtHANES	Y	~~Y~~							
TRICHLOROETHANE 1,1,1	Y	~~N~~					~~18.4mg~~	~~1.03g~~	
TRICHLOROETHANE 1,1,2	Y	~~Y~~					~~0.6ug**~~	~~41.8ug**~~	
TRICHLOROETHYLENE	Y	~~Y~~					~~2.7ug**~~	~~80.7ug**~~	
TRICHLOROPHENOL 2,4,5	N	~~N~~					~~2,600ug~~		
TRICHLOROPHENOL 2,4,6	Y	~~Y~~					~~1.2ug**~~	~~3.6ug**~~	
VINYL CHLORIDE	Y	~~Y~~					~~2ug**~~	~~525ug**~~	
ZINC	Y	~~N~~	120+	110+	95	86			

MEANING OF SYMBOLS:

g = grams ~~M.C.L = Maximum Contaminant Level~~

mg = milligrams + = Hardness Dependent Criteria (100 mg/L used).

The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. Criteria values for hardness may be calculated from the following formulae (CMC refers to Acute Criteria; CCC refers to Chronic Criteria):

$CMC = (\exp(m_A*[\ln(hardness)] + b_A))*CF$

$CCC = (\exp(m_C*[\ln(hardness)] + b_C))*CF$

Chemical	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.828	0.7852	-3.49
Chromium III	0.819	3.688	0.819	1.561
Copper	0.9422	-1.464	0.8545	-1.465
Lead	1.273	-1.46	1.273	-4.705
Nickel	0.846	3.3612	0.846	1.1645
Silver	1.72	-6.52		
Zinc	0.8473	0.8604	0.8473	0.7614

ug = micrograms

* = Insufficient data to develop criteria; value presented is the L.O.E.L – Lower Observed Effect Level.

ng = nanograms

pg = picograms

f = fibers

Y = Yes

N = No

** = Human health criteria for carcinogens reported for three risk levels. Value presented is the 10-6 risk level, which means the probability of one concern case per million people at the stated concentration.

*** = pH Dependent Criteria (7.8 pH used).

1 = Values in Table 20 are applicable to all basins.

Water and Fish Ingestion

Values represent the maximum ambient water concentration for consumption of both contaminated water and fish or other aquatic organisms.

Fish Ingestion

Values represent the maximum ambient water concentrations for consumption of fish or other aquatic organisms

Appendix B. Table 33A Redline/Strikethrough

TABLE 33A

Note: The Environmental Quality Commission adopted the following criteria on May 20, 2004 to become effective February 15, 2005. However, EPA has not yet (as of June 2006) approved the criteria. Thus, Table 33A criteria may be used in NPDES permits, but not for the section 303(d) list of impaired waters.

AQUATIC LIFE WATER QUALITY CRITERIA SUMMARY[A]

The concentration for each compound listed in Table 33A is a criterion not to be exceeded in waters of the state in order to protect aquatic life ~~and human health~~. All values are expressed as micrograms per liter (µg/L) except where noted. Compounds are listed in alphabetical order with the corresponding EPA number (from National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047), the Chemical Abstract Service (CAS) number, aquatic life freshwater acute and chronic criteria, aquatic life saltwater acute and chronic criteria~~, human health water & organism and organism only criteria~~, and Drinking Water Maximum Contaminant Level (MCL). The acute criteria refer to the average concentration for one (1) hour and the chronic criteria refer to the average concentration for 96 hours (4 days), and that these criteria should not be exceeded more than once every three (3) years.

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
56	Acenaphthene			83329									~~670~~		~~990~~		
57	Acenaphthylene			208968													

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
17	Acrolein			107028									~~190~~		~~290~~		
18	Acrylonitrile			107131									~~0.051~~		~~0.250~~		
102	Aldrin			309002	3 O	X			1.3 O	X			~~0.000049~~		~~0.000050~~		
1 N	Alkalinity						20,000 P										
2 N	Aluminum (pH 6.5 - 9.0)			7429905													
3 N	Ammonia			7664417					D	X	D	X					
58	Anthracene			120127									~~8300~~		~~40000~~		
1	Antimony			7440360									~~5.6~~		~~640~~		
2	Arsenic			7440382													~~0.05mg~~
15	Asbestos			1332214													

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
6 N	Barium			7440393									~~1000~~				~~1.0mg~~
19	Benzene			71432													
59	Benzidine			92875									~~0.00008 6~~		~~0.00020~~		
60	Benzo(a)Anthracene			56553									~~0.0038~~		~~0.018~~		
61	Benzo(a)Pyrene			50328									~~0.0038~~		~~0.018~~		
62	Benzo(b)Fluoranthene			205992									~~0.0038~~		~~0.018~~		
63	Benzo(g,h,i)Perylene			191242													
64	Benzo(k)Fluoranthene			207089									~~0.0038~~		~~0.018~~		
3	Beryllium			7440417													
103	BHC alpha-			319846									~~0.0026~~		~~0.0049~~		
104	BHC beta-			319857									~~0.0091~~		~~0.017~~		
106	BHC delta-			319868													
105	BHC gamma- (Lindane)			58899	0.95		0.08	X	0.16 O								~~0.004mg~~
7 N	Boron			7440428													

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
20	Bromoform			75252									~~4.3~~		~~140~~		
69	Bromophenyl Phenyl Ether 4-																
70	Butylbenzyl Phthalate			85687									~~1500~~		~~1900~~		
4	Cadmium			7440439													~~0.010mg~~
21	Carbon Tetrachloride			56235									~~0.23~~		~~1.6~~		
107	Chlordane			57749	2.4 O	X	0.0043 O	X	0.09 O	X	0.004 O	X					
8 N	Chloride			16887006	860000		230000										
9 N	Chlorine			7782505	19	X	11	X	13	X	7.5	X					
22	Chlorobenzene			108907									~~130~~		~~1600~~		
23	Chlorodibromomethane			124481									~~0.40~~		~~13~~		
24	Chloroethane			75003													

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
65	ChloroethoxyMethane Bis2-			111911													
66	ChloroethylEther Bis2-			111444									~~0.030~~		~~0.53~~		
25	Chloroethylvinyl Ether 2-			110758													
26	Chloroform			67663													
67	ChloroisopropylEther Bis2-			108601													
15 N	ChloromethylEther, Bis			542881											~~0.00029~~		
71	Chloronaphthalene 2-			91587									~~1000~~		~~1600~~		
45	Chlorophenol 2-			95578									~~81~~		~~150~~		
10 N	Chlorophenoxy Herbicide (2,4,5,-TP)			93721									~~10 H~~				
11 N	Chlorophenoxy Herbicide (2,4-D)			94757									~~100 H~~				
72	Chlorophenyl Phenyl Ether 4-			7005723													
12 N	Chloropyrifos			2921882	0.083	X	0.041	X	0.011	X	0.0056	X					

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
																	~~0.05mg~~
5a	Chromium (III)																~~0.05mg~~
5b	Chromium (VI)			18540299													~~0.05mg~~
73	Chrysene			218019									~~0.0038~~		~~0.018~~		
6	Copper			7440508									~~1300 H~~				
14	Cyanide			57125	22 S	X	5.2 S	X	1 S	X	1 S	X	~~140~~		~~140~~		
108	DDT 4,4'-			50293	1.1 O,T	X	0.001 O,T	X	0.13 O,T	X	0.001 O,T	X					
109	DDE 4,4'-			72559									~~0.00022~~		~~0.00022~~		
110	DDD 4,4'-			72548									~~0.00031~~		~~0.00031~~		
14N	Demeton			8065483			0.1	X			0.1	X					
74	Dibenzo(a,h)Anthracene			53703									~~0.0038~~		~~0.018~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism~~ [B]	~~Effective~~	~~Organism only~~ [B]	~~Effective~~	~~Drinking Water M.C.L.~~
75	Dichlorobenzene 1,2-			95501									~~420~~		~~1300~~		
76	Dichlorobenzene 1,3-			541731									~~320~~		~~960~~		
77	Dichlorobenzene 1,4-			106467									~~63~~		~~190~~		
78	Dichlorobenzidine 3,3'-			91941									~~0.021~~		~~0.028~~		
27	Dichlorobromomethane			75274									~~0.55~~		~~17~~		
28	Dichloroethane 1,1-			75343													
29	Dichloroethane 1,2-			107062									~~0.38~~		~~37~~		
30	Dichloroethylene 1,1-			75354									~~330~~		~~7100~~		
46	Dichlorophenol 2,4-			120832									~~77~~		~~290~~		
31	Dichloropropane 1,2-			78875									~~0.50~~		~~15~~		
32	Dichloropropene 1,3-			542756									~~0.34~~		~~21~~		
111	Dieldrin			60571	0.24				0.71 O	X	0.0019 O	X	~~0.000052~~		~~0.000054~~		
79	DiethylPhthalate			84662									~~17000~~		~~44000~~		
47	Dimethylphenol 2,4-			105679									~~380~~		~~850~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism~~ [B]	~~Effective~~	~~Organism only~~ [B]	~~Effective~~	~~Drinking Water M.C.L.~~
80	DimethylPhthalate			131113									~~270000~~		~~1100000~~		
81	Di-n-Butyl Phthalate			84742									~~2000~~		~~4500~~		
49	Dinitrophenol 2,4-			51285									~~69~~		~~5300~~		
27 N	Dinitrophenols			2555058 7									~~69~~		~~5300~~		
82	Dinitrotoluene 2,4-			121142									~~0.11~~		~~3.4~~		
83	Dinitrotoluene 2,6-			606202													
84	Di-n-Octyl Phthalate			117840													
16	Dioxin (2,3,7,8-TCDD)			1746016									~~5.0E-09~~		~~5.1E-09~~		
85	Diphenylhydrazine 1,2-			122667									~~0.036~~		~~0.20~~		
68	EthylhexylPhthalate Bis2-			117817									~~1.2~~		~~2.2~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism~~ [B]	~~Effective~~	~~Organism only~~ [B]	~~Effective~~	~~Drinking Water M.C.L.~~
	Endosulfan				0.22 I,P	X	0.056 I,P	X	0.034 I,P	X	0.0087 I,P	X	~~62 I~~		~~89 I~~		
112	Endosulfan alpha-			959988	0.22 O		0.056 O		0.034 O		0.0087 O		~~62~~		~~89~~		
113	Endosulfan beta-			33213659	0.22 O		0.056 O		0.034 O		0.0087 O		~~62~~		~~89~~		
114	Endosulfan Sulfate			1031078									~~62~~		~~89~~		
115	Endrin			72208	0.086				0.037 O		0.0023 O		~~0.059~~		~~0.060~~		~~0.0002 mg~~
116	Endrin Aldehyde			7421934									~~0.29~~		~~0.30~~		
33	Ethylbenzene			100414									~~530~~		~~2100~~		
86	Fluoranthene			206440													
87	Fluorene			86737									~~1100~~		~~5300~~		
17 N	Guthion			86500			0.01	X			0.01	X					

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
117	Heptachlor			76448	0.52 O	X	0.0038 O	X	0.053 O	X	0.0036 O	X	~~0.00007 9~~		~~0.00007 9~~		
118	Heptachlor Epoxide			1024573	0.52 O		0.0038 O		0.053 O		0.0036 O		~~0.00003 9~~		~~0.00003 9~~		
88	Hexachlorobenzene			118741									~~0.00028~~		~~0.00029~~		
89	Hexachlorobutadiene			87683									~~0.44~~		~~18~~		
91	Hexachloroethane			67721									~~1.4~~		~~3.3~~		
19 N	Hexachlorocyclo-hexane-Technical			319868									~~0.0123 J~~		~~0.0414 J~~		
90	Hexachlorocyclopentadiene			77474									~~40~~		~~1100~~		
92	Ideno1,2,3-(cd)Pyrene			193395									~~0.0038~~		~~0.018~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
20 N	Iron			7439896			1,000	X									
93	Isophorone			78591									~~35~~		~~960~~		
7	Lead			7439921													~~0.05mg~~
21 N	Malathion			121755			0.1	X			0.1	X					
22 N	Manganese			7439965													
8a	Mercury			7439976	2.4	X	0.012	X	2.1	X	0.025	X					~~0.002mg~~
23 N	Methoxychlor			72435			0.03	X			0.03	X	~~100 J~~				~~0.1mg~~
34	Methyl Bromide			74839									~~47~~		~~1500~~		
35	Methyl Chloride			74873													
48	Methyl-4,6-Dinitrophenol 2-			534521									~~13~~		~~280~~		
52	Methyl-4-Chlorophenol 3-			59507													
36	Methylene Chloride			75092									~~4.6~~		~~590~~		
8b	Methylmercury			22967926											~~300ug/kg L~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
24 N	Mirex			2385855			0.001	X			0.001	X					
94	Naphthalene			91203													
9	Nickel			7440020													
25 N	Nitrates			14797558									~~10000 J~~				~~10mg~~
95	Nitrobenzene			98953									~~17~~		~~690~~		
50	Nitrophenol 2-			88755													
51	Nitrophenol 4-			100027													
26 N	Nitrosamines			35576911									~~0.0008 J~~		~~1.24 J~~		
28 N	Nitrosodibutylamine,N			924163									~~0.0063~~		~~0.22~~		
29 N	Nitrosodiethylamine,N			55185									~~0.0008 J~~		~~1.24 J~~		
96	N-Nitrosodimethylamine			62759									~~0.00069~~		~~3.0~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
98	N-Nitrosodiphenylamine			86306									~~3.3~~		~~6.0~~		
30 N	Nitrosopyrrolidine,N			930552									~~0.016~~		~~34~~		
97	N-Nitrosodi-n-Propylamine			621647									~~0.0050~~		~~0.51~~		
32 N	Oxygen, Dissolved			7782447													
33 N	Parathion			56382	0.065	X	0.013	X									
119	Polychlorinated Biphenyls PCBs:			1336363	2 U	X	0.014 U	X	10 U	X	0.03 U	X	~~0.000064 U~~		~~0.000064 U~~		
34 N	Pentachlorobenzene			608935									~~1.4~~		~~1.5~~		
53	Pentachlorophenol			87865	M				13		7.9		~~0.27~~		~~3.0~~		
99	Phenanthrene			85018													
54	Phenol			108952											~~1700000~~		
36 N	Phosphorus Elemental			7723140							0.1						

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
100	Pyrene			129000									~~830~~		~~4000~~		
10	Selenium			7782492											~~4200~~		~~0.01mg~~
11	Silver			7440224													~~0.05mg~~
40 N	Sulfide-Hydrogen Sulfide			7783064			2	X			2	X					
43 N	Tetrachlorobenzene,1,2,4,5			95943									~~0.97~~		~~1.1~~		
37	Tetrachloroethane 1,1,2,2-			79345									~~0.17~~		~~4.0~~		
38	Tetrachloroethylene			127184									~~0.69~~		~~3.3~~		
12	Thallium			7440280									~~0.24~~		~~0.47~~		
39	Toluene			108883									~~1300~~		~~15000~~		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism [B]~~	~~Effective~~	~~Organism only [B]~~	~~Effective~~	~~Drinking Water M.C.L.~~
120	Toxaphene			8001352	0.73	X	0.0002	X	0.21	X	0.0002	X	~~0.00028~~		~~0.00028~~		~~0.005mg~~
40	Trans-Dichloroethylene 1,2-			156605									~~140~~		~~10000~~		
44 N	Tributyltin (TBT)			688733													
101	Trichlorobenzene 1,2,4-			120821									~~35~~		~~70~~		
41	Trichloroethane 1,1,1-			71556													
42	Trichloroethane 1,1,2-			79005									~~0.59~~		~~16~~		
43	Trichloroethylene			79016									~~2.5~~		~~30~~		
45 N	Trichlorophenol 2,4,5			95954									~~1800~~		~~3600~~		
55	Trichlorophenol 2,4,6-			88062											~~2.4~~		
44	Vinyl Chloride			75014									~~0.025~~		~~2.4~~		
13	Zinc			7440666									~~7400~~		~~26000~~		

Footnotes for Tables 33A and 33B:

A Values in Table 20 are applicable to all basins.

~~B Human Health criteria values were calculated using a fish consumption rate of 17.5 grams per day (0.6 ounces/day) unless otherwise noted.~~

C Ammonia criteria for freshwater may depend on pH, temperature, and the presence of salmonids or other fish with ammonia-sensitive early life stages. Values for freshwater criteria (of total ammonia nitrogen in mg N/L) can be calculated using the formulae specified in *1999 Update of Ambient Water Quality Criteria for Ammonia* (EPA-822-R-99-014; http://www.epa.gov/ost/standards/ammonia/99update.pdf):

Freshwater Acute:

salmonids present….CMC = $\frac{0.275}{1+10^{7.204-pH}}+\frac{39.0}{1+10^{pH-7.204}}$

salmonids not present…CMC= $\frac{0.411}{1+10^{7.204-pH}}+\frac{58.4}{1+10^{pH-7.204}}$

Freshwater Chronic:

fish early life stages present

CCC = $\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}$ * $MIN(2.85, 1.45*10^{0.028*(25-T)})$

fish early life stages not present

CCC= $\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}$ * $1.45*10^{0.028*(25-MAX(T,7))}$

Note: these chronic criteria formulae would be applied to calculate the 30-day average concentration limit; in addition, the highest 4-day average within the 30-day period should not exceed 2.5 times the CCC.

D Ammonia criteria for saltwater may depend on pH and temperature. Values for saltwater criteria (total ammonia) can be calculated from the tables specified in *Ambient Water Quality Criteria for Ammonia (Saltwater)--1989* (EPA 440/5-88-004; http://www.epa.gov/ost/pc/ambientwqc/ammoniasalt1989.pdf).

E Freshwater and saltwater criteria for metals are expressed in terms of "dissolved" concentrations in the water column, except where otherwise noted (e.g. aluminum).

F The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. Criteria values for hardness may be calculated from the following formulae (CMC refers to Acute Criteria; CCC refers to Chronic Criteria):

$$CMC = (\exp(m_A*[\ln(hardness)] + b_A))*CF$$

$$CCC = (\exp(m_C*[\ln(hardness)] + b_C))*CF$$

where CF is the conversion factor used for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column.

Chemical	m_A	b_A	m_C	b_C
Cadmium	1.0166	-3.924	0.7409	-4.719
Chromium III	0.8190	3.7256	0.8190	0.6848
Copper	0.9422	-1.700	0.8545	-1.702
Lead	1.273	-1.460	1.273	-4.705
Nickel	0.8460	2.255	0.8460	0.0584
Silver	1.72	-6.59		
Zinc	0.8473	0.884	0.8473	0.884

Conversion factors (CF) for dissolved metals (the values for total recoverable metals criteria were multiplied by the appropriate conversion factors shown below to calculate the dissolved metals criteria):

Chemical	Freshwater		Saltwater	
	Acute	Chronic	Acute	Chronic
Arsenic	1.000	1.000	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]	0.994	0.994
Chromium III	0.316	0.860	--	--
Chromium VI	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]	0.951	0.951
Nickel	0.998	0.997	0.990	0.990
Selenium	0.996	0.922	0.998	0.998
Silver	0.85	0.85	0.85	--
Zinc	0.978	0.986	0.946	0.946

~~G Human Health criterion is the same as originally published in the 1976 EPA Red Book (Quality Criteria for Water, EPA-440/9-76-023) which predates the 1980 methodology and did not use the fish ingestion BCF approach.~~

~~H This value is based on a Drinking Water regulation.~~

I This value is based on criterion published in Ambient Water Quality Criteria for Endosulfan (EPA 440/5-80-046) and should be applied as the sum of alpha- and beta-endosulfan.

~~J No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.~~

~~K Human Health criterion is for "dissolved" concentration based on the 1976 EPA Red Book conclusion that adverse effects from exposure at this level are aesthetic rather than toxic.~~

~~L This value is expressed as the fish tissue concentration of methylmercury.~~

M Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: CMC=(exp(1.005(pH)-4.869); CCC=exp(1.005(pH)-5.134).

N This number was assigned to the list of non-priority pollutants in National Recommended Water Quality Criteria: 2002 (EPA-822-R-02-047).

O This criterion is based on EPA recommendations issued in 1980 that were derived using guidelines that differed from EPA's 1985 Guidelines for minimum data requirements and derivation procedures. For example, a "CMC" derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

P Criterion shown is the minimum (i.e. CCC in water should not be below this value in order to protect aquatic life).

Q Criterion is applied as total arsenic (i.e. arsenic (III) + arsenic (V)).

R Arsenic criterion refers to the inorganic form only.

S This criterion is expressed as µg free cyanide (CN)/L.

T This criterion applies to DDT and its metabolites (i.e. the total concentration of DDT and its metabolites should not exceed this value).

U This criterion applies to total PCBs (e.g. the sum of all congener or all isomer or homolog or Arochlor analyses).

V The CMC=1/[(f1/CMC1)+(f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively.

W The acute and chronic criteria for aluminum are 750 µg/L and 87 µg/L, respectively. These values for aluminum are expressed in terms of "total recoverable" concentration of metal in the water column. The criterion applies at pH<6.6 and hardness<12 mg/L (as $CaCO_3$).

X The effective date for the criterion in the column immediately to the left is 1991.

Y No criterion.

Appendix C. Table 33B Redline/Strikethrough

TABLE 33B

Note: The Environmental Quality Commission adopted the following criteria on May 20, 2004 to become effective on EPA approval. EPA has not yet (as of June 2006) approved these criteria. The Table 33B criteria may not be used until they are approved by EPA.

AQUATIC LIFE WATER QUALITY CRITERIA SUMMARY[A]

The concentration for each compound listed in Table 33A is a criterion not to be exceeded in waters of the state in order to protect aquatic life ~~and human health~~. All values are expressed as micrograms per liter (µg/L) except where noted. Compounds are listed in alphabetical order with the corresponding EPA number (from National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047), the Chemical Abstract Service (CAS) number, aquatic life freshwater acute and chronic criteria, aquatic life saltwater acute and chronic criteria, ~~human health water & organism and organism only criteria~~, and Drinking Water Maximum Contaminant Level (MCL). The acute criteria refer to the average concentration for one (1) hour and the chronic criteria refer to the average concentration for 96 hours (4 days), and that these criteria should not be exceeded more than once every three (3) years.

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				~~Human Health For Consumption of:~~				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	~~Water + Organism~~ [B]	~~Effective~~	~~Organism only~~ [B]	~~Effective~~	
2 N	Aluminum (pH 6.5 - 9.0)			7429905	W		W										
3 N	Ammonia			7664417	C		C										
2	Arsenic			7440382									~~0.018 R~~		~~0.14 R~~		
15	Asbestos			1332214									~~7.0E+06 fibers/Liter~~				

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	Water + Organism [B]	Effective	Organism only [B]	Effective	
19	Benzene			71432									2.2		51		
3	Beryllium			7440417									¥		¥		
105	BHC gamma- (Lindane)			58899									0.98		1.8		
4	Cadmium			7440439	E,F		E,F		40 E		8.8 E		¥				
107	Chlordane			57749									0.00080		0.00081		
	CHLORINATED BENZENES												¥		¥		
26	Chloroform			67663									5.7		470		
67	ChloroisopropylEther Bis2-			108601									1400		65000		
15 N	ChloromethylEther, Bis			542881									0.00010				
5a	Chromium (III)				E,F		E,F						¥				
5b	Chromium (VI)			18540299	16 E		11 E						¥		¥		
6	Copper			7440508	E,F		E,F		4.8 E		3.1 E						
108	DDT 4,4'-			50293									0.00022		0.00022		
	DIBUTYLPHTHALATE												¥		¥		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	Water + Organism [B]	Effective	Organism only [B]	Effective	
	DICHLOROBENZENES												¥		¥		
	DICHLOROBENZIDINE												¥		¥		
	DICHLOROETHYLENES												¥		¥		
	DICHLOROPROPENE												¥		¥		
111	Dieldrin			60571			0.056										
	DINITROTOLUENE												¥		¥		
	DIPHENYLHYDRAZINE												¥		¥		
115	Endrin			72208			0.036										
86	Fluoranthene			206440									130		140		
	HALOMETHANES												¥		¥		
20 N	Iron			7439896									300 K				
7	Lead			7439921	E,F		E,F		210 E		8.1 E		¥				
22 N	Manganese			7439965									50 K		100 K		
8a	Mercury			7439976									¥		¥		

EPA NO.	Compound			CAS Number	Freshwater				Saltwater				Human Health For Consumption of:				
					Acute (CMC)	Effective Date	Chronic (CCC)	Effective Date	Acute (CMC)	Effective Date	Chronic (CCC)	Effective	Water + Organism [B]	Effective	Organism only [B]	Effective	
	MONOCHLOROBENZENE												¥		¥		
9	Nickel			7440020	E,F		E,F		74 E		8.2 E		610		4600		
53	Pentachlorophenol			87865			M										
54	Phenol			108952									21000				
	POLYNUCLEAR AROMATIC HYRDOCARBONS												¥		¥		
10	Selenium			7782492	E,V		5 E		290 E		71 E		170				
11	Silver			7440224	E,F,P		0.10 E		1.9 E,P				¥				
44 N	Tributyltin (TBT)			688733	0.46		0.063		0.37		0.01						
41	Trichloroethane 1,1,1-			71556									¥		¥		
55	Trichlorophenol 2,4,6-			88062									1.4				
13	Zinc			7440666	E,F		E,F		90 E		81 E						

Footnotes for Tables 33A and 33B:

A Values in Table 20 are applicable to all basins.

~~B Human Health criteria values were calculated using a fish consumption rate of 17.5 grams per day (0.6 ounces/day) unless otherwise noted.~~

C Ammonia criteria for freshwater may depend on pH, temperature, and the presence of salmonids or other fish with ammonia-sensitive early life stages. Values for freshwater criteria (of total ammonia nitrogen in mg N/L) can be calculated using the formulae specified in *1999 Update of Ambient Water Quality Criteria for Ammonia* (EPA-822-R-99-014; http://www.epa.gov/ost/standards/ammonia/99update.pdf):

Freshwater Acute:

salmonids present….CMC = $\frac{0.275}{1+10^{7.204-pH}}+\frac{39.0}{1+10^{pH-7.204}}$

salmonids not present…CMC= $\frac{0.411}{1+10^{7.204-pH}}+\frac{58.4}{1+10^{pH-7.204}}$

Freshwater Chronic:

fish early life stages present

CCC = $\left(\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}\right)*MIN(2.85,1.45*10^{0.028*(25-T)})$

fish early life stages not present

CCC= $\left(\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}\right)*1.45*10^{0.028*(25-MAX(T,7))}$

Note: these chronic criteria formulae would be applied to calculate the 30-day average concentration limit; in addition, the highest 4-day average within the 30-day period should not exceed 2.5 times the CCC.

D Ammonia criteria for saltwater may depend on pH and temperature. Values for saltwater criteria (total ammonia) can be calculated from the tables specified in *Ambient Water Quality Criteria for Ammonia (Saltwater)--1989* (EPA 440/5-88-004; http://www.epa.gov/ost/pc/ambientwqc/ammoniasalt1989.pdf).

E Freshwater and saltwater criteria for metals are expressed in terms of "dissolved" concentrations in the water column, except where otherwise noted (e.g. aluminum).

F The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. Criteria values for hardness may be calculated from the following formulae (CMC refers to Acute Criteria; CCC refers to Chronic Criteria):

$$CMC = (\exp(m_A*[\ln(hardness)] + b_A))*CF$$

$$CCC = (\exp(m_C*[\ln(hardness)] + b_C))*CF$$

where CF is the conversion factor used for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column.

Chemical	**m_A**	**b_A**	**m_C**	**b_C**
Cadmium	1.0166	-3.924	0.7409	-4.719
Chromium III	0.8190	3.7256	0.8190	0.6848
Copper	0.9422	-1.700	0.8545	-1.702
Lead	1.273	-1.460	1.273	-4.705
Nickel	0.8460	2.255	0.8460	0.0584
Silver	1.72	-6.59		
Zinc	0.8473	0.884	0.8473	0.884

Conversion factors (CF) for dissolved metals (the values for total recoverable metals criteria were multiplied by the appropriate conversion factors shown below to calculate the dissolved metals criteria):

Chemical	Freshwater		Saltwater	
	Acute	Chronic	Acute	Chronic
Arsenic	1.000	1.000	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]	0.994	0.994
Chromium III	0.316	0.860	--	--
Chromium VI	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]	0.951	0.951
Nickel	0.998	0.997	0.990	0.990
Selenium	0.996	0.922	0.998	0.998
Silver	0.85	0.85	0.85	--
Zinc	0.978	0.986	0.946	0.946

~~G Human Health criterion is the same as originally published in the 1976 EPA Red Book (Quality Criteria for Water, EPA-440/9-76-023) which predates the 1980 methodology and did not use the fish ingestion BCF approach.~~

~~H This value is based on a Drinking Water regulation.~~

I This value is based on criterion published in Ambient Water Quality Criteria for Endosulfan (EPA 440/5-80-046) and should be applied as the sum of alpha- and beta-endosulfan.

~~J No BCF was available; therefore, this value is based on that published in the 1986 EPA Gold Book.~~

~~K Human Health criterion is for "dissolved" concentration based on the 1976 EPA Red Book conclusion that adverse effects from exposure at this level are aesthetic rather than toxic.~~

~~L This value is expressed as the fish tissue concentration of methylmercury.~~

M Freshwater aquatic life values for pentachlorophenol are expressed as a function of pH, and are calculated as follows: CMC=(exp(1.005(pH)-4.869); CCC=exp(1.005(pH)-5.134).

N This number was assigned to the list of non-priority pollutants in National Recommended Water Quality Criteria: 2002 (EPA-822-R-02-047).

O This criterion is based on EPA recommendations issued in 1980 that were derived using guidelines that differed from EPA's 1985 Guidelines for minimum data requirements and derivation procedures. For example, a "CMC" derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

P Criterion shown is the minimum (i.e. CCC in water should not be below this value in order to protect aquatic life).

Q Criterion is applied as total arsenic (i.e. arsenic (III) + arsenic (V)).

R Arsenic criterion refers to the inorganic form only.

S This criterion is expressed as µg free cyanide (CN)/L.

T This criterion applies to DDT and its metabolites (i.e. the total concentration of DDT and its metabolites should not exceed this value).

U This criterion applies to total PCBs (e.g. the sum of all congener or all isomer or homolog or Arochlor analyses).

V The CMC=1/[(f1/CMC1)+(f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively.

W The acute and chronic criteria for aluminum are 750 µg/L and 87 µg/L, respectively. These values for aluminum are expressed in terms of "total recoverable" concentration of metal in the water column. The criterion applies at pH<6.6 and hardness<12 mg/L (as $CaCO_3$).

X The effective date for the criterion in the column immediately to the left is 1991.

Y No criterion.

Appendix D. Crosswalk Between Effective Human Health Criteria and Proposed Criteria

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
ACENAPTHENE	Y	N	--	--	95	99
ACROLEIN	Y	N	320	780	0.88	0.93
ACRYLONITRILE	Y	Y	0.058	0.65	0.018	0.025
ALDRIN	Y	Y	0.000074	0.000079	0.0000050	0.0000050
ANTHRACENE	N	N	--	--	2900	4000
ANTIMONY	Y	N	146	45,000	5.1	64
ARSENIC	Y	Y	2.1	2.1 (freshwater) 1.0 (saltwater)	2.1	2.1 (freshwater) 1.0 (saltwater)
ASBESTOS	Y	Y	7,000,000 fibers/L	--	7,000,000 fibers/L	--
BARIUM	N	N	1000	--	1000	--
BENZENE	N	Y	0.66	40	0.44	1.4
BENZIDINE	N	Y	0.00012	0.00053	0.000018	0.000020

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
BENZ(A) ANTHRACENE	N	Y	--	--	0.0013	0.0018
BENZO(A)PYRENE	N	Y	--	--	0.0013	0.0018
BENZO(B)FLUORANTHENE 3,4	N	Y	--	--	0.0013	0.0018
BENZO(K)FLUORANTHENE	N	Y	--	--	0.0013	0.0018
BROMOFORM	N	Y	--	--	3.3	14
BUTYLBENZYL PHTHALATE	N	N	--	--	190	190
CARBON TETRACHLORIDE	Y	Y	0.4	6.94	0.10	0.16
CHLORDANE	Y	Y	0.00046	0.00048	0.000081	0.000081
CHLORINATED BENZENES [CHLOROBENZENE]	Y	Y	488	--	74	160
CHLORODIBROMOMETHANE	N	Y	--	--	0.31	1.3
CHLOROETHYL ETHER (BIS-2)	Y	Y	0.03	1.36	0.020	0.05
CHLOROFORM	Y	Y	0.19	15.7	260	1100
CHLOROISOPROPYL ETHER (BIS-2)	Y	N	34.7	4360	1200	6500
CHLOROMETHYL ETHER (BIS)	N	Y	0.00000376	0.00184	0.000024	0.000029

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
CHLORONAPHTHALENE 2	N	N	--	--	150	160
CHLOROPHENOL 2	Y	N	--	--	14	15
CHLOROPHENOXY HERBICIDES (2,4,5,-TP)	N	N	10	--	10	--
CHLOROPHENOXY HERBICIDES (2,4-D)	N	N	100	--	100	--
CHRYSENE	N	Y	--	--	0.0013	0.0018
COPPER	Y	N	1300	--	1300	--
CYANIDE	Y	N	200	--	130	130
DDT [DDT 4,4']	Y	Y	0.000024	0.000024	0.000022	0.000022
DDD 4, 4'	Y	Y	--	--	0.000031	0.000031
DDE 4, 4'	Y	Y	--	--	0.000022	0.000022
DIBENZO(A,H)ANTHRACENE	N	Y	--	--	0.0013	0.0018
DIBUTYLPHTHALATE [DI-N-BUTYL PHTHALATE]	Y	N	35,000	154,000	400	450

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
DICHLOROBENZENES [DICHLOROBENZENE(O)1,2]	Y	N	400	2,600	110	130
DICHLOROBENZENE(P) 1,4	N	N	--	--	16	19
DICHLOROBENZIDINE [DICHLOROBENZIDINE 3,3']	Y	Y	0.01	0.020	0.0027	0.0028
DICHLOROBROMOMETHANE	N	Y	--	--	0.42	1.7
DICHLOROETHANE 1,2	Y	Y	0.94	243	0.35	3.7
DICHLOROETHYLENES [DICHLOROETHYLENE 1,1]	Y	Y	0.033	1.85	230	710
DICHLOROETHYLENE TRANS 1,2	N	N	--	--	120	1000
DICHLOROPHENOL 2,4	N	N	3,090	--	23	29
DICHLOROPROPANE [DICHLOROPROPANE 1,2]	Y	N	--	--	0.38	1.5
DICHLOROPROPENE [DICHLOROPROPENE 1,3]	Y	N	87	14,100	0.30	2.1
DIELDRIN	Y	Y	0.000071	0.000076	0.0000053	0.0000054

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
DIETHYLPHTHALATE	Y	N	350,000	1,800,000	3800	4400
DIMETHYL PHENOL 2,4	Y	N	--	--	76	85
DIMETHYL PHTHALATE	Y	N	313,000	2,900,000	84,000	110,000
DINITROPHENOL 2,4	Y	N	--	--	62	530
DINITROPHENOLS	Y	N	--	--	62	530
DINITROTOLUENE 2,4	N	Y	0.11	9.1	0.084	0.34
DINITROTOLUENE	Y	N	70	14,300	No criteria	No criteria
DINITRO-O-CRESOL 2,4	Y	N	13.4	765	No criteria	No criteria
DIOXIN (2,3,7,8-TCDD)	Y	Y	0.000000013	0.000000014	0.00000000051	0.00000000051
DIPHENYLHYDRAZINE	Y	N	0.042	0.56	No criteria	No criteria
DIPHENYLHYDRAZINE 1,2	Y	N	--	--	0.014	0.02
DI-2-ETHYLHEXYL PHTHALATE [BIS-2-ETHYLHEXYL PHTHALATE]	Y	N	15,000	50,000	0.20	0.22
ENDOSULFAN	Y	N	74	159	--	--
ENDOSULFAN ALPHA	Y	N	--	--	8.5	8.9

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
ENDOSULFAN BETA	Y	N	--	--	8.5	8.9
ENDOSULFAN SULFATE	Y	N	--	--	8.5	8.9
ENDRIN	Y	N	1	--	0.024	0.024
ENDRIN ALDEHYDE	Y	N	--	--	0.03	0.03
ETHYLBENZENE	Y	N	1,400	3,280	160	210
FLUORANTHENE	Y	N	42	54	14	14
FLUORENE	Y	N	--	--	390	530
HALOMETHANES	Y	Y	0.19	15.7	No criteria	No criteria
HEPTACHLOR	Y	Y	0.00028	0.00029	0.0000079	0.0000079
HEPTACHLOR EPOXIDE	Y	Y	--	--	0.0000039	0.0000039
HEXACHLOROETHANE	N	Y	1.9	8.74	0.29	0.33
HEXACHLOROBENZENE	Y	N	0.00072	0.00074	0.000029	0.000029
HEXACHLOROBUTADIENE	Y	Y	0.45	50	0.36	1.8

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
HEXACHLOROCYCLOHEXANE-ALPHA [BHC ALPHA]	Y	Y	0.0092	0.031	0.00045	0.00049
HEXACHLOROCYCLOHEXANE-BETA [BHC BETA]	Y	Y	0.0163	0.0547	0.0016	0.0017
HEXACHLOROCYCLOHEXANE-GAMA [BHC GAMMA (LINDANE)]	Y	Y	0.0186	0.0625	0.17	0.18
HEXACHLOROCYCLOHEXANE-TECHNICAL	Y	Y	0.0123	0.0414	0.0014	0.0015
HEXACHLOROCYCLOPENTADIENE	Y	N	206	--	30	110
INDENO(1,2,3-CD)PYRENE	Y	Y	--	--	0.0013	0.0018
ISOPHORONE	Y	N	5,200	520,000	27	96
MANGANESE	N	N	--	100	--	100
METHOXYCHLOR	N	N	100	--	100	--
METHYL BROMIDE	Y	N	--	--	37	150

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
METHYL-4,6-DINITROPHENOL 2	Y	N	--	--	9.2	28
METHYLENE CHLORIDE	Y	Y	--	--	4.3	59
METHYLMERCURY (MG/KG)	Y	N	--	--	--	0.040
MONOCHLOROBENZENE	Y	N	488	--	No criteria	No criteria
NICKEL	Y	N	13.4	100	140	170
NITRATES	N	N	10,000	--	10,000	--
NITROBENZENE	Y	N	19,800	--	14	69
NITROSAMINES	Y	Y	0.0008	1.24	0.00079	0.046
NITROSODIBUTYLAMINE N	Y	Y	0.0064	0.587	0.0050	0.02
NITROSODIETHYLAMINE N	Y	Y	0.0008	1.24	0.00079	0.046
NITROSODIMETHYLAMINE N	Y	Y	0.0014	16	0.00068	0.30
NITROSODI-N-PROPYLAMINE, N	Y	Y	--	--	0.0046	0.051
NITROSODIPHENYLAMINE N	Y	Y	4.9	16.1	0.55	0.60
NITROSOPYRROLIDINE N	Y	Y	0.016	91.9	0.016	3.4

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	Priority Pollutant	Carcinogen	Concentration in Units Per Liter for Protection of Human Health CURRENT		Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40	
			Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)	Water and Fish Ingestion (µg/L)	Fish Consumption Only (µg/L)
PCBS	Y	Y	0.000079	0.000079	0.0000064	0.0000064
PENTACHLOROBENZENE	N	N	74	85	0.15	0.15
PENTACHLOROPHENOL	Y	N	1,010	--	0.15	0.30
PHENOL	Y	N	3,500	--	9,400	86,000
POLYNUCLEAR AROMATIC HYDROCARBONS	Y	Y	0.0028	0.0311	No criteria	No criteria
PYRENE	Y	N	--	--	290	400
SELENIUM	Y	N	10	--	120	420
TETRACHLOROBENZENE 1,2,4,5	Y	N	38	48	0.11	0.11
TETRACHLOROETHANE 1,1,2,2	Y	Y	0.17	10.7	0.12	0.40
TETRACHLOROETHYLENE	Y	Y	0.8	8.85	0.24	0.33
THALLIUM	Y	N	13	48	0.043	0.047
TOLUENE	Y	N	14,300	424,000	720	1500
TOXAPHENE	Y	Y	0.00071	0.00073	0.000028	0.000028
TRICHLOROBENZENE 1,2,4	Y	N	--	--	6.4	7.0

Compound Name or Class [Table 40 Name, if different] *Criteria denoted in red indicate proposed additions to the human health criteria*	**Priority Pollutant**	**Carcinogen**	**Concentration in Units Per Liter for Protection of Human Health CURRENT**		**Concentration in Units Per Liter for Protection of Human Health PROPOSED TABLE 40**	
			Water and Fish Ingestion (µg/L)	**Fish Consumption Only (µg/L)**	**Water and Fish Ingestion (µg/L)**	**Fish Consumption Only (µg/L)**
TRICHLOROETHANE 1,1,2	Y	Y	0.6	41.8	0.44	1.6
TRICHLOROETHYLENE	Y	Y	2.7	80.7	1.4	3.0
TRICHLOROPHENOL 2,4,5	N	N	2,600	--	330	360
TRICHLOROPHENOL 2,4,6	Y	Y	1.2	3.6	0.23	0.24
VINYL CHLORIDE	Y	Y	2	525	0.02	0.24
ZINC	Y	N	--	--	2100	2600

Appendix E. TABLE 40: Human Health Water Quality Criteria for Toxic Pollutants

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Human Health Criteria Summary

The concentration for each pollutant listed in Table 40 was derived to protect Oregonians from potential adverse health impacts associated with long-term exposure to toxic substances associated with consumption of fish, shellfish, and water. The "organism only" criteria are established to protect fish and shellfish consumption and apply to waters of the state designated for fishing. The "water + organism" criteria are established to protect the consumption of drinking water, fish, and shellfish, and apply where both fishing and domestic water supply (public and private) are designated uses. All criteria are expressed as micrograms per liter (µg/L), unless otherwise noted. Pollutants are listed in alphabetical order. Additional information includes the Chemical Abstract Service (CAS) number, whether the criterion is based on carcinogenic effects (can cause cancer in humans), and whether there is an aquatic life criterion for the pollutant (i.e. "y"= yes, "n" = no). All the human health criteria were calculated using a fish consumption rate of 175 grams per day unless otherwise noted. A fish consumption rate of 175 grams per day is approximately equal to 23 8-ounce fish meals per month. For pollutants categorized as carcinogens, values represent a cancer risk of one additional case of cancer in one million people (i.e. 10^{-6}), unless otherwise noted. All metals criteria are for total metal concentration, unless otherwise noted. Italicized pollutants represent non-priority pollutants. The human health criteria revisions established by OAR 340-041-0033 and shown in Table 40 do not become applicable for purposes of ORS chapter 468B or the federal Clean Water Act until approved by EPA pursuant to 40 CFR 131.21 (4/27/2000).

No.	Pollutant	CAS No.	Carcinogen	Aquatic Life Criterion	Human Health Criteria for the Consumption of:	
					Water + Organism (µg/L)	Organism Only (µg/L)
1	Acenaphthene	83329	n	n	95	99
2	Acrolein	107028	n	n	0.88	0.93
3	Acrylonitrile	107131	y	n	0.018	0.025
4	Aldrin	309002	y	y	0.0000050	0.0000050
5	Anthracene	120127	n	n	2900	4000
6	Antimony	7440360	n	n	5.1	64
7	Arsenic (inorganic)[A]	7440382	y	n	2.1	2.1(freshwater) 1.0 (saltwater)
	[A] The arsenic criteria are expressed as total inorganic arsenic. The "organism only" criteria are based on a risk level of approximately of 1.1 x 10^{-5}, and the "water + organism" criterion is based on a risk level of 1 x 10^{-4}					
8	Asbestos[B]	1332214	y	n	7,000,000 fibers/L	--
	[B] The human health risks from asbestos are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.					
9	*Barium*[C]	7440393	n	n	1000	--
	[C] The human health criterion for barium is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.					
10	Benzene	71432	y	n	0.44	1.4
11	Benzidine	92875	y	n	0.000018	0.000020
12	Benz(a)anthracene	56553	y	n	0.0013	0.0018
13	Benzo(a)pyrene	50328	y	n	0.0013	0.0018
14	Benzo(b)fluoranthene 3,4	205992	y	n	0.0013	0.0018
15	Benzo(k)fluoranthene	207089	y	n	0.0013	0.0018
16	BHC Alpha	319846	y	n	0.00045	0.00049
17	BHC Beta	319857	y	n	0.0016	0.0017
18	BHC Gamma (Lindane)	58899	n	y	0.17	0.18
19	Bromoform	75252	y	n	3.3	14
20	Butylbenzyl Phthalate	85687	n	n	190	190
21	Carbon Tetrachloride	56235	y	n	0.10	0.16
22	Chlordane	57749	y	y	0.000081	0.000081
23	Chlorobenzene	108907	n	n	74	160
24	Chlorodibromomethane	124481	y	n	0.31	1.3
25	Chloroethyl Ether bis 2	111444	y	n	0.020	0.05
26	Chloroform	67663	n	n	260	1100
27	Chloroisopropyl Ether bis 2	108601	n	n	1200	6500
28	*Chloromethyl ether, bis*	542881	y	n	0.000024	0.000029
29	Chloronaphthalene 2	91587	n	n	150	160
30	Chlorophenol 2	95578	n	n	14	15
31	*Chlorophenoxy Herbicide (2,4,5,-TP)*[D]	93721	n	n	10	--
	[D] The Chlorophenoxy Herbicide (2,4,5,-TP) criterion is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established					

No.	Pollutant	CAS No.	Carcinogen	Aquatic Life Criterion	Human Health Criteria for the Consumption of:	
					Water + Organism (µg/L)	Organism Only (µg/L)
	under the Safe Drinking Water Act.					
32	*Chlorophenoxy Herbicide (2,4-D)* [E]	94757	n	n	100	--
	[E] *The Chlorophenoxy Herbicide (2,4-D) criterion is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*					
33	Chrysene	218019	y	n	0.0013	0.0018
34	Copper [F]	7440508	n	y	1300	--
	[F] *Human health risks from copper are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*					
35	Cyanide [G]	57125	n	y	130	130
	[G] *The cyanide criterion is expressed as total cyanide (CN)/L.*					
36	DDD 4,4'	72548	y	n	0.000031	0.000031
37	DDE 4,4'	72559	y	n	0.000022	0.000022
38	DDT 4,4'	50293	y	y	0.000022	0.000022
39	Dibenz(a,h)anthracene	53703	y	n	0.0013	0.0018
40	Dichlorobenzene(m) 1,3	541731	n	n	80	96
41	Dichlorobenzene(o) 1,2	95501	n	n	110	130
42	Dichlorobenzene(p) 1,4	106467	n	n	16	19
43	Dichlorobenzidine 3,3'	91941	y	n	0.0027	0.0028
44	Dichlorobromomethane	75274	y	n	0.42	1.7
45	Dichloroethane 1,2	107062	y	n	0.35	3.7
46	Dichloroethylene 1,1	75354	n	n	230	710
47	Dichloroethylene trans 1,2	156605	n	n	120	1000
48	Dichlorophenol 2,4	120832	n	n	23	29
49	Dichloropropane 1,2	78875	y	n	0.38	1.5
50	Dichloropropene 1,3	542756	y	n	0.30	2.1
51	Dieldrin	60571	y	y	0.0000053	0.0000054
52	Diethyl Phthalate	84662	n	n	3800	4400
53	Dimethyl Phthalate	131113	n	n	84000	110000
54	Dimethylphenol 2,4	105679	n	n	76	85
55	Di-n-butyl Phthalate	84742	n	n	400	450
56	Dinitrophenol 2,4	51285	n	n	62	530
57	*Dinitrophenols*	25550587	n	n	62	530
58	Dinitrotoluene 2,4	121142	y	n	0.084	0.34
59	Dioxin (2,3,7,8-TCDD)	1746016	y	n	0.00000000051	0.00000000051
60	Diphenylhydrazine 1,2	122667	y	n	0.014	0.020
61	Endosulfan Alpha	959988	n	y	8.5	8.9
62	Endosulfan Beta	33213659	n	y	8.5	8.9
63	Endosulfan Sulfate	1031078	n	n	8.5	8.9
64	Endrin	72208	n	y	0.024	0.024
65	Endrin Aldehyde	7421934	n	n	0.030	0.030

No.	Pollutant	CAS No.	Carcinogen	Aquatic Life Criterion	Human Health Criteria for the Consumption of:	
					Water + Organism (µg/L)	Organism Only (µg/L)
66	Ethylbenzene	100414	n	n	160	210
67	Ethylhexyl Phthalate bis 2	117817	y	n	0.20	0.22
68	Fluoranthene	206440	n	n	14	14
69	Fluorene	86737	n	n	390	530
70	Heptachlor	76448	y	y	0.0000079	0.0000079
71	Heptachlor Epoxide	1024573	y	y	0.0000039	0.0000039
72	Hexachlorobenzene	118741	y	n	0.000029	0.000029
73	Hexachlorobutadiene	87683	y	n	0.36	1.8
74	*Hexachlorocyclo-hexane-Technical*	608731	y	n	0.0014	0.0015
75	Hexachlorocyclopentadiene	77474	n	n	30	110
76	Hexachloroethane	67721	y	n	0.29	0.33
77	Indeno(1,2,3-cd)pyrene	193395	y	n	0.0013	0.0018
78	Isophorone	78591	y	n	27	96
79	*Manganese* [H]	7439965	n	n	--	100
	[H] *The "fish consumption only" criterion for manganese applies only to salt water and is for total manganese. This EPA recommended criterion predates the 1980 human health methodology and does not utilize the fish ingestion BCF calculation method or a fish consumption rate.*					
80	*Methoxychlor* [I]	72435	n	y	100	--
	[I] *The human health criterion for methoxychlor is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*					
81	Methyl Bromide	74839	n	n	37	150
82	Methyl-4,6-dinitrophenol 2	534521	n	n	9.2	28
83	Methylene Chloride	75092	y	n	4.3	59
84	Methylmercury (mg/kg) [J]	22967926	n	n	--	0.040 mg/kg
	[J] *This value is expressed as the fish tissue concentration of methylmercury. Contaminated fish and shellfish is the primary human route of exposure to methylmercury*					
85	Nickel	7440020	n	n	140	170
86	*Nitrates* [K]	14797558	n	n	10000	--
	[K] *The human health criterion for nitrates is the same as originally published in the 1976 EPA Red Book which predates the 1980 methodology and did not utilize the fish ingestion BCF approach. This same criterion value was also published in the 1986 EPA Gold Book. Human health risks are primarily from drinking water, therefore no "organism only" criterion was developed. The "water + organism" criterion is based on the Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act.*					
87	Nitrobenzene	98953	n	n	14	69
88	*Nitrosamines*	35576911	y	n	0.00079	0.046
89	*Nitrosodibutylamine, N*	924163	y	n	0.0050	0.022
90	*Nitrosodiethylamine, N*	55185	y	n	0.00079	0.046
91	Nitrosodimethylamine, N	62759	y	n	0.00068	0.30
92	Nitrosodi-n-propylamine, N	621647	y	n	0.0046	0.051
93	Nitrosodiphenylamine, N	86306	y	n	0.55	0.60
94	*Nitrosopyrrolidine, N*	930552	y	n	0.016	3.4
95	*Pentachlorobenzene*	608935	n	n	0.15	0.15
96	Pentachlorophenol	87865	y	y	0.15	0.30

No.	Pollutant	CAS No.	Carcinogen	Aquatic Life Criterion	*Human Health Criteria for the Consumption of:*	
					Water + Organism (µg/L)	Organism Only (µg/L)
97	Phenol	108952	n	n	9400	86000
98	Polychlorinated Biphenyls (PCBs)[L]	NA	y	y	0.0000064	0.0000064
	[L] *This criterion applies to total PCBs (e.g. determined as Aroclors or congeners).*					
99	Pyrene	129000	n	n	290	400
100	Selenium	7782492	n	n	120	420
101	*Tetrachlorobenzene, 1,2,4,5-*	95943	n	n	0.11	0.11
102	Tetrachloroethane 1,1,2,2	79345	y	n	0.12	0.40
103	Tetrachloroethylene	127184	y	n	0.24	0.33
104	Thallium	7440280	n	n	0.043	0.047
105	Toluene	108883	n	n	720	1500
106	Toxaphene	8001352	y	y	0.000028	0.000028
107	Trichlorobenzene 1,2,4	120821	n	n	6.4	7.0
108	Trichloroethane 1,1,2	79005	y	y	0.44	1.6
109	Trichloroethylene	79016	y	n	1.4	3.0
110	Trichlorophenol 2,4,6	88062	y	n	0.23	0.24
111	*Trichlorophenol, 2, 4, 5-*	95954	n	n	330	360
112	Vinyl Chloride	75014	y	n	0.023	0.24
113	Zinc	7440666	n	n	2100	2600

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DEPARTMENT OF AGRICULTURE

Animal and Plant Health Inspection Service

7 CFR Part 319

[Docket No. APHIS–2015–0005]

RIN 0579–AE09

Importation of Citrus From Peru; Expansion of Citrus-Growing Area

AGENCY: Animal and Plant Health Inspection Service, USDA.

ACTION: Final rule.

SUMMARY: We are amending the fruits and vegetable regulations to allow citrus fruit from the entire country of Peru to be imported into the continental United States. Currently, the regulations allow the importation of citrus fruit to the United States from five approved citrus-producing zones in Peru, subject to a systems approach. However, based on the findings of a pest list and commodity import evaluation document, we have determined that this systems approach also mitigates the plant pest risk associated with citrus fruit produced in all other areas of Peru. This action will allow the importation of citrus fruit from the entire country of Peru while continuing to provide protection against the introduction of plant pests into the continental United States.

DATES: Effective September 14, 2015.

FOR FURTHER INFORMATION CONTACT: Mr. Tony Román, Senior Regulatory Policy Specialist, PPQ, APHIS, 4700 River Road Unit 39, Riverdale, MD 20737–1231; (301) 851–2242.

SUPPLEMENTARY INFORMATION:

Background

The regulations in "Subpart—Fruits and Vegetables" (7 CFR 319.56–1 through 319.56–72, referred to below as the regulations) prohibit or restrict the importation of fruits and vegetables into the United States from certain parts of the world to prevent the introduction and dissemination of plant pests within the United States. The regulations in § 319.56–41 have provided conditions for the importation of citrus from five approved citrus-producing zones in Peru.

On May 1, 2015, we published in the **Federal Register** (80 FR 24838–24840, Docket No. APHIS–2015–0005) a proposal [1] to amend § 319.56–41 to allow citrus from the entire country of Peru to be imported into the continental United States based on the findings of a pest list and commodity import evaluation document (CIED).

We solicited comments on the proposal, pest list, and CIED for 60 days ending June 30, 2015. We received 13 comments by that date. They were from producers, exporters, representatives of State and foreign governments, U.S. citrus industry representatives, a chamber of commerce, a pork producers organization, a port representative, and private citizens. All of the commenters supported the action; however, one commenter asked if the citrus would be required to undergo cold treatment.

As explained in the proposal, citrus from Peru may be imported into the continental United States under a systems approach designated to mitigate the risk presented by four species of fruit fly (*Anastrepha fraterculus, A. obliqua, A. serpentina,* and *Ceratitis capitata*) and a Tortricid (*Ecdytolopha aurantiana*). One of the conditions of the systems approach requires that citrus from Peru, except limes, be cold treated for fruit flies in accordance with 7 CFR part 305.

Therefore, for the reasons given in the proposed rule, we are adopting the proposed rule as a final rule, without change.

Effective Date

This is a substantive rule that relieves restrictions and, pursuant to the provisions of 5 U.S.C. 553, may be made effective less than 30 days after publication in the **Federal Register**.

Immediate implementation of this rule is necessary to provide relief to those persons who are adversely affected by restrictions we no longer find warranted. The shipping season for citrus from Peru is in progress. Making this rule effective immediately will allow interested producers and others in the marketing chain to benefit during this year's shipping season. Therefore, the Administrator of the Animal and Plant Health Inspection Service has determined that this rule should be effective upon publication in the **Federal Register**.

Executive Order 12866 and Regulatory Flexibility Act

This final rule has been determined to be not significant for the purposes of Executive Order 12866 and, therefore, has not been reviewed by the Office of Management and Budget.

In accordance with the Regulatory Flexibility Act, we have analyzed the potential economic effects of this action on small entities. The analysis is summarized below. Copies of the full analysis are available on the Regulations.gov Web site (see footnote 1 in this document for a link to Regulations.gov) or by contacting the person listed under **FOR FURTHER INFORMATION CONTACT**.

The regulations have allowed the importation of fresh grapefruit, lime, mandarin, orange, tangerine or hybrids, sweet orange, and tangelo from five approved citrus-producing zones in Peru to the United States. This rule will allow the importation of these fruits from the entire country of Peru into the continental United States under the same conditions that have been in place for the five zones. This change is expected to increase the area in Peru approved to produce citrus for export to the United States to about 1,500 hectares over 3 years. Additional volumes of citrus expected to be shipped to the United States are 5,000 metric tons (MT) in the first year that the rule is in effect, 6,500 MT in the second year, and 8,000 MT in the third year. These quantities are equivalent to less than 1 percent of annual U.S. citrus production or U.S. citrus imports.

The primary entities that may be affected by this rule are citrus producers, citrus importers, and support industries such as packinghouses. Based on data from the 2012 Census of Agriculture and Small Business Administration small-entity standards, the majority of these operations are small.

[1] To view the proposed rule, pest list, CIED, and the comments we received, go to *http://www.regulations.gov/#!docketDetail;D=APHIS-2015-0005.*

Under these circumstances, the Administrator of the Animal and Plant Health Inspection Service has determined that this action will not have a significant economic impact on a substantial number of small entities.

Executive Order 12988

This final rule allows citrus to be imported into the continental United States from the entire country of Peru. State and local laws and regulations regarding citrus imported under this rule will be preempted while the fruit is in foreign commerce. Fresh fruits are generally imported for immediate distribution and sale to the consuming public, and remain in foreign commerce until sold to the ultimate consumer. The question of when foreign commerce ceases in other cases must be addressed on a case-by-case basis. No retroactive effect will be given to this rule, and this rule will not require administrative proceedings before parties may file suit in court challenging this rule.

Paperwork Reduction Act

In accordance with section 3507(d) of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*), the information collection or recordkeeping requirements included in this final rule, which were filed under 0579–0433, have been submitted for approval to the Office of Management and Budget (OMB). When OMB notifies us of its decision, if approval is denied, we will publish a document in the **Federal Register** providing notice of what action we plan to take.

E-Government Act Compliance

The Animal and Plant Health Inspection Service is committed to compliance with the E-Government Act to promote the use of the Internet and other information technologies, to provide increased opportunities for citizen access to Government information and services, and for other purposes. For information pertinent to E-Government Act compliance related to this rule, please contact Ms. Kimberly Hardy, APHIS' Information Collection Coordinator, at (301) 851–2727.

List of Subjects in 7 CFR Part 319

Coffee, Cotton, Fruits, Imports, Logs, Nursery stock, Plant diseases and pests, Quarantine, Reporting and recordkeeping requirements, Rice, Vegetables.

Accordingly, we are amending 7 CFR part 319 as follows:

PART 319—FOREIGN QUARANTINE NOTICES

■ 1. The authority citation for part 319 continues to read as follows:

Authority: 7 U.S.C. 450, 7701–7772, and 7781–7786; 21 U.S.C. 136 and 136a; 7 CFR 2.22, 2.80, and 371.3.

§ 319.56–41 [Amended]

■ 2. Section 319.56–41 is amended as follows:

■ a. In the introductory text, by adding the word "continental" between the words "the" and "United States".

■ b. By removing paragraph (c).

■ c. By redesignating paragraphs (d) through (h) as paragraphs (c) through (g), respectively.

■ d. By adding the words "(Approved by the Office of Management and Budget under control number 0579–0433)" at the end of the section.

Done in Washington, DC, this 9th day of September 2015.

Michael C. Gregoire,

Associate Administrator, Animal and Plant Health Inspection Service.

[FR Doc. 2015–23039 Filed 9–11–15; 8:45 am]

BILLING CODE 3410–34–P

DEPARTMENT OF AGRICULTURE

Animal and Plant Health Inspection Service

7 CFR Part 319

[Docket No. APHIS–2014–0028]

RIN 0579–AD97

Importation of Fresh Peppers From Peru into the Continental United States and the Territories

AGENCY: Animal and Plant Health Inspection Service, USDA.

ACTION: Final rule.

SUMMARY: We are amending the fruits and vegetables regulations to allow the importation of fresh peppers into the continental United States and the Territories from Peru. As a condition of entry, the fruit will have to be produced in accordance with a systems approach that includes requirements for fruit fly trapping, pre-harvest inspections, production sites, and packinghouse procedures designed to exclude quarantine pests. The fruit will also be required to be imported in commercial consignments and accompanied by a phytosanitary certificate issued by the national plant protection organization of Peru with an additional declaration stating that the consignment was produced in accordance with the requirements of the systems approach. This action allows for the importation of untreated fresh peppers from Peru while continuing to provide protection against the introduction of plant pests into the continental United States and the Territories.

DATES: Effective October 14, 2015.

FOR FURTHER INFORMATION CONTACT: Mr. George Balady, Senior Regulatory Policy Specialist, Plant Health Programs, PPQ, APHIS, 4700 River Road Unit 133, Riverdale, MD 20737; (301) 851–2240.

SUPPLEMENTARY INFORMATION:

Background

The regulations in "Subpart–Fruits and Vegetables" (7 CFR 319.56–1 through 319.56–72, referred to below as the regulations) prohibit or restrict the importation of fruits and vegetables into the United States from certain parts of the world to prevent the introduction and dissemination of plant pests that are new to or not widely distributed within the United States.

On April 24, 2015, we published in the **Federal Register** (80 FR 22934–22938, Docket No. APHIS–2014–0028) a proposal [1] to amend the regulations in order to allow the common chili pepper (*Capsicum annuum* L.), aji pepper (*Capsicum baccatum* L.), habanero chili (*Capsicum chinense* Jacq.), Thai pepper (*Capsicum frutescens* L.), and rocoto (*Capsicum pubescens* Ruiz & Pav.) (hereafter we refer to these species as "fresh peppers") to be imported into the continental United States and the Territories (the Commonwealth of Northern Mariana Islands, the Commonwealth of Puerto Rico, Guam, the Virgin Islands of the United States, and any other territory or possession of the United States).

We prepared a pest risk assessment (PRA) and a risk management document (RMD) to accompany the proposed rule. Based on the conclusions of the PRA and the RMD, we proposed to allow the importation of fresh peppers from Peru into the continental United States and the Territories, provided that the fresh peppers were produced in accordance with a systems approach consisting of the following requirements: Provision of an operational workplan to the Animal and Plant Health Inspection Service (APHIS) by the national plant protection organization (NPPO) of Peru; importation in commercial consignments only; fresh peppers grown in a pest-free, pest-exclusionary structure approved by and registered

[1] To view the proposed rule, supporting documents, and the comments we received, go to *http://www.regulations.gov/#!docketDetail;D=APHIS-V2014-0028.*

with the Peruvian NPPO; inspection of registered production sites prior to harvest for the fruit boring moth, *Neoleucinodes elegantalis* (Guenée), and *Puccinia pampeana* Speg., the pathogenic fungus that causes pepper and green pepper rust, by the Peruvian NPPO or its approved designee; trapping both within and around the production site for the South American fruit fly (*Anastrepha fraterculus* (Wiedemann)) and the Mediterranean fruit fly (Medfly, *Ceratitis capitata* (Wiedemann)); packinghouse procedures including registration and insect-proof cartons, containers, or coverings; and issuance of a phytosanitary certificate.

We also proposed to add a definition for *continental United States* to the regulations in § 319.56–2, as it is used throughout the regulations but not defined.

We solicited comments concerning our proposal for 60 days ending June 23, 2015. We received 23 comments by that date. They were from trade organizations, the Peruvian NPPO, consumer groups, ports, the Peruvian embassy, and private citizens. All comments except one were supportive of the proposed action. The remaining comment is discussed below.

The commenter said that APHIS is dependent on local authorities in Peru to enforce the requirements set forth in the regulations and the operational workplan. The commenter cited the 2015 Index of Economic Freedom issued by The Heritage Foundation [2] as proof that corruption within Peru will most certainly occur in connection with the export of fresh peppers.

Like the United States, Peru is a signatory to the World Trade Organization's Agreement on Sanitary and Phytosanitary Measures (SPS Agreement). As such, it has agreed to respect the phytosanitary measures the United States imposes on the importation of plants and plant products from Peru when the United States demonstrates the need to impose these measures in order to protect plant health within the United States. The PRA that accompanied the proposed rule provided evidence of such a need. That being said, as we mentioned in the proposed rule, APHIS will monitor and audit Peru's implementation of the systems approach for the importation of fresh peppers into the continental United States and the Territories. If we determine that the systems approach has not been fully implemented or maintained, we will take appropriate remedial action to ensure that the importation of fresh peppers from Peru does not result in the dissemination of plant pests within the United States.

The commenter argued that the interests of pepper producers in the United States need to be given the same consideration as U.S. consumers or Peruvian producers. The commenter said that, therefore, APHIS needs to ensure that U.S. pepper producers would truly be marginally affected. To achieve this end, the commenter suggested that APHIS limit the importation of fresh peppers from Peru to domestic out-of-season growing months.

APHIS bases market access on potential pest risk and our capacity to mitigate that risk. APHIS may implement different entry requirements for a commodity based upon port of entry and time of year in order to mitigate the risk posed by a pest, but APHIS does not restrict market access for the purposes of eliminating market competition.

We prepared an initial regulatory flexibility analysis to assess the potential economic impacts associated with the proposed rule. The commenter stated that the initial regulatory flexibility analysis did not fully account for the impacts to domestic producers. The commenter said that, in addition to reduced sales, domestic pepper producers are at a financial disadvantage due to the fact that reductions in crop premium insurance for fresh peppers as detailed in the Agricultural Act of 2014 [3] could potentially lead to further financial losses in the event that a portion of a producer's pepper crop was destroyed and the remaining crop sold at a lower price due to the increased availability of imported peppers in the marketplace.

The purpose of the economic analysis was to examine whether or not the rule will have a significant economic impact on a substantial number of small entities. Despite the other pressures on the financial viability of domestic pepper producers cited by the commenter, any additional impact associated with this rule is expected to be very small. An increase in the U.S. fresh pepper supply of less than 0.03 percent is unlikely to have a significant impact on domestic fresh pepper prices and therefore on domestic producers.

Finally, the commenter maintained that the United States should examine any importation requests from Peru in light of what the commenter categorized as unfair taxation of U.S. biodiesel in that country.

We disagree. Under the authority of the Plant Protection Act (7 U.S.C. 7701 *et seq.*), APHIS may prohibit or restrict the entry of plants and plant products into the United States in order to prevent the introduction of plant pests or noxious weeds. Trade considerations such as those suggested by the commenter do not factor into such determinations.

Therefore, for the reasons given in the proposed rule and in this document, we are adopting the proposed rule as a final rule, without change.

Executive Order 12866 and Regulatory Flexibility Act

This final rule has been determined to be not significant for the purposes of Executive Order 12866 and, therefore, has not been reviewed by the Office of Management and Budget.

In accordance with the Regulatory Flexibility Act, we have analyzed the potential economic effects of this action on small entities. The analysis is summarized below. Copies of the full analysis are available on the Regulations.gov Web site (see footnote 1 in this document for a link to Regulations.gov) or by contacting the person listed under **FOR FURTHER INFORMATION CONTACT.**

The rule will amend the regulations to allow the importation of fresh peppers from Peru into the continental United States and the Territories when a systems approach to pest risk mitigation is used to prevent the introduction of quarantine pests. The systems approach will integrate prescribed mitigation measures that cumulatively achieve the appropriate level of phytosanitary protection.

Peru produced an average of about 9,600 metric tons (MT) of fresh peppers annually from 2005 through 2011. From 2010 to 2014, fresh pepper exports from Peru averaged 356 MT annually, the equivalent of about 4 percent of its annual fresh pepper production.

Based on Peru's pepper production area and yields, APHIS estimates in the pest risk assessment for this rule that no more than 22 containers (440 MT) of fresh peppers will be imported from Peru into the United States annually. This quantity is the equivalent of less than 0.03 percent of annual U.S. fresh pepper consumption.

U.S. pepper producers and current foreign suppliers will face increased competition because of the Peruvian exports. However, economic effects of the rule will be minimal, given the very

[2] The 2015 Index of Economic Freedom may be viewed here: *http://www.heritage.org/index/country/peru.*

[3] You may view the Agricultural Act of 2014 on the Internet at *https://agriculture.house.gov/bill/agricultural-act-2014.*

small quantity of pepper expected to be imported from Peru.

Under these circumstances, the Administrator of the Animal and Plant Health Inspection Service has determined that this action will not have a significant economic impact on a substantial number of small entities.

Executive Order 12988

This final rule allows fresh peppers to be imported into the continental United States and the Territories from Peru. State and local laws and regulations regarding fresh peppers imported under this rule would be preempted while the fruit is in foreign commerce. Fresh vegetables are generally imported for immediate distribution and sale to the consuming public and would remain in foreign commerce until sold to the ultimate consumer. The question of when foreign commerce ceases in other cases must be addressed on a case-by-case basis. No retroactive effect will be given to this rule, and this rule will not require administrative proceedings before parties may file suit in court challenging this rule.

Paperwork Reduction Act

In accordance with section 3507(d) of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*), the information collection or recordkeeping requirements included in this final rule, which were filed under 0579–0434, have been submitted for approval to the Office of Management and Budget (OMB). When OMB notifies us of its decision, if approval is denied, we will publish a document in the **Federal Register** providing notice of what action we plan to take.

E-Government Act Compliance

The Animal and Plant Health Inspection Service is committed to compliance with the EGovernment Act to promote the use of the Internet and other information technologies, to provide increased opportunities for citizen access to Government information and services, and for other purposes. For information pertinent to E-Government Act compliance related to this final rule, please contact Ms. Kimberly Hardy, APHIS' Information Collection Coordinator, at (301) 851–2727.

List of Subjects in 7 CFR Part 319

Coffee, Cotton, Fruits, Imports, Logs, Nursery stock, Plant diseases and pests, Quarantine, Reporting and recordkeeping requirements, Rice, Vegetables.

Accordingly, we are amending 7 CFR part 319 as follows:

PART 319—FOREIGN QUARANTINE NOTICES

■ 1. The authority citation for part 319 continues to read as follows:

Authority: 7 U.S.C. 450, 7701–7772, and 7781–7786; 21 U.S.C. 136 and 136a; 7 CFR 2.22, 2.80, and 371.3.

■ 2. Section 319.56–2 is amended by adding in alphabetical order a definition of *continental United States* to read as follows:

§ 319.56–2 Definitions.

* * * * *

Continental United States. The 48 contiguous States, Alaska, and the District of Columbia.

* * * * *

■ 3. Section 319.56–73 is added to read as follows:

§ 319.56–73 Peppers From Peru.

Fresh peppers (*Capsicum annum* L., *Capsicum baccatum* L., *Capsicum chinense* Jacq., *Capsicum frutescens* L., and *Capsicum pubescens* Ruiz & Pav.) may be imported into the continental United States and its Territories only under the conditions described in this section. These conditions are designed to prevent the introduction of the following quarantine pests: *Anastrepha fraterculus* (Wiedemann), South American fruit fly; *Ceratitis capitata* (Wiedemann), Mediterranean fruit fly; *Neoleucinodes elegantalis* (Guenée), a fruit boring moth; and *Puccinia pampeana* Speg., a pathogenic fungus that causes pepper and green pepper rust.

(a) *Operational workplan.* The national plant protection organization (NPPO) of Peru must provide an operational workplan to APHIS that details the activities that the NPPO of Peru will, subject to APHIS' approval of the workplan, carry out to meet the requirements of this section. The operational workplan must include and describe the quarantine pest survey intervals and other specific requirements as set forth in this section.

(b) *Commercial consignments.* Peppers from Peru may be imported in commercial consignments only.

(c) *Production site requirements.* (1) Pepper production sites must consist of pest-exclusionary structures, which must have double self-closing doors and have all other windows, openings, and vents covered with 1.6 mm (or less) screening.

(2) All production sites that participate in the export program must be registered with the Peruvian NPPO.

(3) The production sites must be inspected prior to harvest for *Neoleucinodes elegantalis* (Guenée) and *Puccinia pampeana* Speg. If either of these pests, or other quarantine pests, are found to be generally infesting or infecting the production site, the NPPO of Peru will immediately prohibit that production site from exporting peppers to the continental United States and its Territories and notify APHIS of this action. The prohibition will remain in effect until the Peruvian NPPO and APHIS determine that the pest risk has been mitigated.

(4) The production sites must contain traps for the detection of *Anastrepha fraterculus* (Wiedemann) and *Ceratitis capitata* (Wiedemann) both within and around the structures. Internal traps must be set for the duration of the time the production site is used to produce peppers for export to the continental United States or the Territories. External traps must be set for at least 2 months before export and trapping must continue to the end of the harvest as follows:

(i) Traps with an approved protein bait must be placed inside the production site at a density of four traps per hectare, with a minimum of two traps per structure. Traps must be serviced once every 7 days.

(ii) If a single *Anastrepha fraterculus* (Wiedemann) or *Ceratitis capitata* (Wiedemann) is detected inside a registered production site or in a consignment, the registered production site will lose its ability to export peppers to the continental United States or its Territories until APHIS and the Peruvian NPPO mutually determine that risk mitigation is achieved.

(iii) Traps with an approved protein bait must be placed inside a buffer area 500 meters wide around the registered production site, at a density of 1 trap per 10 hectares and a minimum of 10 traps. These traps must be checked at least once every 7 days. At least one of these traps must be near the production site.

(iv) Capture of 0.7 or more *Anastrepha fraterculus* (Wiedemann) or *Ceratitis capitata* (Wiedemann) per trap per week will delay or suspend the harvest, depending on whether harvest has begun, for consignments of peppers from that registered production site until APHIS and the Peruvian NPPO can agree that the pest risk has been mitigated.

(v) The Peruvian NPPO must maintain records of trap placement, checking of traps, and any quarantine pest captures. The Peruvian NPPO must maintain an APHIS-approved quality control program to monitor or audit the trapping program. The trapping records must be maintained for APHIS review.

(d) *Packinghouse procedures.* (1) All packinghouses that participate in the export program must be registered with the Peruvian NPPO.

(2) The peppers must be packed within 24 hours of harvest in a pest-exclusionary packinghouse. The peppers must be safeguarded by an insect-proof mesh screen or plastic tarpaulin while in transit to the packinghouse and while awaiting packing. The peppers must be packed in insect-proof cartons or containers, or covered with insect-proof mesh or plastic tarpaulin, for transit into the continental United States or its Territories. These safeguards must remain intact until arrival in the continental United States or its Territories or the consignment will be denied entry into the continental United States or its Territories.

(3) During the time the packinghouse is in use for exporting peppers to the continental United States or its Territories, the packinghouse may only accept peppers from registered approved production sites.

(e) *Phytosanitary certificate.* Each consignment of peppers must be accompanied by a phytosanitary certificate of inspection issued by the Peruvian NPPO stating that the fruit in the consignment has been produced in accordance with the requirements of the systems approach in 7 CFR 319.56–73.

(Approved by the Office of Management and Budget under control number 0579–0434)

Done in Washington, DC, this 9th day of September 2015.

Michael C. Gregoire,

Associate Administrator, Animal and Plant Health Inspection Service.

[FR Doc. 2015–23037 Filed 9–11–15; 8:45 am]

BILLING CODE 3410–34–P

SMALL BUSINESS ADMINISTRATION

13 CFR Part 127

RIN 3245–AG72

Women-Owned Small Business Federal Contract Program

AGENCY: U.S. Small Business Administration.

ACTION: Final rule.

SUMMARY: This rule makes changes to the regulations governing the Women-Owned Small Business (WOSB) program. The U.S. Small Business Administration (SBA) is making changes to those regulations to implement section 825 of the National Defense Authorization Act for Fiscal Year 2015. Specifically, this rule implements the authority set forth in section 825 of the 2015 NDAA allowing sole source awards to Women-Owned Small Businesses (WOSBs) or Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs) in appropriate circumstances.

DATES: This rule is effective October 14, 2015.

FOR FURTHER INFORMATION CONTACT: Brenda Fernandez, U.S. Small Business Administration, Office of Policy, Planning & Liaison, 409 Third Street SW., Washington, DC 20416; (202) 205–7337; *brenda.fernandez@sba.gov.*

SUPPLEMENTARY INFORMATION:

I. Background

The WOSB Program, set forth in section 8(m) of the Small Business Act, 15 U.S.C. 637(m), authorizes Federal contracting officers to restrict competition to eligible Women-Owned Small Businesses (WOSBs) or Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs) for Federal contracts in certain industries. Section 8(m) establishes criteria for the WOSB Program, including the eligibility and contract requirements for the program. Congress recently amended the WOSB Program in section 825 of the National Defense Authorization Act for Fiscal Year 2015, Public Law 113–291, 128 Stat. 3292 (December 19, 2014) (2015 NDAA), which included language granting contracting officers the authority to award sole source awards to WOSBs and EDWOSBs and shortening the time period for SBA to conduct a required study to determine the industries in which WOSBs are underrepresented in Federal contracting. In addition, section 825 of the 2015 NDAA created a requirement that a firm be certified as a WOSB or EDWOSB by a Federal Agency, a State government, SBA, or a national certifying entity approved by SBA.

On May 1, 2015, SBA published in the **Federal Register** a proposed rule to implement the sole source authority for WOSBs and EDWOSBs and the revised timeline for SBA to conduct a study to determine the industries in which WOSBs are underrepresented. 80 FR 24846. The rule proposed amendments to Sec. 127.101 to include sole source contracts as a type of contracting assistance available under part 127. The rule also proposed to revise Sec. 127.102 by adding the term "sole source contracts" to the definitions of "EDWOSB requirement" and "WOSB requirement" and establishing that the terms "Substantial underrepresentation" and "Underrepresentation" would be determined by the study to be conducted. The term "sole source contracts" was also a proposed addition to Sec. 127.500, which concerns the industries in which a contracting officer is authorized to restrict competition under the WOSB program. This change to Sec. 127.500 proposed to authorize contracting officers to award sole source contracts in those industries as well. SBA also proposed amendments to Sec. 127.503 to establish the conditions for awarding a sole source contract. Essentially if, after conducting market research in an industry where a WOSB or EDWOSB set-aside is authorized, a contracting officer cannot identify two or more WOSBs or EDWOSBs that can perform at a fair and reasonable price but identifies one WOSB or EDWOSB that can perform at a fair and reasonable price, a contract may be awarded on a sole source basis, provided the value of the contract, including options, does not exceed $6.5 million for manufacturing contracts and $4 million for all other contracts. SBA also proposed to amend Sec. 127.507 to authorize contracting officers to award sole source contracts in the WOSB program if the contract requirement is valued at or below the simplified acquisition threshold. Finally, the rule proposed to amend the protest regulations in Sec. 127.600 to make them consistent with the protest procedures for sole source contracts involving service-disabled veteran owned small business concerns (SDVO SBC) (Sec. 125.24(a) and HUBZone small business concerns (Sec. 126.800(a).

Paragraph (a) of Sec. 127.501 sets out that the agency will designate "the industries in which WOSBs are underrepresented and substantially underrepresented" by NAICS code. However, because paragraph (b) uses the term "disparity" instead, SBA intended to propose a technical amendment to this paragraph to replace that term with "underrepresentation"; such an amendment would make the paragraph consistent with amendments to the definitions and other sections of the WOSB regulations. This purely technical conforming change to Sec. 127.501 is included in this final rule.

As explained in the proposed rule, SBA recognized that the new certification requirement for WOSBs would require a more prolonged rulemaking. Because SBA did not want to delay the implementation of the WOSB sole source authority by combining it with the new certification requirement, SBA did not propose any changes to implement the certification requirement but rather indicated that it

would do so through a separate future rulemaking. SBA received 495 comments on the proposed rule. With the exception of comments which did not set forth any rationale or make suggestions, SBA discusses and responds fully to all the comments below.

II. Summary of Comments

Most of the comments supported the rule. Specifically, most of the comments favored SBA's decision to quickly implement the sole source authority granted by the 2015 NDAA. Many of the commenters noted that they believe this authority and the quick implementation by SBA will help WOSB and EDWOSB businesses, and will put the program on more equal footing with SBA's other socio-economic contracting programs. In addition, the comments supported incorporating the statutory authority for sole source awards into the regulations and suggested no meaningful changes to the proposed regulatory text. As such, this final rule adopts the changes set forth in the proposed rule regarding sole source awards to WOSBs and EDWOSBs.

The second most covered topic in the comments received pertained to the language of the 2015 NDAA requiring the certification of WOSB and EDWOSB firms. As noted above, SBA did not propose to address the certification portion of the 2015 NDAA in the proposed rule because its implementation is more complicated, could not be accomplished by merely incorporating the statutory language into the regulations, and would have delayed the implementation of the sole source authority unnecessarily. In addition, SBA noted in the supplementary information to the proposed rule that there is no evidence that Congress intended to halt the existing WOSB Program until such time as SBA establishes the infrastructure and issues regulations implementing the statutory certification requirement. SBA continues to believe that the new WOSB sole source authority can and should be implemented as quickly as possible, using existing program rules and procedures, while SBA proceeds with development of the certification requirement through a separate rulemaking.

SBA believes that any certification process must be fair, efficient and comprehensive, but should not be burdensome or prevent new WOSBs and EDWOSBs from entering into the Federal marketplace. SBA wants to balance the need to protect the Government and other participants from fraud, with the goal of increasing WOSB and EDWOSB participation in the program. SBA believes that this process should be implemented in a systematic and thoughtful manner, and that increased public participation in the process will help SBA develop the best possible certification program.

The comments pertaining to certification of WOSBs and EDWOSBs were varied and covered a wide range of topics. SBA is in the process of developing its strategy for implementation of the certification language in the 2015 NDAA. SBA will consider the comments relating to certification received in response to this proposed rule when drafting the rule implementing the certification requirement. The certification rulemaking will give the public an opportunity to provide SBA with comments relating to SBA's proposed approach to the certification process and assist SBA in crafting the best possible certification program.

SBA also received several comments on the definitional changes related to the mandatory study to determine the industries in which WOSBs are underrepresented. The comments were generally supportive of SBA's proposed changes. As such, this final rule adopts the proposed changes to the definitions of the terms "Underrepresentation," "Substantial underrepresentation," "EDWOSB requirement," and "WOSB requirement" in § 127.102.

Several comments recommended that all NAICS codes should be available for WOSB and EDWOSB set-asides. Determining the industries in which WOSB and/or EDWOSB contracts are available is outside the scope of this rule. In addition, section 825 of the 2015 NDAA specifically requires the Administrator to conduct a study to identify the industries in which small business concerns owned and controlled by women are underrepresented with respect to Federal procurement contracting in order to determine the industries in which WOSB and/or EDWOSB contracts can be awarded.

III. Compliance With Executive Orders 12866, 12988, 13132, 13563, the Paperwork Reduction Act (44 U.S.C. Ch. 35), and the Regulatory Flexibility Act (5 U.S.C. 601–612)

Executive Order 12866

The Office of Management and Budget (OMB) has determined that this rule does not constitute a significant regulatory action under Executive Order 12866. This is not a major rule under the Congressional Review Act (CRA), 5 U.S.C. 800.

Executive Order 12988

This action meets applicable standards set forth in Sections 3(a) and 3(b)(2) of Executive Order 12988, Civil Justice Reform, to minimize litigation, eliminate ambiguity, and reduce burden. The action does not have retroactive or preemptive effect.

Executive Order 13132

For the purpose of Executive Order 13132, SBA has determined that the rule will not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. Therefore SBA has determined that this rule has no federalism implications warranting the preparation of a federalism assessment.

Executive Order 13563

A description of the need for this regulatory action, the benefits and costs associated with this action, and any alternatives are included in the Initial Regulatory Flexibility Analysis. In drafting this rule, SBA considered input submitted by three coalitions of women's groups representing women-owned small businesses that support this rule and encourage its quick implementation.

Paperwork Reduction Act, 44 U.S.C., Ch. 35

For the purpose of the Paperwork Reduction Act, SBA has determined that this proposed rule does not impose additional reporting or recordkeeping requirements.

Regulatory Flexibility Act, 5 U.S.C., 601–612

According to the Regulatory Flexibility Act (RFA), when an agency issues a rulemaking, it must prepare a regulatory flexibility analysis to address the impact of the rule on small entities. In accordance with this requirement, SBA has prepared a Final Regulatory Flexibility Analysis addressing the impact of this rule.

1. What are the need for and objective of this final rule?

This final rule is necessary to implement section 825 of the National Defense Authorization Act for Fiscal Year 2015, Public Law 113–291, December 19, 2014, 128 Stat. 3292 (2015 NDAA). Section 825 of the 2015 NDAA included language granting contracting officers the authority to award sole source contracts to Women-Owned Small Businesses (WOSBs) and Economically Disadvantaged Women-

Owned Small Businesses (EDWOSBs). The purpose of this rule is to establish the procedures whereby Federal agencies may award sole source contracts to WOSBs and EDWOSBs and to provide a mechanism to protest such awards. The rule provides an additional tool for Federal agencies to ensure that WOSBs have an equal opportunity to participate in Federal contracting and ensures consistency among SBA's socio-economic small business contracting programs. The objectives of this final rule are to put the WOSB Program on a level playing field with other SBA government contracting programs with sole source authority, and to provide an additional, needed tool for agencies to meet the statutorily mandated 5% prime contracting goal for WOSBs.

Section 825 of the 2015 NDAA also revised the timeline for SBA to conduct a study to determine the industries in which WOSBs are underrepresented. This final rule is necessary to allow SBA to conduct the most reliable and relevant study of WOSB participation in Federal contracting and comply with the new statutorily mandated timeline.

2. What is the legal basis for this final rule?

The legal basis for this final rule is section 825 of the National Defense Authorization Act for Fiscal Year 2015, Public Law 113–291, December 19, 2014, 128 Stat. 3292, which amended section 8(m) of the Small Business Act, 15 U.S.C. 637(m).

3. What is SBA's description and estimate of the number of small entities to which the rule will apply?

The RFA directs agencies to provide a description, and where feasible, an estimate of the number of small business concerns that may be affected by the rule. This final rule establishes a new procurement mechanism to benefit WOSBs. Therefore, WOSBs and EDWOSBs available to compete for Federal contracts under the WOSB Program are the specific group of small business concerns most directly affected by this rule.

SBA searched the Dynamic Small Business Search (DSBS) database and determined that there were approximately 34,000 firms listed as either WOSBs or EDWOSBs under the WOSB Program. In addition, according to the fiscal year 2013 small business goaling report, there were a little over 250,000 actions concerning women-owned small businesses and the total dollar value of those actions was approximately $15 billion. An analysis of the Federal Procurement Data System from April 1, 2011, (the implementation date of the WOSB Program) through January 1, 2013, revealed that there were approximately 26,712 women-owned small business concerns, including 131 EDWOSBs and 388 WOSBs eligible under the WOSB Program, that received Federal contract awards, task or delivery orders, and modifications to existing contracts.

Therefore, this rule could affect a smaller number of EDWOSBs and WOSBs than those eligible under the WOSB Program. We note that the sole source authority can only be used where a contracting officer conducts market research in an industry where a WOSB or EDWOSB set-aside is authorized, and the contracting officer cannot identify two or more WOSBs or EDWOSBs that can perform at a fair and reasonable price, but identifies one WOSB or EDWOSB that can perform. In addition, the sole source authority for WOSBs and EDWOSBs is limited to contracts valued at $6.5 million or less for manufacturing contracts and $4 million or less for all other contracts.

Nonetheless, we believe that this rule may have a significant positive economic impact on EDWOSB concerns competing for Federal contracting opportunities in industries determined by SBA to be underrepresented by WOSB concerns and likewise may positively affect WOSB concerns eligible under the WOSB Program competing in industries determined by SBA to be substantially underrepresented by WOSB concerns, since the sole source authority will still provide greater access to Federal contracting opportunities.

4. What are the projected reporting, recordkeeping, Paperwork Reduction Act, and other compliance requirements?

SBA has determined that this rule does not impose additional reporting or recordkeeping requirements.

5. What relevant federal rules may duplicate, overlap, or conflict with this rule?

SBA has not identified any relevant Federal rules currently in effect that duplicate this rule. The sole source mechanism of the WOSB program will be an addition to the procurement mechanisms available under the existing small business contracting programs that agencies currently administer, such as the HUBZone Program, the Service-Disabled Veteran-Owned (SDVO) Small Business Program, and the 8(a) Business Development Program. The sole source mechanism for WOSBs and EDWOSBs is only authorized where a contracting officer conducts market research in an industry where a WOSB or EDWOSB set aside is authorized, and the contracting officer cannot identify two or more WOSBs or EDWOSBs that can perform at a fair and reasonable price, but identifies one WOSB or EDWOSB that can perform (and so long as the value of the contract, including options, does not exceed $6.5 million for manufacturing contracts and $4 million for all other contracts). Therefore, the addition of the sole source mechanism for WOSBs and EDWOSBs should complement rather than conflict with the goals of existing small business procurement programs.

SBA believes that the Federal Acquisition Regulations (FAR) will need to be amended to include this authority so that there is no conflict between the SBA's rules and the FAR.

6. What significant alternatives did SBA consider that accomplish the stated objectives and minimize and significant economic impact on small entities?

The RFA requires agencies to identify alternatives to the rule in an effort to minimize any significant economic impact of the rule on small entities. The statutory authority for the sole source awards sets forth specific criteria, including dollar value thresholds for the awards. Therefore, the regulations must implement the statutory provisions, and there are no alternatives for these regulations.

List of Subjects in 13 CFR Part 127

Government contracts, Reporting and recordkeeping requirements, Small businesses.

Accordingly, for the reasons stated in the preamble, SBA amends 13 CFR part 127 as follows:

PART 127—WOMEN-OWNED SMALL BUSINESS FEDERAL CONTRACT PROGRAM

■ 1. The authority for part 127 continues to read as follows:

Authority: 15 U.S.C. 632, 634(b)(6), 637(m), and 644.

■ 2. Revise § 127.101 to read as follows:

§ 127.101 What type of assistance is available under this part?

This part authorizes contracting officers to restrict competition or award sole source contracts or orders to eligible Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs) for certain Federal contracts or orders in industries in which the Small Business Administration (SBA) determines that WOSBs are underrepresented in Federal

procurement. It also authorizes contracting officers to restrict competition or award sole source contracts or orders to eligible WOSBs for certain Federal contracts or orders in industries in which SBA determines that WOSBs are substantially underrepresented in Federal procurement and has waived the economically disadvantaged requirement.

■ 3. Amend § 127.102 by revising the definitions of the terms "EDWOSB requirement", "Substantial underrepresentation", "Underrepresentation", and "WOSB requirement" to read as follows:

§ 127.102 What are the definitions of the terms used in this part?

* * * * *

EDWOSB requirement means a Federal requirement for services or supplies for which a contracting officer has restricted competition or awarded a sole source contract or order to eligible EDWOSBs, including Multiple Award Contracts, partial set-asides, reserves, sole source awards, and orders set aside for EDWOSBs issued against a Multiple Award Contract.

* * * * *

Substantial underrepresentation is determined by a study using a reliable and relevant methodology.

* * * * *

Underrepresentation is determined by a study using a reliable and relevant methodology.

* * * * *

WOSB requirement means a Federal requirement for services or supplies for which a contracting officer has restricted competition or awarded a sole source contract or order to eligible WOSBs, including Multiple Award Contracts, partial set-asides, reserves, sole source awards, and orders set aside for WOSBs issued against a Multiple Award Contract.

■ 4. Revise § 127.500 to read as follows:

§ 127.500 In what industries is a contracting officer authorized to restrict competition or make a sole source award under this part?

A contracting officer may restrict competition or make a sole source award under this part only in those industries in which SBA has determined that WOSBs are underrepresented or substantially underrepresented in Federal procurement, as specified in § 127.501.

§ 127.501 [Amended]

■ 5. Amend § 127.501 by removing the word "disparity" in the two places where it appears in paragraph (b) and adding the word "underrepresentation" in its place.

■ 6. Amend § 127.503 as follows:

■ a. Revise the section heading;

■ b. Revise paragraph (a) subject heading and paragraph (b) subject heading;

■ c. Redesignate paragraphs (c), (d), (e) and (f) as paragraphs (e), (f), (g) and (h); and

■ d. Add new paragraphs (c) and (d).

The revisions and additions read as follows:

§ 127.503 When is a contracting officer authorized to restrict competition or award a sole source contract or order under this part?

(a) *Competition restricted to EDWOSBs.* * * *

(b) *Competition restricted to WOSBs.* * * *

(c) *Sole source awards to EDWOSBs.* For requirements in industries designated by SBA as underrepresented pursuant to § 127.501, a contracting officer may issue a sole source award to an EDWOSB when the contacting officer determines that:

(1) The EDWOSB is a responsible contractor with respect to performance of the requirement and the contracting officer does not have a reasonable expectation that 2 or more EDWOSBs will submit offers;

(2) The anticipated award price of the contract (including options) will not exceed $6,500,000 in the case of a contract assigned a North American Industry Classification System (NAICS) code for manufacturing, or $4,000,000 in the case of any other contract opportunity; and

(3) In the estimation of the contracting officer, the award can be made at a fair and reasonable price.

(d) *Sole source awards to WOSBs.* For requirements in industries designated by SBA as substantially underrepresented pursuant to § 127.501, a contracting officer may issue a sole source award to a WOSB when the contacting officer determines that:

(1) The WOSB is a responsible contractor with respect to performance of the requirement and the contracting officer does not have a reasonable expectation that 2 or more WOSBs will submit offers;

(2) The anticipated award price of the contract (including options) will not exceed $6,500,000 in the case of a contract assigned a NAICS code for manufacturing, or $4,000,000 in the case of any other contract opportunity; and

(3) In the estimation of the contracting officer, the award can be made at a fair and reasonable price.

* * * * *

■ 7. Revise § 127.507 to read as follows:

§ 127.507 Are there EDWOSB and WOSB contracting opportunities at or below the simplified acquisition threshold?

If the requirement is valued at or below the simplified acquisition threshold, the contracting officer may set aside the requirement or award the requirement on a sole source basis as set forth in § 127.503.

■ 8. Revise § 127.600 to read as follows:

§ 127.600 Who may protest the status of a concern as an EDWOSB or WOSB?

(a) *For sole source procurements.* SBA or the contracting officer may protest the proposed awardee's EDWOSB or WOSB status.

(b) *For all other EDWOSB or WOSB requirements.* An interested party may protest the apparent successful offeror's EDWOSB or WOSB status.

Maria Contreras-Sweet,

Administrator.

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COMMODITY FUTURES TRADING COMMISSION

17 CFR Part 170

RIN 3038–AE09

Membership in a Registered Futures Association

AGENCY: Commodity Futures Trading Commission.

ACTION: Final rule.

SUMMARY: The Commodity Futures Trading Commission ("Commission" or "CFTC") is adopting a new rule ("Final Rule") to require that all persons registered with the Commission as introducing brokers ("IB"), commodity pool operators ("CPO"), or commodity trading advisors ("CTA"), subject to an exception for those persons who are exempt from registration as a CTA pursuant to a particular provision of the Commission's regulations, must, in each case, become and remain a member of at least one registered futures association ("RFA").

DATES: The Final Rule will become effective November 13, 2015. All persons subject to the Final Rule must comply with the Final Rule by not later than December 31, 2015.

FOR FURTHER INFORMATION CONTACT: Katherine Driscoll, Associate Chief

Counsel, 202–418–5544, *kdriscoll@cftc.gov;* or Jacob Chachkin, Special Counsel, 202–418–5496, *jchachkin@cftc.gov,* Division of Swap Dealer and Intermediary Oversight, Commodity Futures Trading Commission, Three Lafayette Centre, 1155 21st Street NW., Washington, DC 20581.

SUPPLEMENTARY INFORMATION:

I. Background

Part 170 of the Commission's regulations relates to RFAs. An RFA is an association of persons registered with the Commission as such pursuant to Section 17 of the Commodity Exchange Act ("CEA" or "Act").[1] Subject to Commission oversight, RFAs serve a vital self-regulatory role by functioning as frontline regulators of their members (which members also remain subject to Commission oversight).

An RFA cannot enforce its rules over Commission registrants who are not members of the RFA.[2] As such, the Commission promulgated regulations 170.15 and 170.16 to require each registered futures commission merchant ("FCM"), and each registered swap dealer ("SD") and major swap participant ("MSP"), respectively, to be an RFA member, subject to an exception for certain notice registered securities brokers or dealers.[3] Because the National Futures Association ("NFA") was the only RFA under Section 17(a) of the CEA[4] at the time § 170.15 and § 170.16, respectively, were promulgated, these registered FCMs, SDs, and MSPs were required to be NFA members and, thus, were subject to NFA's rules. The Commission did not promulgate regulations requiring other Commission registrants, including IBs,[5] CPOs,[6] and CTAs,[7] to be members of an RFA. One of the NFA rules to which NFA members are subject, however, is NFA's Bylaw 1101. NFA Bylaw 1101 requires that, generally, no NFA member may "carry an account, accept an order or handle a transaction in commodity futures contracts" for, or on behalf of, any non-member of NFA that is required to be registered with the Commission as, among other things, an IB, CPO, or CTA.[8] Accordingly, any IB, CPO, or CTA required to be registered with the Commission that desires to conduct business with respect to commodity futures contracts directly with an FCM that is an NFA member must also become an NFA member, and derivatively, must ensure that it only conducts such business with those IBs, CPOs, or CTAs that also are NFA members. Therefore, § 170.15, at the time it was promulgated, operated in conjunction with NFA Bylaw 1101 "to assure essentially complete NFA membership from the universe of commodity professionals: [FCMs, CPOs, CTAs, and IBs]."[9]

Title VII of the Dodd-Frank Wall Street Reform and Consumer Protection Act ("Dodd-Frank Act") amended the

[1] 7 U.S.C. 21.

[2] Those Commission registrants that are not RFA members are nevertheless subject to the rules and regulations of the Commission. *See* 7 U.S.C. 21(e), which specifies that any person registered under the CEA, who is not an RFA member, "in addition to the other requirements and obligations of [the CEA] and the regulations thereunder shall be subject to such other rules and regulations as the Commission may find necessary to protect the public interest and promote just and equitable principles of trade."

[3] 17 CFR 170.15 and 170.16. *See also* Registration of Swap Dealers and Major Swap Participants, 77 FR 2613 (Jan. 19, 2012).

[4] 7 U.S.C. 21(a). NFA remains the only RFA under Section 17(a) of the CEA and is also a self-regulatory organization ("SRO"). Per Commission regulation 1.3(ee), SROs are designated contract markets, swap execution facilities, and registered futures associations. 17 CFR 1.3(ee). Certain SROs maintain and update, among other things, a standardized audit program and coordinate audit and financial statement surveillance activities over certain types of firms that are members of more than one SRO. *See* 17 CFR 1.52.

[5] IB is defined, subject to certain exclusions and additions, in CEA Section 1a(31) as any person (except an individual who elects to be and is registered as an associated person of a futures commission merchant) (i) who (I) is engaged in soliciting or in accepting orders for (aa) the purchase or sale of any commodity for future delivery, security futures product, or swap; (bb) any agreement, contract, or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i); (cc) any commodity option authorized under Section 4c; or (dd) any leverage transaction authorized under Section 19; and (II) does not accept any money, securities, or property (or extend credit in lieu thereof) to margin, guarantee, or secure any trades or contracts that result or may result therefrom; or (ii) who is registered with the Commission as an IB. 7 U.S.C. 1a(31).

IB is further defined, subject to certain exclusions and additions, in Commission regulation 1.3(mm) as (1) Any person who, for compensation or profit, whether direct or indirect: (i) Is engaged in soliciting or in accepting orders (other than in a clerical capacity) for the purchase or sale of any commodity for future delivery, security futures product, or swap; any agreement, contract or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i) of the Act; any commodity option transaction authorized under Section 4c; or any leverage transaction authorized under Section 19; or who is registered with the Commission as an IB; and (ii) Does not accept any money, securities, or property (or extend credit in lieu thereof) to margin, guarantee, or secure any trades or contracts that result or may result therefrom. 17 CFR 1.3(mm).

IBs are subject to registration with the Commission under CEA Section 4d(g) and Commission regulation 3.4(a). 7 U.S.C. 6d(g) and 17 CFR 3.4(a).

[6] CPO is defined, subject to certain exclusions and additions, in CEA Section 1a(11) as any person (i) engaged in a business that is of the nature of a commodity pool, investment trust, syndicate, or similar form of enterprise, and who, in connection therewith, solicits, accepts, or receives from others, funds, securities, or property, either directly or through capital contributions, the sale of stock or other forms of securities, or otherwise, for the purpose of trading in commodity interests, including any (I) commodity for future delivery, security futures product, or swap; (II) agreement, contract, or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i); (III) commodity option authorized under Section 4c; or (IV) leverage transaction authorized under Section 19; or (ii) who is registered with the Commission as a CPO. 7 U.S.C. 1a(11).

CPO is further defined, subject to certain exclusions and additions, in Commission regulation 1.3(cc) as any person engaged in a business which is of the nature of a commodity pool, investment trust, syndicate, or similar form of enterprise, and who, in connection therewith, solicits, accepts, or receives from others, funds, securities, or property, either directly or through capital contributions, the sale of stock or other forms of securities, or otherwise, for the purpose of trading in commodity interests, including any commodity for future delivery, security futures product, or swap; any agreement, contract or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i) of the Act; any commodity option authorized under Section 4c of the Act; any leverage transaction authorized under Section 19 of the Act; or any person who is registered with the Commission as a CPO, but does not include such persons not within the intent of the definition as the Commission may specify by rule or regulation or by order. 17 CFR 1.3(cc).

CPOs are subject to registration with the Commission under CEA Section 4m and Commission regulation 3.4(a). 7 U.S.C. 6m and 17 CFR 3.4(a).

[7] CTA is defined, subject to certain exclusions and additions, in CEA Section 1(a)(12) as any person who (i) for compensation or profit, engages in the business of advising others, either directly or through publications, writings, or electronic media, as to the value of or the advisability of trading in (I) any contract of sale of a commodity for future delivery, security futures product, or swap; (II) any agreement, contract, or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i); (III) any commodity option authorized under Section 4c; or (IV) any leverage transaction authorized under Section 19; (ii) for compensation or profit, and as part of a regular business, issues or promulgates analyses or reports concerning any of the activities referred to in clause (i); (iii) is registered with the Commission as a CTA; or (iv) the Commission, by rule or regulation, may include if the Commission determines that the rule or regulation will effectuate the purposes of the Act. 7 U.S.C. 1a(12).

CTA is further defined, subject to certain exclusions and additions, in Commission regulation 1.3(bb) as any person who, for compensation or profit, engages in the business of advising others, either directly or through publications, writings or electronic media, as to the value of or the advisability of trading in any contract of sale of a commodity for future delivery, security futures product, or swap; any agreement, contract or transaction described in Section 2(c)(2)(C)(i) or Section 2(c)(2)(D)(i) of the Act; any commodity option authorized under Section 4c of the Act; any leverage transaction authorized under Section 19 of the Act; any person registered with the Commission as a CTA; or any person, who, for compensation or profit, and as part of a regular business, issues or promulgates analyses or reports concerning any of the foregoing. 17 CFR 1.3(bb).

CTAs are subject to registration with the Commission under CEA Section 4m and Commission regulation 3.4(a). 7 U.S.C. 6m and 17 CFR 3.4(a).

[8] NFA Bylaw 1101 is available at: *http://www.nfa.futures.org/nfamanual/NFAManual.aspx?RuleID=BYLAW%201101&Section=3.*

[9] Futures Associations: Futures Commission Merchants: Mandatory Membership, 48 FR 26304, 26306 and n.22 (June 7, 1983).

CEA to establish a comprehensive new regulatory framework for swaps and security-based swaps.[10] The new regulatory framework provides that, among other things, persons that engage in regulated activity with respect to swaps will be required to register with the Commission as IBs, CPOs, or CTAs, as appropriate. Because of these definitional amendments, the intersection of § 170.15 and NFA Bylaw 1101 no longer assures NFA membership for IBs, CPOs, or CTAs that are required to register with the Commission because, as noted above, NFA Bylaw 1101 relates only to commodity futures contracts.[11]

II. Proposed Rule

On November 8, 2013, the Commission proposed to amend part 170 by adding § 170.17, which would, if adopted, have required each IB, CPO, and CTA registered with the Commission to become and remain a member of at least one RFA ("Proposal").[12]

In the Proposal, the Commission specifically solicited comments regarding, among other things, the impact of the Proposal on CTAs that are registered with the Commission despite being eligible to rely on the exemption from registration set forth in Commission regulation 4.14(a)(9) ("§ 4.14(a)(9) Exempted CTAs").[13] Regulation 4.14(a)(9) provides that a person is not required to register with the Commission as a CTA if it does not: (i) Direct any client accounts; or (ii) provide commodity trading advice based on, or tailored to, the commodity interest or cash market positions or other circumstances or characteristics of particular clients.[14] When the Commission promulgated regulation 4.14(a)(9), it stated that "[a] CTA exempt under rule 4.14(a)(9) that wishes to apply for registration or retain its current registration may do so."[15] Therefore, CTAs that may avail themselves of the exemption from registration in regulation 4.14(a)(9) may be currently registered with the Commission and may so register in the future.

The comment period for the Proposal ended on January 7, 2014.[16] The Commission received two substantive comments in response to the Proposal[17] and, in consideration of those comments, is adopting the Proposal subject to certain changes, as noted below.

III. Summary of Comments

In response to the Proposal, the Commission received two substantive comments, one from NFA and one from James W. Lovely, Esq. ("Lovely"),[18] Both comments related to the impact of the Proposal on CTAs. No comments were received in response to the CPO and IB aspects of the Proposal.

A. NFA Comment

NFA supported the Proposal as an appropriate and effective way to require IBs, CPOs, and CTAs engaging in swaps activities that otherwise are not captured by the intersection of NFA Bylaw 1101 or NFA Compliance Rule 2–36[19] to become and remain NFA members, and comply with the applicable NFA requirements. However, NFA recommended that the Commission exclude § 4.14(a)(9) Exempted CTAs from the Proposal. In support of its position, NFA stated that its existing rules focus primarily on an intermediary's conduct with respect to clients and thus have little applicability to CTAs that do not direct client accounts or otherwise exercise discretion (*i.e.*, § 4.14(a)(9) Exempted CTAs).

B. Lovely Comment

Conversely, Lovely generally stated that the Proposal "while well-intentioned, is ill-founded in many respects" and argued that the costs associated with further requiring registered CTAs to become and remain RFA members would be disproportionate to any regulatory benefit.

Lovely discussed those CTAs that register with the Commission even though they may not be required to so register (*e.g.*, because they may avail themselves of a registration exception or exclusion provided under Commission regulation 4.14(a) or Sections 1a(12)(B) or 4m(1) of the CEA, respectively). According to Lovely, these CTAs register for legal comfort in light of the "practical ambiguities around concepts [related to CTA registration requirements] such as 'solely incidental', 'principal business or profession', 'holding out' and 'tailored advice'" but do not have to become NFA members, so long as such CTAs do not manage or exercise discretion over customer accounts or funds.[20] He argues that these CTAs' voluntary registration benefits the CFTC and that such persons will likely deregister if the Commission adopts the Proposal.[21]

Lovely further stated that the CFTC "significantly underestimates the cost of NFA [membership]" for these CTAs who are not currently required to become NFA members. He noted that most of such CTAs "have only incidental involvement with commodity interests" and, if required to become NFA members, "would need to retain external legal counsel or compliance consultants to try to ascertain [which NFA rules] apply to their activities and, if so, how to comply with the same." Notwithstanding that Lovely argues that many NFA rules are not applicable to such CTAs,[22] he estimates that "external

[10] Dodd-Frank Wall Street Reform and Consumer Protection Act, Pub. L. 111–203, 124 Stat. 1376 (2010).

[11] For example, as noted in the Proposal, currently Commission-registered CTAs, CPOs, and IBs engaging solely in swap-related activities are not captured by the intersection of § 170.15 and NFA Bylaw 1101 and, thus, are not required to be NFA members. As such, these registrants, to the extent that they have not voluntarily become NFA members, are not being supervised in the same manner as Commission registrants engaging in similar activities relating to commodity futures contracts, which registrants are effectively required to be NFA members.

[12] *See* Membership in a Registered Futures Association, 78 FR 67078 (Nov. 8, 2013).

[13] 78 FR 67080 (Nov. 8, 2013).

[14] 17 CFR 4.14(a)(9). This exemption from CTA registration generally pertains to persons only providing advice to the general public, such as in a newsletter, and not to specific clients.

[15] *See* Exemption from Registration as a Commodity Trading Advisor, 65 FR 12938, 12941 (March 10, 2000).

[16] The Proposal inaccurately stated the comment period ended on January 17, 2014. To reflect the accurate date, the **Federal Register** published a correction that the comment period ended on January 7, 2014. *See* 78 FR 67985 (Nov. 13, 2013). Nonetheless, the Commission considered all comments received by January 17, 2014.

[17] *See http://comments.cftc.gov/PublicComments/CommentList.aspx?id=1424.*

[18] NFA Comment Letter and James Lovely, Esq. Comment Letter.

[19] Clause (d) of NFA Compliance Rule 2–36 applies to forex transactions and requires that no NFA member carry a forex account for, accept a forex order or account from, handle a forex transaction for or on behalf of, receive compensation (directly or indirectly) for forex transactions from, or pay compensation (directly or indirectly) for forex transactions to any non-member of NFA, or suspended member, that is required to be registered with the Commission as, among other things, an FCM, IB, CPO, or CTA in connection with its forex activities. NFA Compliance Rule 2–36 is available at: *http://www.nfa.futures.org/nfamanual/NFAManual.aspx?RuleID=RULE%202-36&Section=4.*

[20] Presumably Lovely means that such CTAs would not be captured by the intersection of § 170.15 and NFA Bylaw 1101.

[21] In this regard, Lovely also asserted that if the Commission adopts the Proposal, the First Amendment rights of these CTAs could be jeopardized, and, in some cases, such CTAs may drop their CFTC registration entirely "in reliance on . . . [their] commercial free speech rights under the U.S. Constitution."

[22] Lovely provided a non-exhaustive list of what he believes to be inapposite NFA member rules including rules regarding: (1) Account opening, risk disclosure and trading authority; (2) bunched orders and order allocation; (3) suitability or churning security futures products; (4) CTA program and performance disclosure for managed accounts or

legal and compliance assistance . . . could easily cost [such a CTA] $15,000.00 to $20,000.00 per year."

IV. Final Rule

The Commission, in consideration of the comments received by it on the Proposal, is adopting the Proposal but excluding § 4.14(a)(9) Exempted CTAs from the Final Rule.[23] The Final Rule will help ensure the integrity of the swaps and futures market and its participants by subjecting all registered IBs, CPOs, and CTAs, except for § 4.14(a)(9) Exempted CTAs, to NFA's developed set of rules and oversight capabilities.[24] As such, the Commission believes that the markets are better served, and the public better protected, by having persons subject to the requirements of the Final Rule become RFA members.[25]

After considering the comments, the Commission is persuaded by Lovely and NFA that NFA's rules have little applicability to § 4.14(a)(9) Exempted CTAs and, thus, there would be little benefit from requiring § 4.14(a)(9) Exempted CTAs to become and remain RFA members.

The Commission, however, is not persuaded that other registered CTAs, regardless of whether such CTAs are required to register with the Commission, should be excluded from the requirements of the Final Rule. Any registered CTA that does not meet the requirements of § 4.14(a)(9) would, by definition, be engaged in either (i) directing client accounts, or (ii) providing commodity trading advice based on, or tailored to, the commodity interest or cash market positions or other circumstances or characteristics of particular clients. As noted above, and consistent with § 170.15, the Commission believes that RFA supervision of registered CTAs engaging in these activities is beneficial to the markets and the clients of such CTAs.

In addition, the Commission believes that Lovely's cost estimates are very high for retaining advisors in relation to NFA's rules. Assuming a CTA was to contact an attorney familiar with Commission regulations and NFA rules applicable to CTAs, the Commission believes that determining which NFA rules are applicable to such a CTA would be a routine task that would not take a substantial amount of time.[26]

Furthermore, with respect to those CTAs that opt into CFTC registration to avoid making determinations as to their activities in relation to their eligibility for the exceptions or exclusions from the CTA registration requirements noted in Lovely's comments, such persons should review available guidance from the Commission and consult with their advisors and Commission staff, as necessary, to determine if registration is required.[27]

In support of the Final Rule, Section 4p of the CEA authorizes the Commission to "specify by rules and regulations appropriate standards with respect to training, experience, and such other qualifications as the Commission finds necessary or desirable to insure the fitness of persons required to be registered with the Commission." [28]

The Final Rule also provides a means for assuring that the purpose of Section 17(m) of the CEA,[29] allowing for compulsory RFA membership, is achieved.[30] The Commission believes that the Final Rule is reasonably necessary and desirable to effectuate comprehensive and effective market oversight by NFA in its capacity as an SRO. As the only RFA, NFA serves as the frontline regulator of its members, subject to Commission oversight. Without such mandatory membership in NFA or another RFA, effective implementation of the programs required by Section 17 of the CEA and NFA's self-regulatory programs could be impeded.[31]

In summary, by mandating RFA membership by each registered IB, CPO, and CTA, except § 4.14(a)(9) Exempted CTAs, the Final Rule enables the Commission to further ensure the fitness, and provide for direct NFA oversight, of these Commission registrants.

V. Administrative Compliance

A. Paperwork Reduction Act

The Paperwork Reduction Act of 1995 ("PRA") [32] imposes certain requirements on Federal agencies, including the Commission, in connection with their conducting or sponsoring any collection of information, as defined by the PRA. An agency may not conduct or sponsor, and a registered entity is not required to respond to, a collection of information unless it displays a currently valid control number by the Office of Management and Budget ("OMB").

In connection with the Proposal, the Commission anticipated that, if adopted, the Final Rule would simply require an amendment to the number of respondents included in OMB Collection 3038–0023.[33] The basis for this preliminary finding was that, at the time of the Proposal, NFA had indicated that certain CPOs, CTAs, and IBs were registered with the Commission, but not NFA members. Therefore, because registration and membership require the filing of Form 7–R, the Commission initially believed these respondents' paperwork burden would have been affected by the Proposal.

As discussed above, the Final Rule does not require IBs, CPOs, or CTAs to

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pools; (5) solicitation and execution of customer orders; (6) disaster recovery protocols (other than in connection with CFTC mandated record retention); (7) trading programs, performance and related promotional materials; (8) anti-money laundering; and (9) quarterly reporting of assets under management, trading programs, performance, carrying brokers and the like.

[23] Notwithstanding this exclusion, if a person is a § 4.14(a)(9) Exempted CTA and registered as an IB or CPO, then such person shall still be subject to the requirements of the Final Rule in its capacity as a registered IB or CPO, as the case may be.

[24] The Commission notes that, as a result of the Final Rule, any person not required to register, and not registered, with the CFTC would not subsequently become subject to any NFA-imposed requirement unless such person voluntarily elects to become so registered. Any adverse financial, commercial, or other impact, including the potential chilling effect on free speech, which could result from the Final Rule for such CTAs, could be avoided simply by relying on the proper regulatory exclusion or exemption without having to even incur the cost of filing a notice with the CFTC or NFA.

[25] This is consistent with the Commission's rationale for § 170.15; that there should be essentially complete NFA membership from the universe of commodity professionals. *See supra* at n.10.

[26] As noted above, Lovely himself refers to many of these rules as "inapposite." Such a description belies Lovely's argument that any substantial legal review would be required to determine whether NFA rules would apply to one of the CTAs about which Lovely comments.

Moreover, the Commission believes the costs of compliance review in subsequent years would be significantly less than the initial review costs, because it is likely that only the changes to NFA rules that took place during the prior year would need to be considered.

[27] The Commission notes that it is not of the view that making such a definitive determination is impossible or exceedingly difficult, as Lovely's comment suggests. However, the Commission does recognize that, once this determination has been made, and depending on the determination, a Commission registrant may need time to review and possibly reorganize its business in order to ensure its compliance with NFA's rules or undertake the deregistration process, as the case may be. Therefore, the Commission is providing the extended compliance period described in the DATES section above.

[28] 7 U.S.C. 6p. Also, Section 8a(5) of the CEA authorizes the Commission "to make and promulgate such rules and regulations as, in the judgment of the Commission, are reasonably necessary to effectuate any of the provisions or to accomplish any of the purposes" of the CEA.

[29] 7 U.S.C. 21(m).

[30] *See* Futures Associations: Futures Commission Merchants: Mandatory Membership, 48 FR 26304 (June 7, 1983).

[31] The Commission notes that in addition to the authority discussed herein, as noted previously, CPOs and CTAs are subject to registration with the Commission under Section 4m of the CEA, and IBs are subject to such registration under Section 4d(g) of the CEA. 7 U.S.C. 6m and 6d(g).

[32] 44 U.S.C. 3501 *et seq.*

[33] *See* OMB Control No. 3038–0023, *http://www.reginfo.gov/public/do/PRAOMBHistory?ombControlNumber=3038-0023.*

register with the Commission. Rather, the Final Rule only requires that certain of such persons that register with the Commission *become and remain an NFA member.* To indicate NFA membership an applicant needs to "check a box" on Form 7–R.[34] Current OMB Collection 3038–0023 captures the burdens associated with the registration process for these persons, including the filing of and updating of Form 7–R for registration purposes. Therefore, to comply with the Final Rule, such registrants that are not NFA members, would be required to "check-the-box" on Form 7–R indicating their status as an NFA member.

Accordingly, because the burden associated with updating Form 7–R is currently captured in OMB Collection 3038–0023, and those persons who are directly impacted by the Final Rule are either currently registered with the Commission (*i.e.,* have already filed a Form 7–R) or will be required to file a Form 7–R in connection with their registration with the Commission, no adjustment is necessary to take into account the number of Commission registrants who will have to become NFA members as a result of the Final Rule. Further, the Commission believes the additional burden of "checking the box" on Form 7–R to be non-substantive. Therefore, upon further review and for the reasons stated above, the Final Rule does not require amending existing OMB Collection 3038–0023.[35]

B. Regulatory Flexibility Act

The Regulatory Flexibility Act[36] requires federal agencies, in promulgating regulations, to consider the impact of those regulations on small entities. In the Proposal, the Commission certified that the Proposal would not have a significant economic impact on a substantial number of small entities.

1. CPOs

The Commission has previously determined that CPOs are not small entities for purposes of the Regulatory Flexibility Act.[37] Accordingly, the Chairman, on behalf of the Commission, hereby certifies pursuant to 5 U.S.C. 605(b) that the Final Rule will not have a significant economic impact on a substantial number of small entities with respect to CPOs.

2. IBs and CTAs

The Commission has previously determined to evaluate within the context of a particular rule proposal whether all or some IBs or CTAs should be considered to be small entities and, if so, to analyze the economic impact on them of any such rule.[38]

Since there may be some small entities that are IBs or CTAs and would be required to become NFA members, the Commission has considered whether this rulemaking would have a significant economic impact on these entities.

The Final Rule requires all IBs and CTAs, except § 4.14(a)(9) Exempt CTAs, who register with the Commission to become RFA members. This would require such IBs and CTAs to pay membership dues, "check a box" on Form 7–R, and ensure that they are prepared for an NFA audit.[39] As noted in the Proposal, the Commission is of the view that any costs associated with preparing for an audit by the NFA should not be substantially different from, or significantly exceed, the costs associated with preparing for an audit by the Commission, which every registered person would already be responsible to do.[40] Moreover, because the Final Rule only pertains to Commission Registrants, any audit related costs incident to NFA membership would be negligible, and should not have a significant economic impact on IBs or CTAs that may be small entities. The Commission also stated its preliminary belief that NFA membership would impose few additional compliance costs on affected entities, because these entities are already subject to the majority of regulations that NFA enforces, whether or not they are NFA members. The Commission specifically requested comment on any additional compliance costs beyond those an entity would face as a result of it being registered with the Commission.

a. Comments on Costs to CTAs

In response to the Proposal, a comment from Lovely stated that most CTAs that opt into CFTC registration and do not manage or exercise discretion over customer accounts or funds are "small or one-person operations or may have only incidental involvement with commodity interests." Further, Lovely asserts that, although many of NFA's rules are not relevant to such CTAs, the Commission understates the cost of required NFA membership, including that the costs to these CTAs of reviewing and complying with such rules would be approximately $15,000 to $20,000 annually.

As discussed above, the Commission believes that Lovely's compliance cost estimates are very high. Rather, the Commission believes that the costs faced by a CTA would, at most, be approximately $2,950 in the first year and $1,476 in subsequent years.[41] The Commission does not believe that these amounts plus the $750 membership dues required of all NFA members that are CTAs, results in an unreasonable burden on any CTAs (including those that may be small entities under the Regulatory Flexibility Act).[42] Further, as

[34] The Commission has designated NFA to receive Form 7–R submissions on its behalf. The Commission notes that application for NFA membership is incorporated in Form 7–R.

[35] The Commission further believes that many Commission registrants' recordkeeping obligations associated with preparing for an NFA audit are already covered by other OMB control numbers. For example, §§ 4.23 and 4.33 of the Commission's regulations are recordkeeping requirements associated with registered CPOs and CTAs, respectively, which are covered by OMB control number 3038–0005.

[36] 5 U.S.C. 601 *et seq.*

[37] Policy Statement and Establishment of Definitions of "Small Entities" for Purposes of the Regulatory Flexibility Act, 47 FR 18618, 18619 (Apr. 30, 1982).

[38] *See,* with respect to CTAs, 47 FR at 18620 (Apr. 30, 1982); and *see,* with respect to IBs, Introducing Brokers and Associated Persons of Introducing Brokers, Commodity Trading Advisors and Commodity Pool Operators; Registration and Other Regulatory Requirements, 48 FR 35276 (Aug. 3, 1983).

[39] *See* 78 FR 67083 (Nov. 8, 2013). As stated in the booklet titled "NFA Regulatory Requirements: For FCMs, IBs, CPOs, and CTAs," NFA audits have two major objectives: (1) To determine whether the firm is maintaining records in accordance with NFA rules and applicable CFTC regulations; and (2) to ensure that the firm is being operated in a professional manner and that customers are protected against unscrupulous activities and fraudulent or high-pressure sales practices.

[40] As noted above, the Commission believes that many of the recordkeeping obligations associated with preparing for an NFA audit are already required for Commission registrants. Moreover, given the average periodicity for NFA audits, the magnitude of annual audit-related costs is limited.

[41] This estimate is based on the following labor estimates for this determination: for the first year, 6 hours of an attorney; in subsequent years, 3 hours of an attorney, in each case at approximately $492.21/hour. The estimate of the hourly cost is from the Securities Industry and Financial Markets Association's Report on Management and Professional Earnings in the Securities Industry—2013, modified by CFTC staff to account for an 1800-hour work-year and multiplied by 5.35 to account for firm size, employee benefits, and overhead. The Commission believes that the use of this multiplier is appropriate here because the Commission is assuming that persons retain outside advisors to assist in complying with NFA rules. The Commission rounds to two significant digits.

[42] Assuming that IBs would face similar compliance costs as CTAs, the Commission does not believe that these costs result in an unreasonable burden on any IBs (including those that may be small entities under the Regulatory Flexibility Act). Further, as of June 30, 2015, all registered IBs that are not members of NFA are pending withdrawal of their Commission registration. Accordingly, the Commission believes that no currently registered IBs will be impacted by this rule.

discussed above, § 4.14(a)(9) Exempted CTAs (*i.e.*, those CTAs that neither manage nor exercise discretion over customer accounts or funds and that do provide clients advice described in § 4.14(a)(9)(ii)) will not be required to become or remain RFA members pursuant to the Final Rule and, thus, will not face any compliance costs from the Final Rule.

b. Commission Determination

Accordingly, for the reasons stated above, the Commission believes that the Final Rule will not have a significant economic impact on a substantial number of small entities. Therefore, the Chairman, on behalf of the Commission, hereby certifies, pursuant to 5 U.S.C. 605(b), that the Final Rule being published today by this **Federal Register** release will not have a significant economic impact on a substantial number of small entities.

C. Considerations of Costs and Benefits

Section 15(a) of the CEA requires the Commission to consider the costs and benefits of its actions before promulgating a regulation under the CEA or issuing an order. Section 15(a) further specifies that the costs and benefits shall be evaluated in light of the following five broad areas of market and public concern: (1) Protection of market participants and the public; (2) efficiency, competitiveness, and financial integrity of futures markets; (3) price discovery; (4) sound risk management practices; and (5) other public interest considerations. The Commission considers the costs and benefits resulting from its discretionary determinations with respect to the section 15(a) factors.

1. Background

As discussed above, the Dodd-Frank Act amended the CEA to establish a comprehensive new regulatory framework for swaps markets and, in doing so, required IBs, CPOs, and CTAs acting in relation to swaps to register with the Commission. These newly registered persons, however, are not currently required to become NFA members because, as discussed above, they are not captured by the intersection of § 170.15 and NFA Bylaw 1101.

NFA cannot enforce its rules over Commission registrants who do not become NFA members, including IBs, CPOs, and CTAs active solely in relation to swap transactions, which are not currently required to become NFA members. Thus, the Final Rule requires registered IBs, CPOs, and CTAs, except § 4.14(a)(9) Exempted CTAs, to become NFA members similarly to how § 170.15 presently requires FCMs to become NFA members and how § 170.16 requires the same of SDs and MSPs. In conjunction with §§ 170.15 and 170.16, the Commission is intending to create an oversight regime that ensures more consistent treatment of its registered intermediaries. The Commission believes that the Final Rule is reasonably necessary to ensure the fitness and comprehensive regulation and appropriate oversight of such persons.

In assessing the costs and benefits of the Final Rule, the Commission employs a status quo baseline. The Commission analyzes the cost and benefit to those registered persons that, but for the Final Rule, would not have to become RFA members. As of June 30, 2015, the following numbers of Commission registered IBs, CPOs, and CTAs (registered in the below categories) were not NFA members ("Non-member Registrants"):[43]

Registration category	Non-member registrants
IB only	21
CPO only	61
CTA only	573
IB & CPO	1
IB & CTA	2
CTA & CPO	41
FCM & CPO	1
Total	700

Of these Non-member Registrants, however, approximately 138 are pending withdrawal of their Commission registration. The Commission is assuming that these Non-member Registrants will withdraw their registration and, thus, will not be impacted by the Final Rule. In addition, only approximately one percent of the Non-member Registrants registered solely as CTAs reported to the Commission in the most recent reporting cycle that they had directed client accounts.[44] As such, the Commission believes that many of the Non-member Registrants registered solely as CTAs will be § 4.14(a)(9) Exempted CTAs and, thus, will not be required to comply with the Final Rule.[45] Accordingly, the Commission estimates that 296[46] persons registered with the CFTC as a CPO, CTA, or IB will be required to become and remain NFA members as a result of the Final Rule.[47]

Because at this time the Commission cannot reasonably estimate the number of Non-member Registrants that may deregister with the Commission as a result of the Final Rule, the Commission is assuming that no Non-member Registrants will deregister as a result of the Final Rule. The Commission believes that this will lead to an overstatement of the compliance costs relating to the Final Rule.

2. Costs

a. Costs to IBs, CPOs, and CTAs

As discussed above, the process for a Non-member Registrant to become an NFA member amounts to checking a box on the CFTC registration form and updating some contact information. Thus, the Commission believes the cost of filing for membership to be non-substantive.[48]

Affected persons are also subject to certain membership fees. NFA imposes initial membership dues and annual membership dues for IBs, CPOs, and CTAs. Currently, such initial membership dues are $750 for the first year, and the annual dues to maintain membership are $750 per year

The Commission also notes that, pursuant to Section 17(d) of the Act, each CTA or IB that is registered with the Commission, but not an RFA member is required to ". . . pay to the Commission such reasonable fees and charges [established by the Commission] as may be necessary to defray the costs of additional regulatory duties required to be performed by the Commission because such person is not a member of an [RFA]." 7 U.S.C. 21(d). The Commission has not yet established any such fees or charges, but noted in the release for § 170.15 that these charges are likely to be greater than the costs attendant to RFA membership. *See* 48 FR at 26311.

[43] *See* NFA's daily directory of CFTC Registrants and Members available at: *http://www.nfa.futures.org/NFA-registration/NFA-directories.HTML.*

[44] The Commission is assuming that all Non-member Registrants registered solely as CTAs have reported to the Commission the amount of assets they have directed, if any.

[45] For purposes of its analysis, the Commission is assuming that approximately half of the 573 Non-member Registrants registered solely as CTAs (286 Non-member Registrants) will be § 4.14(a)(9) Exempted CTAs and will not be required to comply with the Final Rule, and 20 of these 286 Non-member Registrants will be pending withdrawal of their Commission registration.

[46] To arrive at the estimate, the 700 figure was reduced by the sum of (i) 138 (the Non-member Registrants whose withdrawal from Commission registration is pending) and (ii) 266 (the Non-member Registrants that the Commission assumes will be § 4.14(a)(9) Exempted CTAs net of those pending withdrawal, as described above).

[47] For purposes of assessing the costs of this rule, the Commission is assuming that no Non-member Registrant is, absent the Final Rule, required to be an NFA member.

[48] *See* Form 7–R, *http://www.nfa.futures.org/NFA-registration/templates-and-forms/form7-r.HTML.* Applications forms for NFA membership and Associate membership are incorporated in Forms 7–R and 8–R. *See* NFA Membership and Dues, *http://www.nfa.futures.org/NFA-registration/NFA-membership-and-dues.HTML.*

thereafter.[49] Thus, the 296 affected Non-member Registrants, in the aggregate, will incur an initial and ongoing annual registration/membership cost of approximately $222,000.[50]

The Commission agrees with Lovely that the Final Rule will also impose certain compliance costs on affected Non-member Registrants. However, as noted above, the Commission believes that, given the existing requirements imposed on such registrants, the compliance costs of becoming an NFA member and complying with NFA's rules (including preparing for an audit by NFA) will be partially offset by the costs already incurred by these registrants (*i.e.*, the costs associated with complying with Commission regulations and preparing for examinations by the Commission). In that regard, as discussed above, the Commission disagrees with Lovely's cost estimates and estimates that an affected registrant may, at most, face additional compliance costs of approximately $2,950 initially and $1,476 in subsequent years, equating to an industry total of $873,200 in the first year and $436,896 in subsequent years,[51] plus the indirect costs of the periodic audits. The Commission cannot reasonably provide an exact estimate of these costs due to the idiosyncratic nature of the indirect costs incurred.[52]

b. Other Market Costs

In addition to the direct costs to Commission Registrants, the Commission considered other costs to the markets of the Final Rule. In particular, the Commission considered the impact the Final Rule will have on IBs, CPOs, and CTAs (i) election to not register with the Commission and (ii) optional deregistration, in each case, where such persons are not required to be registered with the Commission. Further, the Commission considered that the requirements of the Final Rule may cause fewer persons to elect to become IBs, CPOs, and CTAs because of the added burden of being an RFA member. The Commission is unable to estimate accurately how many IBs, CPOs, and CTAs will deregister with the Commission or elect not to so register in the future, or how many persons will choose to not become such an intermediary, in each case, as a result of the Final Rule. Further, the Commission believes that if a market participant has chosen not to register with the Commission, the costs incurred by that participant for not registering would be less than the costs that would have been incurred to register. Otherwise, the market participant would likely have chosen to register instead. However, the Commission cannot make a more accurate determination of costs beyond this overestimate without knowing more specifics about a particular market participant.

c. Consideration of the Proposal as an Alternative to the Final Rule

The Commission believes the costs in a. and b. above, respectively, are reduced from those that would have resulted had the Proposal been adopted without modification (the Proposal would have required each registered IB, CPO, and CTA, without exception, to become and remain a member of an RFA), because the Commission has excepted § 4.14(a)(9) Exempted CTAs from the requirements of the Final Rule. This exclusion limits the Commission's ability to oversee these persons through delegation to an RFA; however, the Commission has determined that this reduction in the Commission's oversight abilities is reasonable in light of the burden that the Proposal would otherwise impose on § 4.14(a)(9) Exempted CTAs and the markets. The Commission further notes that, as discussed above, § 4.14(a)(9) Exempted CTAs that are not RFA members are still subject to the Commission's rules and regulations.

3. Benefits

The Final Rule enables the Commission to (i) carry out its obligations pursuant to Section 17 of the CEA to delegate certain oversight responsibility for intermediaries, including IBs, CPOs, and CTAs, to an RFA, and (ii) ensure the fitness of its registrants as described under Section 4p of the CEA. The Commission believes that by requiring RFA membership, the Final Rule results in a more efficient deployment of agency resources which would otherwise have to be used to oversee these registrants who would, without the Final Rule, not be overseen by an RFA. Further, the Commission believes that the Final Rule enables NFA to apply its experience as a SRO to oversee and ensure the fitness of all registered IBs, CPOs, and CTAs, except § 4.14(a)(9) Exempt CTAs. The markets and the public will benefit from NFA's developed set of rules and oversight capabilities to ensure the integrity of the swaps market and its participants.

4. Section 15(a) Factors

The Commission requested comment on all aspects of the Section 15(a) factors. Except as discussed above, the Commission did not receive any comments relating to costs and benefits of the Final Rule.

Section 15(a) of the CEA requires the Commission to consider the effects of its actions in light of the following five factors:

a. Protection of Market Participants and the Public

The Final Rule will protect the public by ensuring that registered IBs, CPOs, and CTAs, except § 4.14(a)(9) Exempt CTAs, are subject to the same level of comprehensive NFA oversight.

b. Efficiency, Competitiveness, and Financial Integrity of Markets

The Final Rule ensures that all registered IBs, CPOs, and CTAs, except § 4.14(a)(9) Exempt CTAs, are subject to a similar level of oversight and regulatory responsibility. In so doing, the Commission believes the integrity of markets is enhanced. Furthermore, the Commission also believes that the Final Rule will promote public confidence in the integrity of derivatives markets by ensuring consistent and adequate regulation and oversight of registered IBs, CPOs, and CTAs, except § 4.14(a)(9) Exempt CTAs.

c. Price Discovery

The Commission has not identified an impact on price discovery as a result of the Final Rule.

d. Sound Risk Management

The Commission has not identified an impact on the risk management decisions of market participants as a result of the Final Rule.

e. Other Public Interest Considerations

The Commission has not identified an impact on other public interest considerations as a result of the Final Rule.

List of Subjects in 17 CFR Part 170

Authority delegations (Government agencies), Commodity futures, Membership in a Registered Futures

[49] *See* NFA Membership and Dues, *http://www.nfa.futures.org/NFA-registration/NFA-membership-and-dues.HTML.*

[50] To arrive at the monetary estimate, the 296 figure was multiplied by the $750.00 per-person annual membership dues.

[51] To arrive at the monetary estimate, the 296 figure was multiplied by the estimated per-person compliance costs.

[52] The Commission also considered that, in addition to the Non-member Registrants discussed above, the Final Rule will cause future persons registering with the Commission as IBs, CPOs, and CTAs because of their activities in relation to swaps to incur additional costs similar to those described above. The Commission expects that many persons will apply for registration under the Commission's swaps market regime in such capacities, but the Commission is not able to accurately estimate the exact number of new Commission registrants that will do so and, thus, be affected by the Final Rule.

Association, Reporting and recordkeeping requirements.

For the reasons stated in the preamble, the Commodity Futures Trading Commission amends 17 CFR part 170 as set forth below:

PART 170—REGISTERED FUTURES ASSOCIATIONS

■ 1. The authority citation for part 170 is revised to read as follows:

Authority: 7 U.S.C. 6d, 6m, 6p, 6s, 12a, and 21.

■ 2. Add § 170.17 to read as follows:

§ 170.17 Introducing brokers, commodity pool operators, and commodity trading advisors.

Each person registered as an introducing broker, commodity pool operator, or commodity trading advisor must become and remain a member of at least one futures association that is registered under Section 17 of the Act and that provides for the membership therein of introducing brokers, commodity pool operators, or commodity trading advisors, as the case may be, unless no such futures association is so registered; provided, however that a person registered as a commodity trading advisor shall not be required to become or remain a member of such a futures association, solely in respect of its registration as a commodity trading advisor, if such person is eligible for the exemption from registration as such pursuant to § 4.14(a)(9) of this chapter.

Issued in Washington, DC, on September 9, 2015, by the Commission.

Christopher J. Kirkpatrick,

Secretary of the Commission.

Note: The following appendix will not appear in the Code of Federal Regulations.

Appendix to Membership in a Registered Futures Association—Commission Voting Summary

On this matter, Chairman Massad and Commissioners Bowen and Giancarlo voted in the affirmative. No Commissioner voted in the negative.

[FR Doc. 2015–23046 Filed 9–11–15; 8:45 am]

BILLING CODE 6351–01–P

DEPARTMENT OF LABOR

Wage and Hour Division

29 CFR Part 552

RIN 1235–AA05

Application of the Fair Labor Standards Act to Domestic Service; Announcement of 30-Day Period of Non-Enforcement

AGENCY: Wage and Hour Division, Department of Labor.

ACTION: Policy statement.

SUMMARY: The Department of Labor's (Department) Final Rule amending regulations regarding domestic service employment, which extends Fair Labor Standards Act (FLSA) protections to most home care workers, had an effective date of January 1, 2015. The Department has not begun enforcement of the Final Rule both because of its previously announced time-limited non-enforcement policy and because it is a party to a federal lawsuit regarding the amended regulations. The U.S. Court of Appeals for the District of Columbia issued an opinion in that case in favor of the Department on August 21, 2015. The Department will not bring enforcement actions against any employer for violations of FLSA obligations resulting from the amended domestic service regulations for 30 days after the date the Court of Appeals issues a mandate making its opinion effective.

DATES: This policy statement was signed on September 9, 2015.

FOR FURTHER INFORMATION CONTACT: Mary Ziegler, Assistant Administrator, Office of Policy, U.S. Department of Labor, Wage and Hour Division, 200 Constitution Avenue NW., Room S–3502, FP Building, Washington, DC 20210; telephone: (202) 343–5940 (this is not a toll-free number), email: *HomeCare@dol.gov.* Copies of this Policy Statement may be obtained in alternative formats (Large Print, Braille, Audio Tape, or Disc), upon request, by calling (202) 693–0675 (not a toll-free number). TTY/TTD callers may dial toll-free (877) 889–5627 to obtain information or request materials in alternative formats.

SUPPLEMENTARY INFORMATION:

I. 30-Day Non-Enforcement Period After Mandate Issues

The Department's Final Rule amending regulations regarding domestic service employment, 78 FR 60454, which extends FLSA protections to most home care workers, had an effective date of January 1, 2015. The Department has not begun enforcement of the Final Rule both because of its time-limited non-enforcement policy, 79 FR 60974 (October 9, 2014), and because it is a party to a federal lawsuit regarding the amended regulations in which the U.S. District Court for the District of Columbia issued opinions and orders vacating the rule's major provisions. *Home Care Ass'n of Am.* v. *Weil,* 76 F. Supp. 3d 138 (D.D.C. 2014); *Home Care Ass'n of Am.* v. *Weil,* 78 F. Supp. 3d 123 (D.D.C. 2015). On August 21, 2015, the U.S. Court of Appeals for the District of Columbia Circuit reversed the district court's judgment. *Home Care Ass'n of America* v. *Weil,* . . . F.3d . . . , No. 15–5018, 2015 WL 4978980 (D.C. Cir. Aug. 21, 2015). The Court of Appeals opinion will become effective when that court issues a mandate directing the district court to enter a new judgment in favor of the Department. Although it is not yet known on what date the mandate will issue, the Department will not bring enforcement actions against any employer for violations of FLSA obligations resulting from the amended domestic service regulations for 30 days after the date the mandate issues.

This 30-day non-enforcement policy does not replace or affect the timeline of the Department's existing time-limited non-enforcement policy announced in October 2014. 79 FR 60974. Under that policy, through December 31, 2015, the Department will exercise prosecutorial discretion in determining whether to bring enforcement actions, with particular consideration given to the extent to which States and other entities have made good faith efforts to bring their home care programs into compliance with the FLSA since the promulgation of the Final Rule. The Department will also continue to provide intensive technical assistance to the regulated community, as it has since promulgation of the Final Rule.

II. Regulatory Requirements

This Policy Statement is guidance articulating considerations relevant to the Department's exercise of its enforcement authority under the FLSA. It is therefore exempt from the notice-and-comment rulemaking requirements under the Administrative Procedure Act pursuant to 5 U.S.C. 553(b).

Because no notice of proposed rulemaking is required, the Regulatory Flexibility Act does not require an initial or final regulatory flexibility analysis. 5 U.S.C. 603(a), 604(a). The Department has determined that this guidance does not impose any new or revise any existing recordkeeping,

reporting, or disclosure requirements on covered entities or members of the public that would be collections of information requiring OMB approval under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.*

Dated: September 9, 2015.

David Weil,

Administrator, Wage and Hour Division.

[FR Doc. 2015–23092 Filed 9–11–15; 8:45 am]

BILLING CODE 4510–27–P

DEPARTMENT OF HOMELAND SECURITY

Coast Guard

33 CFR Part 117

[Docket No. USCG–2015–0841]

Drawbridge Operation Regulation; Saugus River, Saugus, Massachusetts

AGENCY: Coast Guard, DHS.

ACTION: Notice of deviation from drawbridge regulation.

SUMMARY: The Coast Guard has issued a temporary deviation from the operating schedule that governs the Saugus RR Bridge, across the Saugus River, mile 2.1, at Saugus, Massachusetts. This deviation is necessary to facilitate essential maintenance repairs. This deviation allows the bridge to remain in the closed position during the maintenance repairs.

DATES: This deviation is effective from 12:01 a.m. on September 19, 2015 to 11:59 p.m. on September 20, 2015.

ADDRESSES: The docket for this deviation, [USCG–2015–0841] is available at *http://www.regulations.gov.* Type the docket number in the "SEARCH" box and click "SEARCH." Click on Open Docket Folder on the line associated with this deviation. You may also visit the Docket Management Facility in Room W12–140, on the ground floor of the Department of Transportation West Building, 1200 New Jersey Avenue SE., Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: If you have questions on this temporary deviation, contact Mr. Joe Arca, Project Officer, First Coast Guard District, telephone (212) 514–4336, email *joe.m.arca@uscg.mil.* If you have questions on viewing the docket, call Ms. Cheryl Collins, Program Manager, Docket Operations, telephone (202) 366–9826.

SUPPLEMENTARY INFORMATION: The Saugus RR Bridge, mile 2.1, across Saugus River has a vertical clearance in the closed position of 7 feet at mean high water and 17 feet at mean low water. The existing bridge operating regulations opens on schedule as required by 33 CFR 117.5.

Saugus River is transited by commercial lobstermen and recreational vessel traffic.

Keolis Commuter Railroad requested this temporary deviation from the normal operating schedule to facilitate essential maintenance repairs.

Under this temporary deviation, the Saugus RR Bridge may remain in the closed position from 12:01 a.m. on September 19, 2015 to 11:59 p.m. on September 20, 2015.

There is no alternate route for vessel traffic; however, vessels that can pass under the closed draws during this closure may do so at any time. The bridge will be able to open in the event of an emergency.

The Coast Guard will inform the users of the waterway through our Local Notice to Mariners of the change in operating schedule for the bridge so that vessels can arrange their transits to minimize any impact caused by the temporary deviation.

In accordance with 33 CFR 117.35(e), the drawbridge must return to its regular operating schedule immediately at the end of the effective period of this temporary deviation. This deviation from the operating regulations is authorized under 33 CFR 117.35.

Dated: September 1, 2015.

C.J. Bisignano,

Supervisory Bridge Management Specialist, First Coast Guard District.

[FR Doc. 2015–23067 Filed 9–11–15; 8:45 am]

BILLING CODE 9110–04–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[EPA–R07–OAR–2015–0299; FRL–9933–84–Region 7]

Approval and Promulgation of Air Quality Implementation Plans; State of Kansas Regional Haze State Implementation Plan Revision and 2014 Five-Year Progress Report

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: The Environmental Protection Agency (EPA) is taking final action to approve the Kansas State Implementation Plan (SIP) revision submitted to EPA by the State of Kansas on March 10, 2015, documenting that the State's existing plan is making adequate progress to achieve visibility goals by 2018. The Kansas SIP revision addressed the Regional Haze Rule (RHR) requirements under the Clean Air Act (CAA or Act) to submit a report describing progress in achieving reasonable progress goals (RPGs) to improve visibility in Federally designated areas in nearby states that may be affected by emissions from sources in Kansas. EPA is taking final action to approve Kansas' determination that the existing Regional Haze (RH) SIP is adequate to meet the visibility goals and requires no substantive revision at this time.

DATES: This final rule is effective October 14, 2015.

ADDRESSES: EPA has established a docket for this action under Docket ID No. EPA–R07–OAR–2015–0299. All documents in the docket are listed on the *www.regulations.gov* Web site. Although listed in the index, some information is not publicly available, *i.e.,* CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically through *www.regulations.gov* or at the Environmental Protection Agency, Air Planning and Development Branch, 11201 Renner Boulevard, Lenexa, Kansas 66219. The Regional Office's official hours of business are Monday through Friday, 8:00 a.m. to 4:30 p.m., excluding Federal holidays. The interested persons wanting to examine these documents should make an appointment with the office at least 24 hours in advance.

FOR FURTHER INFORMATION CONTACT: Stephen Krabbe, Environmental Protection Agency, Air Planning and Development Branch, 11201 Renner Boulevard, Lenexa, Kansas 66219 at 913–551–7991, or by email at *krabbe.stephen@epa.gov.*

SUPPLEMENTARY INFORMATION: Throughout this document "we", "us", or "our" refer to EPA. This section provides additional information by addressing the following:

I. Background
II. Summary of SIP Revision
III. Final Action
IV. Statutory and Executive Order Reviews

I. Background

On June 10, 2015, (80 FR 32874), EPA published a notice of proposed rulemaking (NPR) for the State of

Kansas. In the NPR, EPA proposed approval of Kansas's progress report SIP, a report on progress made in the first implementation period towards RPGs for Class I areas that are affected by emissions from Kansas sources. This progress report SIP and accompanying cover letter also included a determination that Kansas's existing regional haze SIP requires no substantive revision to achieve the established regional haze visibility improvement and emissions reduction goals for 2018.

States are required to submit a progress report in the form of a SIP revision every five years that evaluates progress towards the RPGs for each mandatory Class I Federal area within the state and in each mandatory Class I Federal area outside the state which may be affected by emissions from within the state. See 40 CFR 51.308(g). In addition, the provisions under 40 CFR 51.308(h) require states to submit, at the same time as the 40 CFR 51.308(g) progress report, a determination of the adequacy of the state's existing regional haze SIP. The first progress report SIP is due five years after submittal of the initial regional haze SIP. On October 26, 2009, KDHE submitted its regional haze SIP in accordance with the requirements of 40 CFR 51.308. The progress report SIP revision was submitted by Kansas on March 10, 2015, and EPA finds that it satisfies the requirements of 40 CFR 51.308(g) and (h). No comments were received regarding the NPR.

II. Summary of SIP Revision

On March 10, 2015, Kansas submitted a SIP revision to describe the progress made towards the RPGs of Class I areas in and outside Kansas that are affected by emissions from Kansas' sources. This progress report SIP also includes a determination of the adequacy of Kansas' existing regional haze SIP to achieve these RPGs.

Kansas has no Class I areas within its borders. Kansas notes in its progress report SIP that Kansas sources were also identified as potentially impacting four Class I areas in three neighboring states: Caney Creek Wilderness Area in Arkansas, Hercules-Glades Wilderness Area in Missouri, Mingo Wilderness Area in Missouri, and Wichita Mountains Wilderness Area in Oklahoma.

The provisions in 40 CFR 51.308(g) require a progress report SIP to address seven elements. EPA finds that Kansas' progress report SIP addressed each element under 40 CFR 51.308(g). The seven elements and EPA's conclusion are briefly summarized in this rulemaking action.

The provisions in 40 CFR 51.308(g) require progress report SIPs to include a description of the status of measures in the approved regional haze SIP; a summary of emissions reductions achieved; an assessment of visibility conditions for each Class I area in the state; an analysis of changes in emissions from sources and activities within the state; an assessment of any significant changes in anthropogenic emissions within or outside the state that have limited or impeded progress in Class I areas impacted by the state's sources; an assessment of the sufficiency of the approved regional haze SIP; and a review of the state's visibility monitoring strategy. As explained in detail in the NPR, EPA finds that Kansas' progress report SIP addressed each element and has therefore satisfied the requirements under 40 CFR 51.308(g).

In addition, pursuant to 40 CFR 51.308(h), states are required to submit, at the same time as the progress report SIP, a determination of the adequacy of their existing regional haze SIP and to take one of four possible actions based on information in the progress report. One possible action is submission of a negative declaration to EPA that no further substantive revision to the state's existing regional haze SIP is needed. In its progress report SIP, Kansas submitted a negative declaration that it had determined that its existing regional haze SIP requires no further substantive revision to achieve the RPGs for the Class I areas that are affected by emissions from Kansas's sources. As explained in detail in the NPR, EPA concludes Kansas has adequately addressed 40 CFR 51.308(h) because the visibility data trends at the Class I areas impacted by Kansas's sources and the emissions trends of the largest emitters of visibility-impairing pollutants both indicate that the RPGs for 2018 will be met or exceeded. Therefore, EPA concludes Kansas' progress report SIP meets the requirements of 40 CFR 51.308(h).

III. Final Action

EPA is taking final action to approve Kansas' regional haze five-year progress report and SIP revision, submitted March 10, 2015, as meeting the applicable regional haze requirements as set forth in 40 CFR 51.308(g) and 51.308(h).

Statutory and Executive Order Reviews

Under the Clean Air Act (CAA), the Administrator is required to approve a SIP submission that complies with the provisions of the Act and applicable Federal regulations. 42 U.S.C. 7410(k); 40 CFR 52.02(a). Thus, in reviewing SIP submissions, EPA's role is to approve state choices, provided that they meet the criteria of the CAA. Accordingly, this action merely approves state law as meeting Federal requirements and does not impose additional requirements beyond those imposed by state law. For that reason, this action:

- Is not a significant regulatory action subject to review by the Office of Management and Budget under Executive Orders 12866 (58 FR 51735, October 4, 1993) and 13563 (76 FR 3821, January 21, 2011);
- Does not impose an information collection burden under the provisions of the Paperwork Reduction Act (44 U.S.C. 3501 *et seq.*);
- Is certified as not having a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*);
- Does not contain any unfunded mandate or significantly or uniquely affect small governments, as described in the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4);
- Does not have Federalism implications as specified in Executive Order 13132 (64 FR 43255, August 10, 1999);
- Is not an economically significant regulatory action based on health or safety risks subject to Executive Order 13045 (62 FR 19885, April 23, 1997);
- Is not a significant regulatory action subject to Executive Order 13211 (66 FR 28355, May 22, 2001);
- Is not subject to requirements of Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note) because application of those requirements would be inconsistent with the CAA; and
- Does not provide EPA with the discretionary authority to address, as appropriate, disproportionate human health or environmental effects, using practicable and legally permissible methods, under Executive Order 12898 (59 FR 7629, February 16, 1994).

The SIP is not approved to apply on any Indian reservation land or in any other area where EPA or an Indian tribe has demonstrated that a tribe has jurisdiction. In those areas of Indian country, the rule does not have tribal implications and will not impose substantial direct costs on tribal governments or preempt tribal law as specified by Executive Order 13175 (65 FR 67249, November 9, 2000).

The Congressional Review Act, 5 U.S.C. 801 *et seq.*, as added by the Small Business Regulatory Enforcement Fairness Act of 1996, generally provides that before a rule may take effect, the

agency promulgating the rule must submit a rule report, which includes a copy of the rule, to each House of the Congress and to the Comptroller General of the United States. EPA will submit a report containing this action and other required information to the U.S. Senate, the U.S. House of Representatives, and the Comptroller General of the United States prior to publication of the rule in the **Federal Register**. A major rule cannot take effect until 60 days after it is published in the **Federal Register**. This action is not a "major rule" as defined by 5 U.S.C. 804(2).

Under section 307(b)(1) of the CAA, petitions for judicial review of this action must be filed in the United States Court of Appeals for the appropriate circuit by November 13, 2015. Filing a petition for reconsideration by the Administrator of this final rule does not affect the finality of this action for the purposes of judicial review nor does it extend the time within which a petition for judicial review may be filed, and shall not postpone the effectiveness of such rule or action. This action may not be challenged later in proceedings to enforce its requirements. (See section 307(b)(2).)

List of Subjects in 40 CFR Part 52

Environmental protection, Air pollution control, Carbon monoxide, Incorporation by reference, Intergovernmental relations, Lead, Nitrogen dioxide, Ozone, Particulate matter, Reporting and recordkeeping requirements, Sulfur oxides, Volatile organic compounds.

Dated: August 20, 2015.

Mark Hague,

Acting Regional Administrator, Region 7.

For the reasons stated in the preamble, EPA amends 40 CFR part 52 as set forth below:

PART 52—APPROVAL AND PROMULGATION OF IMPLEMENTATION PLANS

■ 1. The authority citation for part 52 continues to read as follows:

Authority: 42 U.S.C. 7401 *et seq.*

Subpart R—Kansas

■ 2. In § 52.870, the table in paragraph (e) is amended by adding entry (42) at the end of the table to read as follows:

§ 52.870 Identification of plan.

* * * * *

(e)* * *

EPA-APPROVED KANSAS NONREGULATORY PROVISIONS

Name of nonregulatory SIP provision	Applicable geographic or nonattainment area	State submittal date	EPA approval date	Explanation
*	*	*	*	*
(42) State Implementation Plan (SIP) Revision for the Attainment and Maintenance of National Ambient Air Quality Standards for Regional Haze (2014 Five-Year Progress Report).	Statewide	3/10/15	9/14/15 [*Insert* **Federal Register** *citation*]	

[FR Doc. 2015–23074 Filed 9–11–15; 8:45 am]
BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 271

[EPA–R06–2015–0070 RCRA; FRL–9933–79–Region 6]

Louisiana: Final Authorization of State Hazardous Waste Management Program Revision

AGENCY: Environmental Protection Agency (EPA).

ACTION: Direct final rule.

SUMMARY: Louisiana has applied to the Environmental Protection Agency (EPA) for final authorization of the changes to its hazardous waste program under the Resource Conservation and Recovery Act (RCRA). The EPA has determined that these changes satisfy all requirements needed to qualify for final authorization, and is authorizing the State's changes through this direct final action. The EPA is publishing this rule to authorize the changes without a prior proposal because we believe this action is not controversial and do not expect comments that oppose it. Unless we receive written comments which oppose this authorization during the comment period, the decision to authorize Louisiana's changes to its hazardous waste program will take effect. If we receive comments that oppose this action, we will publish a document in the **Federal Register** withdrawing this rule before it takes effect, and a separate document in the proposed rules section of this **Federal Register** will serve as a proposal to authorize the changes.

DATES: This final authorization will become effective on November 13, 2015 unless the EPA receives adverse written comment by October 14, 2015. If the EPA receives such comment, it will publish a timely withdrawal of this direct final rule in the **Federal Register** and inform the public that this authorization will not take effect.

ADDRESSES: Submit any comments identified by Docket ID No. EPA–R06–RCRA–2015–0070, by one of the following methods:

1. *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the on-line instructions for submitting comments.

2. *Email: patterson.alima@epa.gov.*

3. *Mail:* Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas Texas 75202–2733.

4. *Hand Delivery or Courier.* Deliver your comments to Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733.

Instructions: Do not submit information that you consider to be CBI or otherwise protected through regulations.gov, or email. Direct your comment to Docket No. EPA–R06–RCRA–2015–0070. The Federal regulations.gov Web site is an "anonymous access" system, which means the EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to the EPA without going through regulations.gov, your email address will be automatically captured and included as part of the

comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, the EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If the EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, the EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. You can view and copy Louisiana's application and associated publicly available materials from 8:30 a.m. to 4 p.m. Monday through Friday at the following locations: Louisiana Department of Environmental Quality, 602 N. Fifth Street, Baton Rouge, Louisiana 70884–2178, phone number (225) 219–3559 and EPA, Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733, phone number (214) 665–8533. Interested persons wanting to examine these documents should make an appointment with the office at least two weeks in advance.

FOR FURTHER INFORMATION CONTACT: Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733, (214) 665–8533) and Email address *patterson.alima@epa.gov.*

SUPPLEMENTARY INFORMATION:

A. Why are revisions to State programs necessary?

States which have received final authorization from the EPA under RCRA section 3006(b), 42 U.S.C. 6926(b), must maintain a hazardous waste program that is equivalent to, consistent with, and no less stringent than the Federal program. As the Federal program changes, States must change their programs and ask the EPA to authorize the changes. Changes to State programs may be necessary when Federal or State statutory or regulatory authority is modified or when certain other changes occur.

Most commonly, States must change their programs because of changes to the EPA's regulations in 40 Code of Federal Regulations (CFR) parts 124, 260 through 268, 270, 273, and 279.

B. What decisions have we made in this rule?

We conclude that Louisiana's application to revise its authorized program meets all of the statutory and regulatory requirements established by RCRA. Therefore, we grant Louisiana final authorization to operate its hazardous waste program with the changes described in the authorization application. Louisiana has responsibility for permitting treatment, storage, and disposal facilities within its borders (except in Indian Country) and for carrying out the aspects of the RCRA program described in its revised program application, subject to the limitations of the Hazardous and Solid Waste Amendments of 1984 (HSWA). New Federal requirements and prohibitions imposed by Federal regulations that the EPA promulgates under the authority of HSWA take effect in authorized States before they are authorized for the requirements. Thus, the EPA will implement those requirements and prohibitions in Louisiana including issuing permits, until the State is granted authorization to do so.

C. What is the effect of today's authorization decision?

The effect of this decision is that a facility in Louisiana subject to RCRA will now have to comply with the authorized State requirements instead of the equivalent Federal requirements in order to comply with RCRA. Louisiana has enforcement responsibilities under its State hazardous waste program for violations of such program, but the EPA retains its authority under RCRA sections 3007, 3008, 3013, and 7003, which include, among others, authority to:

- Do inspections, and require monitoring, tests, analyses, or reports;
- enforce RCRA requirements and suspend or revoke permits and
- take enforcement actions after notice to and consultation with the State.

This action does not impose additional requirements on the regulated community because the regulations for which Louisiana is being authorized by today's action are already effective under State law, and are not changed by today's action.

D. Why wasn't there a proposed rule before today's rule?

The EPA did not publish a proposal before today's rule because we view this as a routine program change and do not expect comments that oppose this approval. We are providing an opportunity for public comment now. In addition to this rule, in the proposed rules section of today's **Federal Register** we are publishing a separate document that proposes to authorize the State program changes.

E. What happens if the EPA receives comments that oppose this action?

If the EPA receives comments that oppose this authorization, we will withdraw this rule by publishing a document in the **Federal Register** before the rule becomes effective. The EPA will base any further decision on the authorization of the State program changes on the proposal mentioned in the previous paragraph. We will then address all public comments in a later final rule. You may not have another opportunity to comment. If you want to comment on this authorization, you must do so at this time. If we receive comments that oppose only the authorization of a particular change to the State hazardous waste program, we will withdraw only that part of this rule, but the authorization of the program changes that the comments do not oppose will become effective on the date specified above. The **Federal Register** withdrawal document will specify which part of the authorization will become effective, and which part is being withdrawn.

F. For what has Louisiana previously been authorized?

The State of Louisiana initially received final authorization on February 7, 1985, (50 FR 3348), to implement its base Hazardous Waste Management Program. We granted authorization for changes to their program on November 28, 1989 (54 FR 48889) effective January 29, 1990; August 26, 1991 (56 FR 41958), as corrected October 15, 1991 (56 FR 51762) effective October 25, 1991; November 7, 1994 (59 FR 55368) effective January 23, 1995 (Note: on January 23, 1995 (60 FR 4380), the EPA responded to public adverse comments and affirmed the effective date for the November 7, 1994 final rule. Then on April 11, 1995 (60 FR 18360), the EPA also made administrative corrections for the January 23, 1995 **Federal Register** document); December 23, 1994 (59 FR 66200) effective March 8, 1995; October 17, 1995 (60 FR 53704) effective January 2, 1996; March 28, 1996 (61 FR 13777) effective June 11, 1996; December 29, 1997 (62 FR 67572) effective March 16, 1998; October 23, 1998 (63 FR 56830) effective December 22, 1998; August 25, 1999 (64 FR 46302) effective October 25, 1999; September 2, 1999 (64 FR 48099) effective November 1, 1999; February 28, 2000 (65 FR 10411) effective April 28, 2000; January 2, 2001 (66 FR 23) effective March 5, 2001; December 9, 2003 (68 FR 68526) effective February 9, 2004; June 10, 2005 (70 FR 33852) effective August 9, 2005; November 13, 2006 (71 FR 66116) effective January 12,

2007; August 16, 2007 (72 FR 45905) effective October 15, 2007; May 20, 2009 (74 FR 23645) effective July 20, 2009; June 24, 2011(76 FR 122) effective August 23, 2011; and June 28, 2012 (77 FR 38530) effective August 27, 2012. On October 31, 2014, Louisiana applied for approval of its program revisions for specific rules in RCRA Clusters XXI, XXII and XXIII, in accordance with 40 CFR 271.21(b)(3).

Since 1979 through the Environmental Affairs Act, Act 449 enabled the Office of Environmental Affairs within the Louisiana Department of Natural Resources, as well as, the Environmental Control Commission to conduct an effective program designed to regulate those who generate, transport, treat, store, dispose or recycle hazardous waste. During the 1983 Regular Session of the Louisiana Legislature, Act 97 was adopted, which amended and reenacted La. R. S. 30:1051 *et seq.* as the Environmental Quality Act, renaming the Environmental Affairs Act (Act 1938 of 1979). This Act created Louisiana Department of Environmental Quality (LDEQ), including provisions for new offices within this new Department of Environmental Quality. Act 97 also transferred the duties and responsibilities previously delegated to the Department of Natural Resources, Office of Environmental Affairs, to the new Department. The LDEQ has lead agency jurisdictional authority for administering the Resource Conservation and Recovery Act (RCRA) Subtitle C program in Louisiana. Also, the LDEQ is designated to facilitate communication between the EPA and the State. During the 1999 Regular Session of Louisiana Legislature, Act 303 revised the La. R. S. 30:2011 *et seq.*, allowing LDEQ to reengineer the Department to perform more efficiently and to meet its strategic goals.

G. What changes are we authorizing with today's action?

On October 31, 2014, Louisiana submitted a final complete program revision application, seeking authorization of their changes in accordance with 40 CFR 271.21. We now make an immediate final decision, subject to receipt of written comments that oppose this action, that Louisiana's hazardous waste program revision satisfies all of the requirements necessary to qualify for Final authorization. Therefore, we grant the State of Louisiana Final authorization for the following changes: The State of Louisiana's program revisions consist of regulations which specifically govern Revision Checklists 227, 228, and 229 from RCRA Clusters XXI, XXII, XXIII, respectively, as documented in this **Federal Register**:

Description of Federal requirement (include checklist #, if relevant)	**Federal Register** date and page (and/or RCRA statutory authority)	Analogous State authority
1. Revision of the Land Disposal Treatment Standards for Carbamate Wastes. (Checklist 227).	76 FR 34147–34157, June 13, 2011.	Environmental Regulatory Code, Louisiana Department of Environmental Quality, ERC Title 33, Part V. Hazardous Waste and Hazardous Materials, 2013 edition. Section 2299 Appendix Table 2, Treatment Standards for Hazardous Waste, and Table 7, Universal Treatment Standards, effective September 20, 2013.
2. Hazardous Waste Technical Corrections and Clarifications Rule. (Checklist 228).	77 FR 22229–22232 April 13, 2012.	Environmental Regulatory Code, Louisiana Department of Environmental Quality, ERC Title 33, Part V. Hazardous Waste and Hazardous Materials, 2010 edition and the March 2012 Supplement. Sections 4901.C.Table 2, Hazardous Wastes from Specific Sources, and 4139.B.2, effective March 20, 2012.
3. Conditional Exclusions for Solvent Contaminated Wipes. (Checklist 229).	78 FR 46448–46485 July 31, 2013	Environmental Regulatory Code, Louisiana Department of Environmental Quality, ERC Title 33, Part V. Hazardous Waste and Hazardous Materials, 2013 edition and the July 2014 Supplement. Sections 109 No Free Liquids, 109.Solvent Contaminated wipe, 109.Wipe, 105.D.1.w, and 105.D.2.q, effective July 20, 2014.

H. Where are the revised State rules different from the Federal Rules?

In this authorization of the State of Louisiana program revisions for the RCRA Cluster XXI, XXII, and XXIII rules, there are no provisions that are more stringent or broader in scope.

I. Who handles permits after the authorization takes effect?

Louisiana will issue permits for all the provisions for which it is authorized and will administer the permits it issues. The EPA will continue to administer any RCRA hazardous waste permits or portions of permits which we issued prior to the effective date of this authorization. We will not issue any more new permits or new portions of permits for the provisions listed in the Table in this document after the effective date of this authorization. The EPA will continue to implement and issue permits for HSWA requirements for which Louisiana is not yet authorized.

J. How does today's action affect Indian Country in Louisiana?

Louisiana is not authorized to carry out its Hazardous Waste Program in Indian Country within the State. This authority remains with EPA. Therefore, this action has no effect in Indian Country.

K. What is codification and is the EPA codifying Louisiana's Hazardous Waste Program as authorized in this rule?

Codification is the process of placing the State's statutes and regulations that comprise the State's authorized hazardous waste program into the CFR. We do this by referencing the authorized State rules in 40 CFR part 272. We reserve the amendment of 40 CFR part 272, subpart T for this authorization of Louisiana's program changes until a later date. In this authorization application the EPA is not codifying the rules documented in this **Federal Register** notice.

L. Administrative Requirements

The Office of Management and Budget (OMB) has exempted this action (RCRA State Authorization) from the requirements of Executive Order 12866 (58 FR 51735, October 4, 1993) and 13563 (76 FR 3821, January 21, 2011). Therefore, this action is not subject to review by OMB. This action authorizes State requirements for the purpose of RCRA 3006 and imposes no additional requirements beyond those imposed by State law. Accordingly, this action will not have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (5

U.S.C. 601 *et seq.*). Because this action authorizes pre-existing requirements under State law and does not impose any additional enforceable duty beyond that required by State law, it does not contain any unfunded mandate or significantly or uniquely affect small governments, as described in the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4). For the same reason, this action also does not significantly or uniquely affect the communities of Tribal governments, as specified by Executive Order 13175 (65 FR 67249, November 9, 2000). This action will not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132 (64 FR 43255, August 10, 1999), because it merely authorizes State requirements as part of the State RCRA hazardous waste program without altering the relationship or the distribution of power and responsibilities established by RCRA. This action also is not subject to Executive Order 13045 (62 FR 19885, April 23, 1997), because it is not economically significant and it does not make decisions based on environmental health or safety risks. This rule is not subject to Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 FR 28355 (May 22, 2001)) because it is not a significant regulatory action under Executive Order 12866.

Under RCRA 3006(b), the EPA grants a State's application for authorization as long as the State meets the criteria required by RCRA. It would thus be inconsistent with applicable law for the EPA, when it reviews a State authorization application, to require the use of any particular voluntary consensus standard in place of another standard that otherwise satisfies the requirements of RCRA. Thus, the requirements of section 12(d) of the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note) do not apply. As required by section 3 of Executive Order 12988 (61 FR 4729, February 7, 1996), in issuing this rule, the EPA has taken the necessary steps to eliminate drafting errors and ambiguity, minimize potential litigation, and provide a clear legal standard for affected conduct. The EPA has complied with Executive Order 12630 (53 FR 8859, March 15, 1988) by examining the takings implications of the rule in accordance with the "Attorney General's Supplemental Guidelines for the Evaluation of Risk and Avoidance of Unanticipated Takings" issued under the Executive Order. This rule does not impose an information collection burden under the provisions of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*). Executive Order 12898 (59 FR 7629, Feb. 16, 1994) establishes federal executive policy on environmental justice. It's main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. Because this rule authorizes pre-existing State rules which are at least equivalent to, and no less stringent than existing federal requirements, and impose no additional requirements beyond those imposed by State law, and there are no anticipated significant adverse human health or environmental effects, the rule is not subject to Executive Order 12898.

The Congressional Review Act, 5 U.S.C. 801 *et seq.*, as added by the Small Business Regulatory Enforcement Fairness Act of 1996, generally provides that before a rule may take effect, the agency promulgating the rule must submit a rule report, which includes a copy of the rule, to each House of the Congress and to the Comptroller General of the United States. The EPA will submit a report containing this document and other required information to the U.S. Senate, the U.S. House of Representatives, and the Comptroller General of the United States prior to publication in the **Federal Register**. A major rule cannot take effect until 60 days after it is published in the **Federal Register**. This action is not a "major rule" as defined by 5 U.S.C. 804(2). This action nevertheless will be effective November 13, 2015.

List of Subjects in 40 CFR Part 271

Environmental protection, Administrative practice and procedure, Confidential business information, Hazardous waste, Hazardous waste transportation, Indian lands, Intergovernmental relations, Penalties, Reporting and recordkeeping requirements.

Authority: This action is issued under the authority of sections 2002(a), 3006, and 7004(b) of the Solid Waste Disposal Act as amended 42 U.S.C. 6912(a), 6926, 6974(b).

Dated: August 21, 2015.

Ron Curry,

Regional Administrator, Region 6.

[FR Doc. 2015–23073 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Part 577

[Docket No. NHTSA–2015–0048]

RIN 2127–AL60

Defect and Noncompliance Notification

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: This final rule amends NHTSA's regulation requiring motor vehicle manufacturers and replacement equipment manufacturers to notify owners and purchasers of a defect or noncompliance in vehicles or equipment that they produced. The amendments in this final rule will clarify that a manufacturer of replacement equipment providing a defect or noncompliance notification pursuant to this regulation can inform the purchaser of the replacement equipment of the manufacturer's intent to remedy the defect or noncompliance by refunding the purchase price of the replacement equipment. NHTSA is amending this regulation so that the regulation conforms to changes in the defect and noncompliance remedy provisions in the National Traffic and Motor Vehicle Safety Act (Safety Act) contained in the Moving Ahead for Progress in the 21st Century Act (MAP–21).

DATES: *Effective date:* This final rule is effective November 13, 2015.

Petitions for reconsideration: Petitions for reconsideration of this final rule must be received not later than October 29, 2015.

ADDRESSES: Any petitions for reconsideration should refer to the docket number of this document and be submitted to: Administrator, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE., West Building, Ground Floor, Docket Room W12–140, Washington, DC 20590.

FOR FURTHER INFORMATION CONTACT: Thomas Healy, Office of Chief Counsel, NHTSA, 1200 New Jersey Avenue SE., Washington, DC 20590. Mr. Healy's telephone number is (202) 366–2992. His fax number is (202) 493–3820.

SUPPLEMENTARY INFORMATION:

I. Background

The Safety Act requires manufacturers of motor vehicles or items of replacement equipment to notify NHTSA and owners and purchasers of the vehicles or equipment if the manufacturer determines that a motor vehicle or item of motor vehicle equipment contains a defect related to motor vehicle safety or does not comply with an applicable motor vehicle safety standard and to remedy the defect or noncompliance without charge. 49 U.S.C. 30118(c), 30120. Manufacturers must provide notification pursuant to the procedures set forth in section 30119 of the Safety Act. Section 30119 sets forth the contents of the notification, which includes a clear description of the defect or noncompliance, the timing of the notification, means of providing notification and when a second notification is required. 49 U.S.C. 30119.

Section 30120 of the Safety Act provides a list of permissible remedies from which manufacturers must choose when determining how to remedy at defect. Section 30120 contains different remedy provisions for manufacturers of motor vehicles and manufacturers of replacement equipment. Section 30120 allows manufacturers of motor vehicles to remedy a defect or noncompliance "by repairing the vehicle; . . . by replacing the vehicle with an identical or reasonably equivalent vehicle; or . . . by refunding the purchase price, less a reasonable allowance for depreciation." 49 U.S.C. 30120(a)(1)(A). Prior to MAP–21, Section 30120 allowed manufacturers of replacement equipment to remedy a defect or noncompliance by "repairing the equipment or replacing the equipment with identical or reasonable equivalent equipment." 49 U.S.C. 30120(a)(1)(B) (2011). MAP–21 amended section 30120 by expanding the list of permissible remedies available to replacement equipment manufacturers to include refunding the purchase price of the equipment.[1]

The conduct of a recall notification campaign, including how and when owners, dealers, and distributors are notified, is addressed by regulation in 49 CFR part 577, *Defect and Noncompliance Notification.* Section 577.5 specifies the required content and structure of the owner notifications. Section 577.6 specifies the required content and structure of the notification if the owner notification is sent pursuant to an order by the NHTSA Administrator. Section 577.5 and 577.6 both specify that that the owner notification must include a statement notifying the owner of the vehicle or replacement equipment how the manufacturer intends to remedy the defect or noncompliance.

This final rule amends §§ 577.5 and 577.6 of 49 CFR part 577 so that the requirements for the statement notifying owners or purchasers of replacement equipment how the manufacturer intends to remedy a defect or noncompliance reflect the MAP–21 amendment allowing manufacturers of replacement equipment to remedy a defect or noncompliance by refunding the purchase price.

II. Public Comment

NHTSA did not issue an NPRM prior to this final rule. While the Administrative Procedure Act (APA) requires that agencies publish a general NPRM in the **Federal Register** prior to issuing a final rule, an agency is not required to publish an NPRM if the agency is able to make and makes a good cause finding that notice and public comment is "impracticable, unnecessary, or contrary to the public interest." [2]

NHTSA finds that notice and public comment prior to issuing this final rule is unnecessary. The DC Circuit has held that the notice and public comment requirements of APA are unnecessary when the "rule is a routine determination, insignificant in nature and impact, and inconsequential to the industry and to the public." [3] The amendments in this final rule do not create any new rights or obligations not already present in 49 U.S.C. 30120. The amendments in this final rule update the notification requirements in 49 CFR 577.5 and 577.6 to reflect that the option to refund the purchase price of the replacement equipment is available to manufacturers as a remedy for a defect or noncompliance. Furthermore, these changes were made by statutory amendment. Therefore, the amendments contained in this final rule do not involve the exercise of discretion on the part of the agency. Because this final rule does not create any rights or obligations not already present in 49 U.S.C. 30120 or involve the exercise of discretion by the agency, the impacts of this rule are insignificant and inconsequential to industry and the public making notice and public comment unnecessary.

III. Regulatory Notices and Analyses

A. Executive Order 12866, Executive Order 13563, and DOT Regulatory Policies and Procedures

NHTSA has considered the impact of this rulemaking action under Executive Order 12866, Executive Order 13563, and the DOT's regulatory policies and procedures. This final rule was not reviewed by the Office of Management and Budget (OMB) under E.O. 12866, "Regulatory Planning and Review." It is not considered to be significant under E.O. 12866 or the Department's regulatory policies and procedures.

This regulation amends 49 CFR part 577 to include refund of the purchase price of replacement equipment as a remedy available to replacement equipment manufacturers remedying a defect or noncompliance. This final rule does not require replacement equipment manufacturers to take any actions that they are not otherwise already required to take. Because there are not any costs or savings associated with this rulemaking, we have not prepared a separate economic analysis for this rulemaking.

B. Regulatory Flexibility Act

In compliance with the Regulatory Flexibility Act, 5 U.S.C. 601 *et seq.,* NHTSA has evaluated the effects of this action on small entities. I hereby certify that this rule would not have a significant impact on a substantial number of small entities. The final rule affects manufacturers of motor vehicle replacement equipment some of which qualify as small businesses. However, this final rule does not significantly affect these entities because it does not require any additional actions on the part of equipment manufacturers not already required by 49 CFR part 577.

C. Executive Order 13132

NHTSA has examined this rule pursuant to Executive Order 13132 (64 FR 43255, August 10, 1999) and concluded that no additional consultation with States, local governments or their representatives is mandated beyond the rulemaking process. The agency has concluded that the rulemaking would not have sufficient federalism implications to warrant consultation with State and local officials or the preparation of a federalism summary impact statement. The final rule would not have "substantial direct effects on the States, on the relationship between the national government and the States, or on the

[1] Public Law 112–141, 126 Stat. 771 (2012), Section 31311.

[2] 5 U.S.C. 553.

[3] *Mack Trucks, Inc.* v. *E.P.A.* 682 F.3d 87, 92 (D.C. Cir. 2012) (quoting *Util. Solid Waste Activities Grp.* v. *E.P.A.*, 236 F.3d 749, 754 (D.C. Cir. 2001).

distribution of power and responsibilities among the various levels of government." This final rule also will not preempt any state law.

D. National Environmental Policy Act

NHTSA has analyzed this final rule for the purposes of the National Environmental Policy Act. The agency has determined that implementation of this action will not have any significant impact on the quality of the human environment.

E. Paperwork Reduction Act

Under the procedures established by the Paperwork Reduction Act of 1995, a person is not required to respond to a collection of information by a Federal agency unless the collection displays a valid OMB control number. The information collection requirements for 49 CFR part 577, *Defect and Noncompliance Notification,* are covered by OMB control number 2127–0004. The amendments in this final rule have no impact on the burden associated with this information collection.

F. National Technology Transfer and Advancement Act

Under the National Technology Transfer and Advancement Act of 1995 (NTTAA) (Pub. L. 104–113), "all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments." The amendments in this final rule consist of minor revisions to the required content of letters that manufacturers of replacement equipment for motor vehicles must sent to purchasers and owners to notify them of a defect or noncompliance and do not involve any voluntary consensus standards.

G. Civil Justice Reform

With respect to the review of the promulgation of a new regulation, section 3(b) of Executive Order 12988, "Civil Justice Reform" (61 FR 4729, February 7, 1996) requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect; (2) clearly specifies the effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct, while promoting simplification and burden reduction; (4) clearly specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. This document is consistent with that requirement.

Pursuant to this Order, NHTSA notes as follows. The preemptive effect of this final rule is discussed above. NHTSA notes further that there is no requirement that individuals submit a petition for reconsideration or pursue other administrative proceeding before they may file suit in court.

H. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 requires agencies to prepare a written assessment of the costs, benefits and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted for inflation with base year of 1995). This final rule would not result in expenditures by State, local or tribal governments, in the aggregate, or by the private sector in excess of $100 million annually.

I. Executive Order 13211

Executive Order 13211 (66 FR 28355, May 18, 2001) applies to any rulemaking that: (1) Is determined to be economically significant as defined under E.O. 12866, and is likely to have a significantly adverse effect on the supply of, distribution of, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action. This rulemaking is not subject to E.O. 13211.

J. Regulation Identifier Number (RIN)

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. You may use the RIN contained in the heading at the beginning of this document to find this action in the Unified Agenda.

List of Subjects in 49 CFR Part 577

Imports, Motor vehicle safety, Motor vehicles, Tires, Reporting and recordkeeping requirements.

In consideration of the foregoing, NHTSA amends 49 CFR part 577 as follows:

PART 577—DEFECT AND NONCOMPLIANCE NOTIFICATION

■ 1. The authority citation for part 577 continues to read as follows:

Authority: 49 U.S.C. 30102, 30103, 30116–30121, 30166; delegation of authority at 49 CFR 1.95 and 49 CFR 501.8.

■ 2. Section 577.5 is amended by revising paragraphs (g)(1)(i) and (vi) to read as follows:

§ 577.5 Notification pursuant to a manufacturer's decision.

* * * * *

(g) * * *

(1) * * *

(i) A statement that he will cause such defect to be remedied without charge, and whether such remedy will be by repair, replacement, or refund of the purchase price (in the case of remedy of a vehicle, less depreciation).

* * * * *

(vi) In the case of a remedy of a vehicle by refund of purchase price, the method or basis for the manufacturer's assessment of depreciation.

* * * * *

■ 3. Section 577.6 is amended by revising paragraph (b)(9)(i)(B) to read as follows:

§ 577.6 Notification pursuant to Administrator's decision.

* * * * *

(b) * * *

(9) * * *

(i) * * *

(B) A statement of the method of remedy. If the manufacturer has not yet determined the method of remedy, he will select either repair, replacement with an equivalent vehicle or item of replacement equipment, or refund of the purchase price (in the case of remedy of a vehicle, less depreciation); and

* * * * *

Issued in Washington, DC, on September 2, 2015 under authority delegated in 49 CFR part 1.95.

Mark R. Rosekind,

Administrator.

[FR Doc. 2015–22922 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–59–P

Proposed Rules

Federal Register
Vol. 80, No. 177
Monday, September 14, 2015

This section of the FEDERAL REGISTER contains notices to the public of the proposed issuance of rules and regulations. The purpose of these notices is to give interested persons an opportunity to participate in the rule making prior to the adoption of the final rules.

DEPARTMENT OF ENERGY

10 CFR Part 430

[Docket Number EERE–2014–BT–STD–0031]

RIN 1904–AD20

Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Notice of data availability.

SUMMARY: The U.S. Department of Energy (DOE) has completed a provisional analysis of the potential economic impacts and energy savings that could result from promulgating amended energy conservation standards for residential non-weatherized gas furnaces (NWGFs) that include two product classes defined by input capacity and has published the data on its Web page. DOE encourages stakeholders to provide any additional data or information that may improve the analysis.

DATES: DOE will accept comments, data, and information regarding this NODA no later than October 14, 2015. See section IV for details.

ADDRESSES: Any comments submitted must identify the NODA for Energy Conservation Standards for Residential Furnaces, and provide docket number EERE–2014–BT–STD–0031 and/or regulatory information number (RIN) number 1904–AD20. Comments may be submitted using any of the following methods:

1. *Federal eRulemaking Portal: www.regulations.gov.* Follow the instructions for submitting comments.

2. *Email: ResFurnaces2014STD0031@ee.doe.gov.* Include the docket number and/or RIN in the subject line of the message. Submit electronic comments in Word Perfect, Microsoft Word, PDF, or ASCII file format, and avoid the use of special characters or any form on encryption.

3. *Postal Mail:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, Mailstop EE–5B, 1000 Independence Avenue SW., Washington, DC 20585–0121. If possible, please submit all items on a compact disc (CD), in which case it is not necessary to include printed copies.

4. *Hand Delivery/Courier:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, 950 L'Enfant Plaza SW., Suite 600, Washington, DC 20024. Telephone: (202) 586–2945. If possible, please submit all items on a CD, in which case it is not necessary to include printed copies.

No telefacsimilies (faxes) will be accepted. For detailed instructions on submitting comments and additional information on the rulemaking process, see section IV of this document (Submission of Comments).

Docket: The docket, which includes **Federal Register** documents, comments, and other supporting documents/materials, is available for review at *www.regulations.gov.* All documents in the docket are listed in the *www.regulations.gov* index. However, not all documents listed in the index may be publicly available, such as information that is exempt from public disclosure.

A link for access to the docket Web page can be found at: *https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=62.* The *www.regulations.gov* Web page contains instructions on how to access all documents in the docket.

FOR FURTHER INFORMATION CONTACT: Mr. John Cymbalsky, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, EE–5B, 1000 Independence Avenue SW., Washington, DC 20585–0121. Telephone: (202) 287–1692. Email: *residential_furnaces_and_boilers@ee.doe.gov.*

Ms. Johanna Hariharan, U.S. Department of Energy, Office of the General Counsel, GC–33, 1000 Independence Avenue SW., Washington, DC 20585–0121. Telephone: (202) 586–9507 or (202) 287–6307. Email: *Johanna.Hariharan@hq.doe.gov.*

For further information on how to review other public comments and the docket, contact Ms. Brenda Edwards at (202) 586–2945 or by email: *Brenda.Edwards@ee.doe.gov.*

SUPPLEMENTARY INFORMATION:

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I. Background

On March 10, 2015, DOE published in the **Federal Register** a notice of proposed rulemaking (NOPR) and public meeting to amend energy conservation standards for residential non-weatherized gas furnaces (NWGF) and mobile home gas furnaces (MHGF). 80 FR 13119. The proposed standards, which are expressed as minimum annual fuel utilization efficiencies (AFUE), are shown in Table I.1. These proposed standards, if adopted, would apply to all products listed in Table I.1 and manufactured in, or imported into, the United States on or after the date 5 years after the publication of the final rule for this rulemaking.

TABLE I.1—PROPOSED AFUE ENERGY CONSERVATION STANDARDS FOR NON-WEATHERIZED GAS FURNACES AND MOBILE HOME GAS FURNACES (TSL 3)

Product class	AFUE %
Non-Weatherized Gas-Fired Furnaces	92
Mobile Home Gas-Fired Furnaces	92

A number of stakeholders objected to a national standard at 92 percent AFUE, which would effectively only be able to be met by using condensing technology. The objections raised by stakeholders covered a wide range of issues, but the negative impacts of the proposed

standards on some furnace consumers were highlighted by many stakeholders.

A letter dated June 8, 2015, signed by 121 members of the U.S. House of Representatives, expressed concern that a nationwide energy efficiency standard that effectively precludes a consumer from choosing to install a non-condensing furnace would result in many homeowners either abandoning the use of natural gas to heat their homes or paying substantially more for the installation of a furnace that meets the new standard. It stated that many families will be faced with the difficult choice of having to replace their non-condensing furnace with either a condensing furnace with higher installation costs or electric heat and accompanying higher monthly energy bills. (United States House of Representatives, No. 67 at p. 1) Comments from the Pennsylvania Chambers of Commerce, Business, and Industry, Meeks, Payne, Jr., Bishop, Jr., and Carrier make similar statements. (Pennsylvania Chambers of Commerce, Business, and Industry, No. 82 at p. 1; Meeks, No. 140 at p. 1; Payne, Jr., No. 75 at p. 1; Bishop, Jr., No. 76 at p. 1)

The American Gas Association (AGA), Goodman, and American Energy Alliance (AEA *et al.*) stated that even assuming DOE's analysis is correct, many consumers could incur costs under the proposed standard. They stated that, according to DOE's analysis, 20 percent of households nationwide would face higher life-cycle costs under the proposed standard, and in the replacement market, one-quarter of all households replacing their natural gas furnaces would see a life-cycle cost increase. (AGA, No. 118 at p. 27; AEA *et al.*, No. 69 at p. 1; Goodman, No. 135 at p. 2) AGA, Goodman, and Southern Gas Association (SGA) added that consumers in the South and low-income families would be disproportionately impacted. (AGA, No. 118 at p. 27; Goodman, No. 135 at p. 2; SGA, No. 145 at p. 1)

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI), Carrier, Rheem, and Ingersoll Rand expressed concern that the proposed standards will result in 10–20 percent of homes switching from gas furnaces to electric heat pumps because venting of a condensing gas furnace is difficult to impossible. (AHRI, No. 159 at p. 3; Carrier, No. 116 at p. 2; Rheem, No. 142 at p. 3; Ingersoll Rand, No. 156 at p. 2) AGA expressed a similar concern, and asserted that the resulting adverse energy and environmental impacts of this fuel switching are very substantial. (AGA, No. 118 at p. 28)

Several stakeholders, who expressed general support for the proposed standards and suggested more stringent standards could be justified, provided a recommendation for reducing negative impacts on some furnace consumers while maintaining the overall economic and environmental benefits of the standards. The American Council for an Energy-Efficient Economy (ACEEE) recommended that DOE establish a separate product class for small furnaces (tentatively those with an input capacity of 50,000 Btu/hour or less) and leave the standard level for these units at 80-percent AFUE, while adopting a higher standard level of 95-percent AFUE for larger furnaces. (ACEEE, No. 113 at p. 1) The Alliance to Save Energy made a similar recommendation, but referred to an input capacity of no more than 50,000 to 65,000 Btu/hour for smaller furnaces. (Alliance to Save Energy, No. 115 at p. 1) The Natural Resources Defense Council (NRDC) urged DOE to adopt an 80-percent AFUE standard level for furnaces below a specified maximum capacity threshold, and set the capacity threshold low enough that the national energy, economic, and environmental benefits are largely preserved while allowing consumers in small and moderately-sized, well insulated and weatherized homes in moderate and warm climates to have a non-condensing option. (NRDC, No. 134 at p. 2) AGLR stated that DOE should establish a separate product class for small furnaces with an input capacity of less than 45,000 Btu/hour, citing section 305(f) of EPCA as authority for DOE to establish separate product classes based on product capacity. (AGLR, No. 112 at pp. 15–16)

ACEEE also stated that creating two product classes based on furnace size would reduce the number of households that would experience net costs under the proposed standard (many of whom are in the south). ACEEE stated that many of the consumers who would experience net costs will have small furnaces and recommended that DOE specifically examine this issue and estimate the economics of separate standard levels as a function of furnace input capacity. ACEEE noted that a size threshold provides another option for some households with very high installation costs—if they weatherize their home and get the needed capacity below 50,000 Btu/h, they can avoid the extra installation cost of a condensing furnace. ACEEE added that a size threshold would not present the potential enforcement challenges associated with regional standards. (ACEEE, No. 113 at p. 3)

Although DOE believes that the standards proposed in the March 2015 NOPR meet the statutory criteria for amended standards, given the concerns and suggestions described above, DOE undertook an analysis of the consumer economics and national impacts of establishing separate standard levels for large and small residential furnaces. In so doing, it examined the effect of alternative size thresholds for a small furnace. Because the issues raised by stakeholders primarily concern NWGFs, DOE only considered that product in its analysis and did not examine mobile home gas furnaces. The analysis is described in section II of this NODA; section III provides the results of the analysis.

DOE notes that this NODA does not propose any energy conservation standards for residential furnaces. DOE may revise the analyses presented in today's NODA based on any new or updated information or data it obtains during the course of the rulemaking. DOE encourages stakeholders to provide any additional data or information that may improve the analysis.

II. Summary of the Analyses Performed by DOE

DOE conducted an analysis of the consumer impacts (life-cycle cost and payback period) and national impacts (national energy savings and net present value of national benefits) of potential standard levels for the considered NWGF product classes. The tools used in preparing these analyses and their respective results are available at: *https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=62.* Each individual spreadsheet includes an introduction that provides an overview of the contents of the spreadsheet. These spreadsheets present the various inputs and outputs to the analysis and, where necessary, instructions. Brief descriptions of the analyses and of the supporting spreadsheet tools are provided below.

If DOE were to consider adopting energy conservation standards for residential furnaces that set separate levels based on input capacity, it would do so in a future supplemental NOPR (SNOPR). DOE would also publish a technical support document (TSD) containing a detailed written account of the analyses performed in support of the SNOPR, which will include updates to the analyses made available in this NODA.

The analysis conducted for this NODA used the same analytical

framework as the March 2015 NOPR.[1] Key aspects of the present analysis and DOE's updates to the NOPR analysis are described in the sections below.

A. Introduction

The analysis conducted for this NODA estimated impacts for the potential standard level combinations shown in Table II.1. The key aspect of this analysis is that only large furnaces would need to use condensing technology to meet the standard. Thus, households installing a small furnace would not need to incur the costs associated with installing a condensing furnace.

TABLE II.1—POTENTIAL STANDARD LEVEL COMBINATIONS ANALYZED FOR LARGE AND SMALL FURNACES

Furnance size	Annual fuel utilization efficiency (%)			
Large	90	92	95	98
Small	80	80	80	80

This NODA analysis used the same sample of residential furnace consumers as the March 2015 NOPR. Each sample household was assigned a furnace size (in terms of input capacity) based on a number of features, as discussed in section II.C. The share of households that would install a small furnace depends on how "small furnace" is defined in terms of input capacity. For this analysis, DOE considered the following small furnace definitions: ≤45 kBtu/hour, ≤50 kBtu/hour, ≤55 kBtu/hour, ≤60 kBtu/hour, and ≤65 kBtu/hour. In each case, large furnaces would be defined as all sizes above the given thresholds. The share of households that would install a furnace meeting a small furnace standard rises as the size cutoff in the small furnace definition increases, as illustrated in Table II.2.[2]

TABLE II.2—SHARE OF SAMPLE HOUSEHOLDS BY FURNACE SIZE

[percent]

Furnace size	Small furnace definition				
	≤45 kBtu/hour	≤50 kBtu/hour	≤55 kBtu/hour	≤60 kBtu/hour	≤65 kBtu/hour
Large	92	86	85	68	62
Small	8	14	15	32	38
Total	100	100	100	100	100

B. Engineering Analysis

The engineering analysis establishes the relationship between the manufacturer production cost (MPC) and energy efficiency for residential furnaces. This relationship between MPC and energy efficiency serves as the basis for calculations performed in the other analysis tools to estimate the costs and benefits to individual consumers, manufacturers, and the nation. For each NWGF efficiency level that was analyzed, the MPC was estimated for four furnace capacities (60 kBtu/hour, 80 kBtu/hour, 100 kBtu/hour, and 120 kBtu/hour). For the NODA analysis, DOE updated the MPCs from the NOPR to incorporate the most recent available data for material,[3] component, labor, and overhead costs, and also updated the MPCs to 2014$.

C. Life-Cycle Cost and Payback Period Analyses

The life-cycle cost (LCC) and payback period (PBP) analyses determine the economic impact of potential standards on individual consumers who purchase a furnace in the expected compliance year (assumed to be 2021 for this analysis). The LCC is the total cost of purchasing, installing and operating a residential furnace over the course of its lifetime. DOE determines the LCC by considering: (1) The total installed cost to the consumer (which consists of manufacturer selling price, distribution channel markups, sales taxes, and installation costs); (2) the annual energy consumption (natural gas or LPG and electricity) of residential furnaces as they are used in the field; (3) the operating cost of residential furnaces (*i.e.*, energy cost and maintenance and repair cost); (4) equipment lifetime; and (5) a discount rate that reflects the consumer cost of capital and puts the LCC in present-value terms. The PBP represents the number of years needed to recover the increase in purchase price of higher-efficiency residential furnaces through savings in the operating cost.

For each considered standards case, DOE measures the change in LCC relative to a no-new-standards case, which reflects the market in the absence of amended energy conservation standards, including market trends for equipment that exceeds the current energy conservation standards.

In the March 2015 NOPR and in today's NODA, DOE developed nationally-representative household samples for residential furnaces from the 2009 Residential Energy Consumption Survey (RECS).[4] DOE analyzed the net effect of potential amended residential furnace standards on consumers by calculating the LCC savings and PBP for each household by efficiency level.

DOE performed the LCC and PBP analyses using a spreadsheet model

[1] Please see the March 2015 NOPR and the accompanying TSD for details, which are available at *http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx?ruleid=62*.

[2] The shares in Table II.2 reflect the likelihood that some consumers would down-size a new furnace to meet the "small furnace" definition. See section II.C for discussion.

[3] DOE uses 5-year averages for metal materials and current prices for all other materials.

[4] U.S. Department of Energy: Energy Information Administration, Residential Energy Consumption Survey: 2009 RECS Survey Data (2013), available at: *http://www.eia.gov/consumption/residential/data/2009/* (last accessed July 29, 2015).

combined with Crystal Ball [5] to account for uncertainty and variability among the input variables. Each Monte Carlo simulation consists of 10,000 LCC and PBP calculations using input values that are either sampled from probability distributions and household samples or characterized with single point values. The analytical results include a distribution of 10,000 data points showing the range of LCC savings for a given efficiency level relative to the no-new-standards case efficiency distribution. In performing an iteration of the Monte Carlo simulation for a given consumer, product efficiency is chosen based on its probability. If the chosen product efficiency is greater than or equal to the efficiency of the standard level under consideration, the LCC and PBP calculation reveals that a consumer is not impacted by the standard level. By accounting for consumers who already purchase more-efficient products, DOE avoids overstating the potential benefits from increasing product efficiency.

1. Furnace Size Assignment

For the March 2015 NOPR, DOE assigned an input capacity for the existing furnace of each housing unit based on an algorithm that correlates the heating square footage and the outdoor design temperature for heating (*i.e.*, the temperature that is exceeded by the 30-year minimum average temperature 1 percent of the time) with the distribution of input capacity of furnaces.[6] DOE assumed that, for the new furnace installation, the input capacity would remain the same. DOE's analysis accounted for the typical over-sizing of furnace capacity (*i.e.*, the furnace is larger than it needs to be to fulfill the building heating load).

If there is a separate standard for small furnaces, DOE expects that some consumers who would otherwise install a typically-oversized furnace would choose to down-size in order to be able to purchase a non-condensing furnace. For the NODA analysis, DOE identified those sample households that might down-size at the considered small furnace definitions. DOE first determined if a household would install a non-condensing furnace with an input capacity greater than the small furnace size limit without amended standards. In the standards case, DOE assumed that a fraction of such consumers would down-size to the input capacity limit for small furnaces.

2. Energy Prices

For this NODA, DOE updated current energy prices and also the projection of future energy prices. Current average and marginal monthly energy prices are based on the latest data (2013 energy prices) from EIA (Form 861 data [7] to calculate commercial electricity prices, Natural Gas Navigator [8] to calculate commercial natural gas prices, and State Energy Data System [9] to calculate LPG prices). The update to 2013 energy prices had a very small impact on the LCC and PBP results.[10] Future energy prices are based on the projection of average annual percent change in national-average residential natural gas and electricity prices in the *Annual Energy Outlook 2015* (*AEO 2015*).

3. Other Updates

For this NODA, DOE updated the efficiency distribution in the no-new-standards case to reflect AHRI shipments data from 2010 to 2014.[11] The update resulted in decreased fraction of consumers being impacted by an efficiency standard requiring efficiencies of 90-percent AFUE and above.[12] DOE also made minor updates to the markups, product price trend, and the building shell efficiency and climate indexes used to adjust energy use. These are described in the LCC spreadsheet.

D. National Impact Analysis

The national impacts analysis (NIA) estimates the national energy savings (NES) and the net present value (NPV) of total consumer costs and savings expected to result from potential new standards. DOE calculated NES and NPV as the difference between a case without amended standards and each standards case.

DOE calculated the annual energy consumption for each case using the appropriate per-unit annual energy use data multiplied by the projected residential furnaces shipments for each year. To estimate impacts of separate standards for small and large furnaces, DOE needed to disaggregate NWGF shipments by input capacity. To do so, DOE assumed that the shares of each size category in NWGF shipments are the same as the shares estimated for the household sample. The shares were assumed to remain constant over time.

Cumulative energy savings are the sum of the annual NES determined for the lifetime of furnaces shipped during a 30-year period assumed to start in the expected compliance year. Energy savings include the full-fuel cycle energy savings (*i.e.*, the energy needed to extract, process, and deliver primary fuel sources such as coal and natural gas, and the conversion and distribution losses of generating electricity from those fuel sources).

To develop the national NPV of consumer benefits from potential energy conservation standards, DOE calculated projected annual operating costs (energy costs and repair and maintenance costs) and annual installation costs for the no-new-standards case and the standards cases. DOE calculated annual energy expenditures from annual energy consumption using forecasted energy prices in each year. DOE calculated annual product expenditures by multiplying the price per unit times the projected shipments in each year.

The aggregate difference each year between operating cost savings and increased installation costs is the net savings or net costs. DOE multiplies the net savings in future years by a discount factor to determine their present value. DOE estimates the NPV of consumer benefits using both a 3-percent and a 7-percent real discount rate, in accordance with guidance provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis.[13]

[5] Crystal Ball is a commercial software program developed by Oracle and used to conduct stochastic analysis using Monte Carlo simulation. A Monte Carlo simulation uses random sampling over many iterations of the simulation to obtain a probability distribution of results. Certain key inputs to the analysis are defined as probability distributions rather than single-point values.

[6] The distribution of input capacity is based on shipments data by input capacity bins for the year 2000 provided by AHRI (AHRI (formerly GAMA). Furnace and Boiler Shipments data provided to DOE for Furnace and Boiler ANOPR. January 23, 2002). AHRI data was further disaggregated into 5-kBtu/h bins using the reduced models dataset from the NOPR analysis. Appendix 7B of the NOPR TSD provides details about furnace sizing method.

[7] Energy Information Administration (EIA), Survey form EIA–861—Annual Electric Power Industry Report (Available at: *http://www.eia.gov/electricity/data/eia861/index.html*) (Last accessed July 15, 2015).

[8] Energy Information Administration (EIA), Natural Gas Navigator (Available at: *http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm*) (Last accessed July 15, 2015).

[9] Energy Information Administration (EIA), State Energy Data System (SEDS) (Available at: *http://www.eia.gov/state/seds/*) (Last accessed July 15, 2015).

[10] For the NOPR, 2012 energy prices from the same sources were used.

[11] Air-Conditioning, Heating, and Refrigeration Institute, Personal communication. May 12, 2015. *http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0031-0052.*

[12] For the NOPR, the AHRI shipments data was not available and DOE instead relied on shipments data from the ENERGY STAR program to derive its estimates. Based on the AHRI shipments data, DOE's estimate of the condensing furnace market share in 2021 increased from 47-percent in the NOPR to 53-percent in the NODA.

[13] Office of Management and Budget, OMB Circular A–4, section E, Identifying and Measuring Benefits and Costs (2003), *available at http://www.whitehouse.gov/omb/memoranda/m03-21.html.*

For the NODA analysis, DOE updated energy price trends and several other inputs with data from *AEO 2015*, as described in the NIA spreadsheet.

III. Results of the Analysis

A. Economic Impacts on Consumers

As mentioned in section II.C, for each considered standards case, DOE measures the change in LCC relative to a no-new-standards case. For example, in the case of a separate standard of 90-percent AFUE for large furnaces and 80-percent AFUE for small furnaces, the analysis reflects the likelihood that some consumers would purchase a furnace at or above those efficiency levels without standards, and thus would not be affected by the standards. The average LCC savings in Table III.1 only include those consumers who would be affected at a given standard level.

Table III.2 shows the percentage of consumers that would experience a net cost under each considered standards case, and Table III.3 shows the percentage of consumers in the South that would experience a net cost.[14] For these consumers, the LCC would increase under the standard compared to the furnace they would purchase in no-new-standards case. As expected, the percentage of consumers that would experience a net cost declines as the definition of small furnace expands to include more furnaces.

TABLE III.1—AVERAGE LCC SAVINGS FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS

[2014$]

Minimum AFUE (%)		Average LCC savings (2014$) *				
Large	Small	Small furnace definition (kBtu/hour)				
		≤45	≤50	≤55	≤60	≤65
90	80	$383	$400	$400	$492	$484
92	80	463	478	479	553	525
95	80	439	447	449	479	437
98	80	365	372	374	388	347

* The average LCC savings only include those consumers who would be affected at a given standard level.

TABLE III.2—SHARE OF ALL CONSUMERS EXPERIENCING A NET COST FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS

Minimum AFUE (%)		% of consumers experiencing a net cost				
Large	Small	Small furnace definition (kBtu/hour)				
		≤45	≤50	≤55	≤60	≤65
90	80	19	15	13	11	7
92	80	17	13	12	10	6
95	80	21	17	15	12	9
98	80	35	34	33	26	23

TABLE III.3—SHARE OF CONSUMERS IN THE SOUTH EXPERIENCING A NET COST FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS

Minimum AFUE (%)		% of consumers in the south experiencing a net cost				
Large	Small	Small furnace definition (kBtu/hour)				
		≤45	≤50	≤55	≤60	≤65
90	80	27	20	19	13	7
92	80	25	18	17	11	7
95	80	28	22	21	14	10
98	80	35	31	30	20	14

Table III.4 compares the key consumer economic impacts of a single standard for all furnaces to a separate standard for large and small furnaces.[15] Under a separate standard for large and small furnaces, the average LCC savings increase somewhat but the share of consumers with a net cost declines considerably. The impacts of a separate standard for large and small furnaces would vary depending on the small furnace definition. For example, if the definition was ≤60 kBtu/hour instead of ≤55 kBtu/hour, the difference between the single standard for all furnaces and separate standards for large and small furnaces would be greater than shown.

[14] The analysis used the same definition of the South region as the March 2015 NOPR.

[15] The results for a single standard for all furnaces differ slightly from the results in the March 2015 NOPR because of the input revisions discussed in section II. DOE believes that showing a direct comparison with the NOPR results would not serve the purpose of the NODA analysis.

TABLE III.4—COMPARISON OF CONSUMER IMPACTS OF SINGLE STANDARD VS. SEPARATE STANDARD FOR LARGE AND SMALL FURNACES *

Single standard for all furnaces			Separate standard for large and small furnaces		
AFUE (%)	Avg. LCC savings (2014$)	Share of consumers with net cost (%)	AFUE (%) large/small	Avg. LCC savings (2014$)	Share of consumers with net cost (%)
90	$347	20	90/80	$400	13
92	425	18	92/80	479	12
95	420	22	95/80	449	15
98	343	41	98/80	374	33

* Using small furnace definition of ≤55 kBtu/hour.

Table III.5 and Table III.6 show a similar comparison for consumers in the south and low-income consumers, with similar results.[16]

TABLE III.5—COMPARISON OF IMPACTS FOR CONSUMERS IN THE SOUTH OF SINGLE STANDARD VS. SEPARATE STANDARD FOR LARGE AND SMALL FURNACES *

Single standard for all furnaces			Separate standard for large and small furnaces		
AFUE (%)	Avg. LCC savings (2014$)	Share of consumers with net cost (%)	AFUE (%) large/small	Avg. LCC savings (2014$)	Share of consumers with net cost (%)
90	$291	31	90/80	$335	19
92	357	28	92/80	405	17
95	357	33	95/80	379	21
98	319	44	98/80	368	30

* Using small furnace definition of ≤55 kBtu/hour.

TABLE III.6—COMPARISON OF IMPACTS FOR LOW-INCOME CONSUMERS OF SINGLE STANDARD VS. SEPARATE STANDARD FOR LARGE AND SMALL FURNACES *

Single standard for all furnaces			Separate standard for large and small furnaces		
AFUE (%)	Avg. LCC savings (2014$)	Share of consumers with net cost (%)	AFUE (%) large/small	Avg. LCC savings (2014$)	Share of consumers with net cost (%)
90	$210	22	90/80	$274	12
92	301	20	92/80	379	11
95	363	24	95/80	423	13
98	356	44	98/80	447	31

* Using small furnace definition of ≤55 kBtu/hour.

In the NOPR analysis, DOE estimated that some consumers faced with significant costs to install a condensing furnace would instead choose to switch to electric heating with a heat pump or electric furnace. If there were a separate, lower standard level for small furnaces, fewer consumers would be faced with installing a condensing furnace, and there would be less switching. Table III.7 shows this outcome.

TABLE III.7—COMPARISON OF FUEL SWITCHING IMPACTS OF SINGLE STANDARD VS. SEPARATE STANDARD FOR LARGE AND SMALL FURNACES *

Single standard for all furnaces			Separate standard for large and small furnaces		
AFUE (%)	Switch to heat pump (% of consumers)	Switch to electric furnace (% of consumers)	AFUE (%) large/small	Switch to heat pump (% of consumers)	Switch to electric furnace (% of consumers)
90	6.7	3.0	90/80	2.9	1.8
92	6.9	3.1	92/80	3.0	1.9
95	8.3	3.5	95/80	3.9	2.3
98	11.7	4.2	98/80	6.5	2.8

* Using small furnace definition of ≤55 kBtu/hour.

[16] The results in Table III.6 overstate the percentage of low-income households that would actually be negatively impacted by proposed higher-efficiency furnace standards. Close to 60 percent of low-income households in RECS 2009 are either renters or residents of public housing. In these cases, the furnace would be purchased by the property owner, and the cost of a higher-efficiency furnace might be passed on over time in the rent (or perhaps not all in the case of public housing). DOE's current analysis assumes that in cases where the property owner does not pay for energy, the cost of a higher-efficiency furnace is passed on immediately, which would tend to overstate any negative impact.

B. National Impacts

The estimated national energy savings (full-fuel-cycle) of the considered combinations of minimum AFUE for large and small furnaces are shown in Table III.8.

Table III.9 and Table III.10 show the national NPV of benefits for alternative furnace standard level combinations at 7-percent and 3-percent discount rates, respectively. The national energy savings decrease as the small furnace definition expands.

TABLE III.8—NATIONAL ENERGY SAVINGS FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS

[Quads]

Minimum AFUE (%)		Small furnace definition (kBtu/hour)				
Large	Small	≤45	≤50	≤55	≤60	≤65
92	80	2.9	2.9	2.9	2.3	1.8
95	80	4.2	4.2	4.1	3.4	2.8
98	80	5.8	5.7	5.7	4.9	4.2

TABLE III.9—NATIONAL NET PRESENT VALUE OF BENEFITS FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS AT 7-PERCENT DISCOUNT RATE

[Billion 2014$]

Minimum AFUE (%)		Small furnace definition (kBtu/hour)				
Large	Small	≤45	≤50	≤55	≤60	≤65
92	80	3.1	3.5	3.5	3.0	2.4
95	80	4.2	4.6	4.6	4.2	3.6
98	80	3.8	4.4	4.4	4.6	4.0

TABLE III.10—NATIONAL NET PRESENT VALUE OF BENEFITS FOR ALTERNATIVE FURNACE STANDARD LEVEL COMBINATIONS AT 3-PERCENT DISCOUNT RATE

[Billion 2014$]

Minimum AFUE (%)		Small furnace definition (kBtu/hour)				
Large	Small	≤45	≤50	≤55	≤60	≤65
92	80	14.7	14.8	14.8	11.8	9.1
95	80	20.2	20.1	20.0	16.9	13.9
98	80	23.9	24.0	23.9	21.3	18.4

Table III.11 compares the national energy savings and NPV of a single standard for all furnaces vs. a separate standard for large and small furnaces. The national energy savings are higher in the case of a separate standard for large and small furnaces mainly because there is less switching from gas to electric heating.[17] The NPV is higher in the case of a separate standard for large and small furnaces mainly because the LCC savings are higher. The impacts of a separate standard for large and small furnaces would vary depending on the small furnace definition.

TABLE III.11—COMPARISON OF NATIONAL IMPACTS OF SINGLE STANDARD VS. SEPARATE STANDARD FOR LARGE AND SMALL FURNACES *

Single standard for all furnaces			Separate standard for large and small furnaces		
AFUE (%)	National energy savings (quads)	National net present value, 7% (billion 2014$)	AFUE (%) large/small	National energy savings (quads)	National net present value, 7% (billion 2014$)
92	2.6	2.2	92/80	2.9	3.5
95	3.9	3.3	95/80	4.1	4.6
98	5.4	2.6	98/80	5.7	4.4

* Using small furnace definition of ≤55 kBtu/hour.

[17] In terms of FFC energy, switching from gas to electricity increases energy use considerably because of the losses in thermal electricity generation.

IV. Submission of Comments

DOE will accept comments, data, and information regarding this analysis before or after the public meeting, but no later than the date provided in the **DATES** section at the beginning of this document. Interested parties may submit comments, data, and other information using any of the methods described in the **ADDRESSES** section at the beginning of this document.

Submitting comments via *www.regulations.gov*. The *www.regulations.gov* Web page will require you to provide your name and contact information. Your contact information will be viewable to DOE Building Technologies staff only. Your contact information will not be publicly viewable except for your first and last names, organization name (if any), and submitter representative name (if any). If your comment is not processed properly because of technical difficulties, DOE will use this information to contact you. If DOE cannot read your comment due to technical difficulties and cannot contact you for clarification, DOE may not be able to consider your comment.

However, your contact information will be publicly viewable if you include it in the comment itself or in any documents attached to your comment. Any information that you do not want to be publicly viewable should not be included in your comment, nor in any document attached to your comment. Otherwise, persons viewing comments will see only first and last names, organization names, correspondence containing comments, and any documents submitted with the comments.

Do not submit to *www.regulations.gov* information for which disclosure is restricted by statute, such as trade secrets and commercial or financial information (hereinafter referred to as Confidential Business Information (CBI)). Comments submitted through *www.regulations.gov* cannot be claimed as CBI. Comments received through the Web site will waive any CBI claims for the information submitted. For information on submitting CBI, see the Confidential Business Information section below.

DOE processes submissions made through *www.regulations.gov* before posting. Normally, comments will be posted within a few days of being submitted. However, if large volumes of comments are being processed simultaneously, your comment may not be viewable for up to several weeks. Please keep the comment tracking number that *www.regulations.gov* provides after you have successfully uploaded your comment.

Submitting comments via email, hand delivery/courier, or mail. Comments and documents submitted via email, hand delivery/courier, or mail also will be posted to *www.regulations.gov*. If you do not want your personal contact information to be publicly viewable, do not include it in your comment or any accompanying documents. Instead, provide your contact information in a cover letter. Include your first and last names, email address, telephone number, and optional mailing address. The cover letter will not be publicly viewable as long as it does not include any comments

Include contact information each time you submit comments, data, documents, and other information to DOE. If you submit via mail or hand delivery/courier, please provide all items on a CD, if feasible, in which case it is not necessary to submit printed copies. No telefacsimiles (faxes) will be accepted.

Comments, data, and other information submitted to DOE electronically should be provided in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format. Provide documents that are not secured, that are written in English, and that are free of any defects or viruses. Documents should not contain special characters or any form of encryption and, if possible, they should carry the electronic signature of the author.

Confidential Business Information. Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery/courier two well-marked copies: One copy of the document marked "confidential" including all the information believed to be confidential, and one copy of the document marked "non-confidential" with the information believed to be confidential deleted. Submit these documents via email or on a CD, if feasible. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

Factors of interest to DOE when evaluating requests to treat submitted information as confidential include: (1) A description of the items; (2) whether and why such items are customarily treated as confidential within the industry; (3) whether the information is generally known by or available from other sources; (4) whether the information has previously been made available to others without obligation concerning its confidentiality; (5) an explanation of the competitive injury to the submitting person that would result from public disclosure; (6) when such information might lose its confidential character due to the passage of time; and (7) why disclosure of the information would be contrary to the public interest.

It is DOE's policy that all comments may be included in the public docket, without change and as received, including any personal information provided in the comments (except information deemed to be exempt from public disclosure).

Issued in Washington, DC, on September 4, 2015.

Kathleen B. Hogan,

Deputy Assistant Secretary for Energy Efficiency, Energy Efficiency and Renewable Energy.

[FR Doc. 2015–23021 Filed 9–11–15; 8:45 am]

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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 39

[Docket No. FAA–2015–3628; Directorate Identifier 2015–NM–025–AD]

RIN 2120–AA64

Airworthiness Directives; The Boeing Company Airplanes

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: We propose to supersede Airworthiness Directive (AD) 2012–12–04, which applies to certain The Boeing Company Model 737–300, –400, and –500 series airplanes. AD 2012–12–04 currently requires repetitive external detailed inspections and nondestructive inspections to detect cracks in the fuselage skin along the chem-mill steps at stringers S–1 and S–2R, between station (STA) 400 and STA 460, and repair if necessary. Since we issued AD 2012–12–04, we have determined that, for certain airplanes, the skin pockets adjacent to the Air Traffic Control (ATC) antenna are susceptible to widespread fatigue damage. This proposed AD would require a preventive modification of the fuselage skin at crown stringers S–1 and S–2R. This proposed AD would reduce inspection thresholds and repetitive intervals for certain airplanes. We are proposing this AD to detect and correct fatigue cracking of the fuselage skin panels at the chem-mill steps, which could result in sudden fracture and failure of the fuselage skin panels,

and consequent rapid decompression of the airplane.

DATES: We must receive comments on this proposed AD by October 29, 2015.

ADDRESSES: You may send comments, using the procedures found in 14 CFR 11.43 and 11.45, by any of the following methods:

- Federal eRulemaking Portal: Go to *http://www.regulations.gov*. Follow the instructions for submitting comments.
- Fax: 202–493–2251.
- Mail: U.S. Department of Transportation, Docket Operations, M–30, West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue SE., Washington, DC 20590.
- Hand Delivery: Deliver to Mail address above between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

For service information identified in this proposed AD, contact Boeing Commercial Airplanes, Attention: Data & Services Management, P.O. Box 3707, MC 2H–65, Seattle, WA 98124–2207; telephone 206–544–5000, extension 1; fax 206–766–5680; Internet *https://www.myboeingfleet.com*. You may view this referenced service information at the FAA, Transport Airplane Directorate, 1601 Lind Avenue SW., Renton, WA. For information on the availability of this material at the FAA, call 425–227–1221. It is also available on the Internet at *http://www.regulations.gov* by searching for and locating Docket No. FAA–2015–3628.

Examining the AD Docket

You may examine the AD docket on the Internet at *http://www.regulations.gov* by searching for and locating Docket No. FAA–2015–3628; or in person at the Docket Management Facility between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays. The AD docket contains this proposed AD, the regulatory evaluation, any comments received, and other information. The street address for the Docket Office (phone: 800–647–5527) is in the **ADDRESSES** section. Comments will be available in the AD docket shortly after receipt.

FOR FURTHER INFORMATION CONTACT: Wayne Lockett, Aerospace Engineer, Airframe Branch, ANM–120S, FAA, Seattle Aircraft Certification Office, 1601 Lind Avenue SW., Renton, WA 98057–3356; phone: 425–917–6447; fax: 425–917–6590; email: *wayne.lockett@faa.gov*.

SUPPLEMENTARY INFORMATION:

Comments Invited

We invite you to send any written relevant data, views, or arguments about this proposed AD. Send your comments to an address listed under the **ADDRESSES** section. Include "Docket No. FAA–2015–3628; Directorate Identifier 2015–NM–025–AD" at the beginning of your comments. We specifically invite comments on the overall regulatory, economic, environmental, and energy aspects of this proposed AD. We will consider all comments received by the closing date and may amend this proposed AD because of those comments.

We will post all comments we receive, without change, to *http://www.regulations.gov*, including any personal information you provide. We will also post a report summarizing each substantive verbal contact we receive about this proposed AD.

Discussion

On May 31, 2012, we issued AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), for certain The Boeing Company Model 737–300, –400, and –500 series airplanes. AD 2012–12–04 requires repetitive external detailed inspections and nondestructive inspections to detect cracks in the fuselage skin along the chem-mill steps at stringers S–1 and S–2R, between station (STA) 400 and STA 460, and repair if necessary. AD 2012–12–04 resulted from reports of crack findings of the fuselage skin at the chem-mill steps. We issued AD 2012–12–04 to detect and correct fatigue cracking of the fuselage skin panels at the chem-mill steps, which could result in sudden fracture and failure of the fuselage skin panels, and consequent rapid decompression of the airplane.

Widespread Fatigue Damage

Structural fatigue damage is progressive. It begins as minute cracks, and those cracks grow under the action of repeated stresses. This can happen because of normal operational conditions and design attributes, or because of isolated situations or incidents such as material defects, poor fabrication quality, or corrosion pits, dings, or scratches. Fatigue damage can occur locally, in small areas or structural design details, or globally. Global fatigue damage is general degradation of large areas of structure with similar structural details and stress levels. Multiple-site damage is global damage that occurs in a large structural element such as a single rivet line of a lap splice joining two large skin panels. Global damage can also occur in multiple elements such as adjacent frames or stringers. Multiple-site-damage and multiple-element-damage cracks are typically too small initially to be reliably detected with normal inspection methods. Without intervention, these cracks will grow, and eventually compromise the structural integrity of the airplane, in a condition known as widespread fatigue damage (WFD). As an airplane ages, WFD will likely occur, and will certainly occur if the airplane is operated long enough without any intervention.

The FAA's WFD final rule (75 FR 69746, November 15, 2010) became effective on January 14, 2011. The WFD rule requires certain actions to prevent structural failure due to WFD throughout the operational life of certain existing transport category airplanes and all of these airplanes that will be certificated in the future. For existing and future airplanes subject to the WFD rule, the rule requires that DAHs establish a limit of validity (LOV) of the engineering data that support the structural maintenance program. Operators affected by the WFD rule may not fly an airplane beyond its LOV, unless an extended LOV is approved.

The WFD rule (75 FR 69746, November 15, 2010) does not require identifying and developing maintenance actions if the DAHs can show that such actions are not necessary to prevent WFD before the airplane reaches the LOV. Many LOVs, however, do depend on accomplishment of future maintenance actions. As stated in the WFD rule, any maintenance actions necessary to reach the LOV will be mandated by airworthiness directives through separate rulemaking actions.

In the context of WFD, this action is necessary to enable DAHs to propose LOVs that allow operators the longest operational lives for their airplanes, and still ensure that WFD will not occur. This approach allows for an implementation strategy that provides flexibility to DAHs in determining the timing of service information development (with FAA approval), while providing operators with certainty regarding the LOV applicable to their airplanes.

Actions Since AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), Was Issued

The preamble to AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), specified that we considered the requirements "interim action." AD 2012–12–04 explained that we might consider further rulemaking if final action is later identified. We now

have determined that it is necessary to initiate further rulemaking to require modification of the fuselage skin at crown stringers S–1 and S–2R, and to reduce inspection thresholds and repetitive intervals for certain airplanes.

Related Service Information Under 1 CFR Part 51

We reviewed Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015. The service information describes procedures for repetitive external detailed inspections and non-destructive inspections to detect cracks in the fuselage skin along the chem-mill steps at stringers S–1 and S–2R, between STA 400 and STA 460, and repair of any cracking. The service information also describes procedures for a modification of the chem-milled steps at the locations identified, including related investigative actions and corrective actions. This service information is reasonably available because the interested parties have access to it through their normal course of business or by the means identified in the **ADDRESSES** section of this NPRM.

FAA's Determination

We are proposing this AD because we evaluated all the relevant information and determined the unsafe condition described previously is likely to exist or develop in other products of the same type design.

Proposed AD Requirements

Although this proposed AD does not explicitly restate the requirements of AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), this proposed AD would retain all of the requirements. Those requirements are referenced in the service information identified previously, which, in turn, is referenced in this proposed AD. This proposed AD would require accomplishing the actions specified in the service information described previously, except as discussed under "Difference Between This Proposed AD and the Service Bulletin." For information on the procedures and compliance times, see this service information at *http://www.regulations.gov* by searching for and locating Docket No. FAA–2015–3628.

The phrase "related investigative actions" is used in this proposed AD. "Related investigative actions" are follow-on actions that (1) are related to the primary action, and (2) further investigate the nature of any condition found. Related investigative actions in an AD could include, for example, inspections.

The phrase "corrective actions" is used in this proposed AD. "Corrective actions" are actions that correct or address any condition found. Corrective actions in an AD could include, for example, repairs.

Explanation of Compliance Time

The compliance time for the modification specified in this proposed AD for addressing WFD was established to ensure that discrepant structure is modified before WFD develops in airplanes. Standard inspection techniques cannot be relied on to detect WFD before it becomes a hazard to flight. We will not grant any extensions of the compliance time to complete any AD-mandated service bulletin related to WFD without extensive new data that would substantiate and clearly warrant such an extension.

Difference Between This Proposed AD and the Service Bulletin

Although Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, specifies that operators may contact the manufacturer for disposition of certain repair conditions, this proposed AD would require repairing those conditions in one of the following ways:

- In accordance with a method that we approve; or
- Using data that meet the certification basis of the airplane, and that have been approved by the Boeing Commercial Airplanes Organization Designation Authorization (ODA) whom we have authorized to make those findings.

Costs of Compliance

We estimate that this proposed AD affects 186 airplanes of U.S. registry.

We estimate the following costs to comply with this proposed AD:

ESTIMATED COSTS

Action	Labor cost	Parts cost	Cost per product	Cost on U.S. operators
Retained inspections from AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012).	Between 7 and 15 work-hours × $85 per hour, depending on airplane configuration = between $595 and $1,275 per inspection cycle.	$0	Between $595 and $1,275 per inspection cycle.	Between $110,670 and $237,150 per inspection cycle.
New modification	236 work-hours × $85 per hour = $20,060.	(1)	$20,060	$3,731,160.

[1] We currently have no specific cost estimates associated with the parts necessary for the proposed modification. We cannot determine the cost of the materials because the modification parts must be sized at the time the modification is installed, taking into account any existing repairs in the area.

We have received no definitive data that would enable us to provide a cost estimate for the on-condition actions specified in this proposed AD.

Authority for This Rulemaking

Title 49 of the United States Code specifies the FAA's authority to issue rules on aviation safety. Subtitle I, Section 106, describes the authority of the FAA Administrator. Subtitle VII, Aviation Programs, describes in more detail the scope of the Agency's authority.

We are issuing this rulemaking under the authority described in Subtitle VII, Part A, Subpart III, Section 44701, "General requirements." Under that section, Congress charges the FAA with promoting safe flight of civil aircraft in air commerce by prescribing regulations for practices, methods, and procedures the Administrator finds necessary for safety in air commerce. This regulation is within the scope of that authority because it addresses an unsafe condition that is likely to exist or develop on products identified in this rulemaking action.

Regulatory Findings

We have determined that this proposed AD would not have federalism implications under Executive Order 13132. This proposed AD would not have a substantial direct effect on the States, on the relationship between the national Government and the States, or

on the distribution of power and responsibilities among the various levels of government.

For the reasons discussed above, I certify that the proposed regulation:

(1) Is not a "significant regulatory action" under Executive Order 12866,

(2) Is not a "significant rule" under the DOT Regulatory Policies and Procedures (44 FR 11034, February 26, 1979),

(3) Will not affect intrastate aviation in Alaska, and

(4) Will not have a significant economic impact, positive or negative, on a substantial number of small entities under the criteria of the Regulatory Flexibility Act.

List of Subjects in 14 CFR Part 39

Air transportation, Aircraft, Aviation safety, Incorporation by reference, Safety.

The Proposed Amendment

Accordingly, under the authority delegated to me by the Administrator, the FAA proposes to amend 14 CFR part 39 as follows:

PART 39—AIRWORTHINESS DIRECTIVES

■ 1. The authority citation for part 39 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701.

§ 39.13 [Amended]

■ 2. The FAA amends § 39.13 by removing Airworthiness Directive (AD) 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), and adding the following new AD:

The Boeing Company: Docket No. FAA–2015–3628; Directorate Identifier 2015–NM–025–AD.

(a) Comments Due Date

The FAA must receive comments on this AD action by October 29, 2015.

(b) Affected ADs

This AD replaces AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012).

(c) Applicability

This AD applies to The Boeing Company Model 737–300, –400, and –500 series airplanes, certificated in any category, as identified in Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015.

(d) Subject

Air Transport Association (ATA) of America Code 53, Fuselage.

(e) Unsafe Condition

This AD was prompted by reports of cracks found on the fuselage skin at the chem-mill steps, and the determination that, for certain airplanes, the skin pockets adjacent to the Air Traffic Control (ATC) antenna are susceptible to widespread fatigue damage. We are issuing this AD to detect and correct fatigue cracking of the fuselage skin panels at the chem-mill steps, which could result in sudden fracture and failure of the fuselage skin panels, and consequent rapid decompression of the airplane.

(f) Compliance

Comply with this AD within the compliance times specified, unless already done.

(g) Inspections

At the applicable time specified in tables 1, 2, 3, and 5 of paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, except as required by paragraphs (j)(1) and (j)(2) of this AD: Do the actions specified in paragraphs (g)(1) and (g)(2) of this AD, in accordance with the Accomplishment Instructions of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, except as required by paragraph (j)(3) of this AD. Repeat the applicable inspections thereafter at the applicable times specified in paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015.

(1) Do an external detailed inspection for cracking of the fuselage skin chem-mill steps.

(2) Do an external non-destructive (medium frequency eddy current, magneto optical imaging, C-Scan, or ultrasonic phased array) inspection for cracking of the fuselage skin chem-mill steps.

(h) Preventive Modification or Repair

If any cracking is found during any inspection required by paragraph (g) of this AD, do the applicable actions specified in paragraph (h)(1) or (h)(2) of this AD.

(1) Repair before further flight in accordance with Part 2 of the Accomplishment Instructions of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015.

(2) At the applicable time specified in tables 1, 2, 3, and 5 of paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, except as required by paragraphs (j)(1) and (j)(2) of this AD: Do a preventive modification of the fuselage skin at crown stringers S–1 and S–2R, including all applicable related investigative actions in accordance with Part 9 of the Accomplishment Instructions of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015. Do all applicable related investigative actions concurrently with the modification.

(i) Post-Repair Inspections/Post-Modification Inspections

The post-repair/post-modification inspections specified in tables 4 and 6 of paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, are not required by this AD.

Note 1 to paragraph (h) of this AD: The post-repair/post-modification inspections specified in tables 4 and 6 of paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, may be used in support of compliance with section 121.1109(c)(2) or 129.109(c)(2) of the Federal Aviation Regulations (14 CFR 121.1109(c)(2) or 14 CFR 129.109(c)(2)). The corresponding actions specified in the Accomplishment Instructions of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, are not required by this AD.

(j) Exceptions to Service Bulletin Specifications

(1) Where Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, specifies a compliance time "after the Revision 3 date of this service bulletin," this AD requires compliance within the specified compliance time after the effective date of this AD.

(2) Where the Condition column of paragraph 1.E., "Compliance," of Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, specifies a condition based on when an airplane has or has not been inspected, this AD bases the condition on whether an airplane has or has not been inspected on the effective date of this AD.

(3) Where Boeing Alert Service Bulletin 737–53A1293, Revision 3, dated January 23, 2015, specifies to contact Boeing for repair instructions: Before further flight, repair using a method approved in accordance with the procedures specified in paragraph (k) of this AD.

(k) Credit for Previous Actions

(1) This paragraph provides credit for actions required by paragraphs (g) and (h) of this AD, if those actions were performed before July 23, 2012 (the effective date of AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012)), using Boeing Alert Service Bulletin 737–53A1293, Revision 1, dated July 7, 2010, which is not incorporated by reference in this AD.

(2) This paragraph provides credit for actions required by paragraphs (g) and (h) of this AD, if those actions were performed before the effective date of this AD using Boeing Alert Service Bulletin 737–53A1293, Revision 2, dated August 10, 2011, which was incorporated by reference in AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012).

(l) Alternative Methods of Compliance (AMOCs)

(1) The Manager, Los Angeles Aircraft Certification Office (ACO), FAA, has the authority to approve AMOCs for this AD, if requested using the procedures found in 14 CFR 39.19. In accordance with 14 CFR 39.19, send your request to your principal inspector or local Flight Standards District Office, as appropriate. If sending information directly to the manager of the ACO, send it to the attention of the person identified in paragraph (l)(1) of this AD. Information may be emailed to: *9-ANM-LAACO-AMOC-Requests@faa.gov.*

(2) Before using any approved AMOC, notify your appropriate principal inspector,

or lacking a principal inspector, the manager of the local flight standards district office/certificate holding district office.

(3) An AMOC that provides an acceptable level of safety may be used for any repair required by this AD if it is approved by the Boeing Commercial Airplanes Organization Designation Authorization (ODA) that has been authorized by the Manager, Los Angeles ACO, to make those findings. For a repair method to be approved, the repair must meet the certification basis of the airplane, and the approval must specifically refer to this AD.

(4) AMOCs approved for AD 2012–12–04, Amendment 39–17083 (77 FR 36134, June 18, 2012), are approved as AMOCs for the corresponding provisions of paragraph (g) of this AD.

(m) Related Information

(1) For more information about this AD, contact Wayne Lockett, Aerospace Engineer, Airframe Branch, ANM–120S, FAA, Seattle ACO, 1601 Lind Avenue SW., Renton, WA 98057–3356; phone: 425–917–6447; fax: 425–917–6590; email: *wayne.lockett@faa.gov.*

(2) For service information identified in this AD, contact Boeing Commercial Airplanes, Attention: Data & Services Management, P.O. Box 3707, MC 2H–65, Seattle, WA 98124–2207; telephone 206–544–5000, extension 1; fax 206–766–5680; Internet *https://www.myboeingfleet.com.* You may view this referenced service information at the FAA, Transport Airplane Directorate, 1601 Lind Avenue SW., Renton, WA. For information on the availability of this material at the FAA, call 425–227–1221.

Issued in Renton, Washington, on September 1, 2015.

Michael Kaszycki,

Acting Manager, Transport Airplane Directorate, Aircraft Certification Service.

[FR Doc. 2015–22724 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 71

[Docket No. FAA–2015–3361; Airspace Docket No. 15–AEA–4]

RIN 2120–AA66

Proposed Amendment of Air Traffic Service (ATS) Routes; Northeast United States

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This action proposes to modify jet routes J–6, J–97, and J–222, and VOR Federal airways V–196, and V–489, in the northeastern United States due to the planned decommissioning of the Plattsburgh, NY, VORTAC facility.

DATES: Comments must be received on or before October 29, 2015.

ADDRESSES: Send comments on this proposal to the U.S. Department of Transportation, Docket Operations, M–30, 1200 New Jersey Avenue SE., West Building Ground Floor, Room W12–140, Washington, DC 20590–0001; telephone: (202) 366–9826. You must identify FAA Docket No. FAA–2015–3361 and Airspace Docket No. 15–AEA–4 at the beginning of your comments. You may also submit comments through the Internet at *http://www.regulations.gov.*

FAA Order 7400.9Y, Airspace Designations and Reporting Points, and subsequent amendments can be viewed online at *http://www.faa.gov/air_traffic/publications/.* For further information, you can contact the Airspace Policy and Regulations Group, Federal Aviation Administration, 800 Independence Avenue, SW., Washington, DC, 20591; telephone: 202–267–8783. The Order is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to *http://www.archives.gov/federal_register/code_of_federal-regulations/ibr_locations.html.*

FAA Order 7400.9, Airspace Designations and Reporting Points, is published yearly and effective on September 15.

FOR FURTHER INFORMATION CONTACT: Paul Gallant, Airspace Policy and Regulations Group, Office of Airspace Services, Federal Aviation Administration, 800 Independence Avenue SW., Washington, DC 20591; telephone: (202) 267–8783.

SUPPLEMENTARY INFORMATION:

Authority for This Rulemaking

The FAA's authority to issue rules regarding aviation safety is found in Title 49 of the United States Code. Subtitle I, Section 106 describes the authority of the FAA Administrator. Subtitle VII, Aviation Programs, describes in more detail the scope of the agency's authority. This rulemaking is promulgated under the authority described in Subtitle VII, Part A, Subpart I, Section 40103. Under that section, the FAA is charged with prescribing regulations to assign the use of the airspace necessary to ensure the safety of aircraft and the efficient use of airspace. This regulation is within the scope of that authority as it modifies the air traffic service route structure in the northeast United States to maintain the efficient flow of air traffic.

Comments Invited

Interested parties are invited to participate in this proposed rulemaking by submitting such written data, views, or arguments as they may desire. Comments that provide the factual basis supporting the views and suggestions presented are particularly helpful in developing reasoned regulatory decisions on the proposal. Comments are specifically invited on the overall regulatory, aeronautical, economic, environmental, and energy-related aspects of the proposal.

Communications should identify both docket numbers (FAA Docket No. FAA–2015–3361 and Airspace Docket No. 15–AEA–4) and be submitted in triplicate to the Docket Management Facility (see **ADDRESSES** section for address and phone number). You may also submit comments through the Internet at *http://www.regulations.gov.*

Commenters wishing the FAA to acknowledge receipt of their comments on this action must submit with those comments a self-addressed, stamped postcard on which the following statement is made: "Comments to FAA Docket No. FAA–2015–3361 and Airspace Docket No. 15–AEA–4." The postcard will be date/time stamped and returned to the commenter.

All communications received on or before the specified comment closing date will be considered before taking action on the proposed rule. The proposal contained in this action may be changed in light of comments received. All comments submitted will be available for examination in the public docket both before and after the comment closing date. A report summarizing each substantive public contact with FAA personnel concerned with this rulemaking will be filed in the docket.

Availability of NPRMs

An electronic copy of this document may be downloaded through the Internet at *http://www.regulations.gov.*

You may review the public docket containing the proposal, any comments received and any final disposition in person in the Dockets Office (see **ADDRESSES** section for address and phone number) between 9:00 a.m. and 5:00 p.m., Monday through Friday, except Federal holidays. An informal docket may also be examined during normal business hours at the office of the Eastern Service Center, Federal Aviation Administration, Room 210, 1701 Columbia Ave., College Park, GA, 30337.

Persons interested in being placed on a mailing list for future NPRMs should contact the FAA's Office of Rulemaking, (202) 267–9677, for a copy of Advisory Circular No. 11–2A, Notice of Proposed

Rulemaking Distribution System, which describes the application procedure.

Availability and Summary of Documents for Incorporation by Reference

This document proposes to amend FAA Order 7400.9Y, Airspace Designations and Reporting Points, dated August 6, 2014, and effective September 15, 2014. FAA Order 7400.9Y is publicly available as listed in the **ADDRESSES** section of this proposed rule. FAA Order 7400.9Y lists Class A, B, C, D, and E airspace areas, air traffic service routes, and reporting points.

The Proposal

The FAA is proposing an amendment to Title 14, Code of Federal Regulations (14 CFR) part 71 to modify the descriptions of jet routes J–6, J–97 and J–222; and VOR Federal airways V–196 and V–489, due to the planned decommissioning of the Plattsburgh, NY, VORTAC. The proposed route changes are outlined below.

J6 Jet route J–6 extends from Salinas, CA, across the United States to Albany, NY, then terminates at Plattsburgh, NY. The FAA proposes to terminate the route at Albany, eliminating the segment between Albany and Plattsburgh.

J–97 Jet route J–97 extends between the SLATN fix and Plattsburgh, NY. The FAA proposes to terminate the route at Boston, MA, eliminating the segment between Boston and Plattsburgh.

J–222 Jet route J–222 extends between Robbinsville, NJ, and Plattsburgh, NY. The FAA proposes to terminate the route at Cambridge, NY, eliminating the segment between Cambridge and Plattsburgh.

V–196 VOR Federal airway V–196 extends from Utica, NY, to Saranac Lake, NY to Plattsburgh, NY. The FAA proposes to terminate the route at the intersection of the Saranac Lake, NY 058°(T) and the Burlington, VT 296°(T) radials, eliminating the segment between that intersection and Plattsburgh.

V–489 VOR Federal airway V–489 extends between the intersection of the Sparta, NJ 300°(T) and the Huguenot, NY 196°(T) radials and Plattsburgh, NY. The FAA proposes to terminate the route at Glens Falls, NY, eliminating the segment between Glens Falls and Plattsburgh.

Except for VOR Federal airway V–196, all radials in the route descriptions below are stated in True degrees. Both True and Magnetic degrees are used to describe the intersecting radials in V–196 since this intersection would be added to the airway description.

Jet routes are published in paragraph 2004, and VOR Federal airways are published in paragraph 6010(a), respectively, of FAA Order 7400.9Y dated August 6, 2014, and effective September 15, 2014, which is incorporated by reference in 14 CFR 71.1. The jet routes and VOR Federal airways listed in this document would be subsequently published in the Order.

Regulatory Notices and Analyses

The FAA has determined that this proposed regulation only involves an established body of technical regulations for which frequent and routine amendments are necessary to keep them operationally current. Therefore, this proposed regulation: (1) is not a "significant regulatory action" under Executive Order 12866; (2) is not a "significant rule" under Department of Transportation (DOT) Regulatory Policies and Procedures (44 FR 11034; February 26, 1979); and (3) does not warrant preparation of a regulatory evaluation as the anticipated impact is so minimal. Since this is a routine matter that will only affect air traffic procedures and air navigation, it is certified that this proposed rule, when promulgated, will not have a significant economic impact on a substantial number of small entities under the criteria of the Regulatory Flexibility Act.

Environmental Review

This proposal will be subject to an environmental analysis in accordance with FAA Order 1050.1E, "Environmental Impacts: Policies and Procedures" prior to any FAA final regulatory action.

List of Subjects in 14 CFR Part 71

Airspace, Incorporation by reference, Navigation (air).

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration proposes to amend 14 CFR part 71 as follows:

PART 71—DESIGNATION OF CLASS A, B, C, D, AND E AIRSPACE AREAS; AIR TRAFFIC SERVICE ROUTES; AND REPORTING POINTS

■ 1. The authority citation for part 71 continues to read as follows:

Authority: 49 U.S.C. 106(f), 106(g); 40103, 40113, 40120; E.O. 10854, 24 FR 9565, 3 CFR, 1959–1963 Comp., p. 389.

§ 71.1 [Amended]

■ 2. The incorporation by reference in 14 CFR 71.1 of FAA Order 7400.9Y, Airspace Designations and Reporting Points, dated August 6, 2014 and effective September 15, 2014, is amended as follows:

Paragraph 2004 Jet Routes

* * * * *

J–6 [Amended]

From Salinas, CA, via INT Salinas 145° and Avenal, CA, 292° radials; Avenal; INT Avenal 119° and Palmdale, CA, 310° radials; Palmdale; Hector, CA; Needles, CA; Drake, AZ; Zuni, AZ; Albuquerque, NM; Tucumcari, NM; Panhandle, TX; Will Rogers, OK; Little Rock, AR; Bowling Green, KY; Charleston, WV; INT Charleston 076° and Martinsburg, WV, 243° radials; Martinsburg; Lancaster, PA; Broadway, NJ; Sparta, NJ; to Albany, NY.

J–97 [Amended]

From lat. 39°07′00″ N., long. 67°00′00″ W. via Nantucket, MA; to Boston, MA.

J–222 [Amended]

From Robbinsville, NJ; INT Robbinsville 039° and Kennedy, NY, 253° radials; Kennedy; INT Kennedy 022° and Cambridge, NY, 179° radials; to Cambridge.

* * * * *

Paragraph 6010(a) Domestic VOR Federal Airways

V–196 [Amended]

From Utica, NY, Saranac Lake, NY; to INT Saranac Lake 058°(T)/072°(M) and Burlington, VT 296°(T)311°(M) radials.

V–489 [Amended]

From INT Sparta, NJ, 300° and Huguenot, NY, 196° radials; Huguenot; INT Huguenot 008° and Albany, NY, 209° radials; Albany; to Glens Falls, NY.

Issued in Washington, DC, on September 3, 2015.

Gary A. Norek,

Manager, Airspace Policy and Regulations Group.

[FR Doc. 2015–22876 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–13–P

SOCIAL SECURITY ADMINISTRATION

20 CFR Part 404 and 416

[Docket No. SSA–2014–0081]

RIN 0960–AH74

Vocational Factors of Age, Education, and Work Experience in the Adult Disability Determination Process

AGENCY: Social Security Administration.

ACTION: Advance notice of proposed rulemaking.

SUMMARY: We are soliciting public input about how we should consider the vocational factors of age, education, and work experience in adult disability claims under titles II and XVI of the Social Security Act (Act). There have been significant changes in technology

use and workforce demographics since we first adopted our vocational factor regulations in 1978. We are requesting public comments, along with any supporting data, to assist in our efforts to streamline, simplify, and ensure the ongoing relevance of our disability determination programs.

DATES: To be sure that we consider your comments, we must receive them no later than November 13, 2015.

ADDRESSES: You may submit comments by any one of three methods—Internet, fax, or mail. Do not submit the same comments multiple times or by more than one method. Regardless of which method you choose, please state that your comments refer to Docket No. SSA–2014–0081, so that we may associate your comments with the correct regulation.

Caution: You should be careful to include in your comments only information that you wish to make publicly available. We strongly urge you not to include in your comments any personal information, such as Social Security numbers or medical information.

1. Internet: We strongly recommend that you submit your comments via the Internet. Please visit the Federal eRulemaking portal at *http://www.regulations.gov*. Use the Search function to find docket number SSA–2014–0081. The system will issue a tracking number to confirm your submission. You will not be able to view your comment immediately because we must post each comment manually. It may take up to a week for your comment to be viewable.

2. Fax: Fax comments to (410) 966–2830.

3. Mail: Address your comments to the Office of Regulations and Reports Clearance, Social Security Administration, 3100 West High Rise Building, 6401 Security Boulevard, Baltimore, Maryland 21235–6401.

Comments are available for public viewing on the Federal eRulemaking portal at *http://www.regulations.gov* or in person, during regular business hours, by arranging with the contact person identified below.

FOR FURTHER INFORMATION CONTACT: Mary Quatroche, Office of Disability Policy, Social Security Administration, 6401 Security Boulevard, Baltimore, MD 21235–6401, (410) 966–4794. For information on eligibility or filing for benefits, call our national toll-free number, 1–800–772–1213 or TTY 1–800–325–0778, or visit our Internet site, Social Security Online, at *http://www.socialsecurity.gov*.

SUPPLEMENTARY INFORMATION:

Background

The Act defines "disability" for titles II and XVI as the "inability to engage in any substantial gainful activity by reason of any medically determinable physical or mental impairment which can be expected to result in death or which has lasted or can be expected to last for a continuous period of not less than 12 months." [1] The Act also states that "[a]n individual shall be determined to be under a disability only if his physical or mental impairment or impairments are of such severity that he is not only unable to do his previous work but cannot, considering his age, education, and work experience, engage in any other kind of substantial gainful work which exists in the national economy, regardless of whether such work exists in the immediate area in which he lives, or whether a specific job vacancy exists for him, or whether he would be hired if he applied for work. For purposes of the preceding sentence (with respect to any individual), "work which exists in the national economy" means work which exists in significant numbers either in the region where such individual lives or in several regions of the country.[2]

We use a five-step sequential evaluation process to determine whether an adult is disabled under the Act.[3] If we can make a determination or decision whether a claimant is disabled or not disabled at a step, we do not go on to the next step.[4] If we cannot make a determination or decision at a step, we continue to the next step in the sequential evaluation process.[5]

The vocational factors of age, education, and work experience are relevant at step 5 when we consider a claimant's capacity to adjust to other work. Specifically, at step 5 we consider whether a claimant's impairment(s) prevents him or her from doing any other work that exists in significant numbers in the national economy, considering his or her residual functional capacity (RFC) [6] and the vocational factors of age,[7] education,[8] and work experience.[9] If we find that the claimant does not have the capacity to adjust to other work that exists in significant numbers in the national economy, we find the claimant disabled. If we find that the claimant has the capacity to adjust to other work, we find the claimant not disabled. We do not consider an individual's ability to obtain work.[10]

To help make our step 5 determination, we use both the medical-vocational profiles (the profiles) [11] and the medical-vocational guidelines (the guidelines) when appropriate.[12] The profiles and the guidelines are based on several assumptions:

- We consider aging to be a limiting factor in a person's ability to adjust to other work.
- We consider higher levels of education and certain types of recent education to enhance a person's ability to adjust to other work.
- We consider that an individual who has done skilled or semi-skilled work may have acquired skills and abilities from that past work. Those acquired skills and abilities may be transferable to other work. Under our rules, unskilled work does not convey transferable skills to an individual.

What is the purpose of this ANPRM?

We are soliciting public comments along with supporting research and data about how vocational factors such as age, education, and work experience affect an individual's ability to adjust to other work that exists in the national economy. In addition to seeking public input on the specific questions below, we are also asking for public assistance to help identify research and data to assist us.

What will we consider when we decide whether to propose revisions?

We will consider the public comments in addition to other input, research, and data that we obtain through other methods. This ANPRM is one component of the our larger effort to collect information about how we consider the vocational factors of age, education, and work experience when we determine whether an individual can adjust to other work. We commissioned several studies and are examining how the vocational factors influence an individual's ability to adjust to doing new work. For your consideration while preparing your comments to this ANPRM, these studies are included in the References section of

[1] 42 U.S.C. 423(d)(1)(A) and 1382c(a)(3)(A); see also 20 CFR 404.1505(a) and 416.905(a).

[2] 42 U.S.C. 423(d)(2)(A) and 1382c(a)(3)(B).

[3] 20 CFR 404.1520(a)(4) and 416.920(a)(4).

[4] Id.

[5] Id.

[6] The RFC is the individual's maximum remaining ability to do sustained work activities in an ordinary work setting on a regular and continuing basis. See 20 CFR 404.1545 and 416.945.

[7] See 20 CFR 404.1520(a)(4)(v), 404.1563, 416.920(a)(4)(v), and 416.963.

[8] See 20 CFR 404.1520(a)(4)(v), 404.1564, 416.920(2)(4)(v), and 416.964.

[9] See 20 CFR 404.1520(a)(4)(v), 404.1565, 416.920(a)(4)(v), and 416.965.

[10] See 20 CFR 404.1566(c) and 416.966(c).

[11] See 20 CFR 404.1562 and 416.962 and POMS DI 25010.001.

[12] See 20 CFR part 404 Subpart P Appendix 2.

this notice, and are included in the docket folder for this rule at *http://www.regulations.gov*. In addition, we are undertaking outreach efforts to engage federal and private stakeholders, including the scientific community. We will consider the results of these information-gathering efforts collectively when we evaluate how to consider the vocational factors in determining whether an individual can adjust to other work.

What should you comment about?

When we determine whether an individual can adjust to other work, we consider an individual's functional capacities and limitations, the occupational base in the national economy, and the vocational factors of age, education, and work experience. We have ongoing activities related to each of these considerations. Although complementary, our activities related to functional limitations and the occupational base are independent and are occurring on separate timeframes from our effort on the vocational factors. Accordingly, we are narrowing the scope of this ANPRM to solicit public comments on only the vocational factors. We are not soliciting public comments on how we assess an individual's functional limitations. We are also not soliciting public comments in this notice on sources of occupational data we use at step 5, such as the Dictionary of Occupational Titles, because we are working with the Bureau of Labor Statistics (BLS) to test the collection of updated occupational information that we intend to use to develop a new occupational information system.[13]

Specifically, given today's work environment and advances in technology and medicine, we are seeking public input, research, and data about the following:

1. Is the factor of age predictive in determining an individual's ability to work or to adjust to other work? If it is predictive, what are the vocationally significant age milestones we should consider? If it is not predictive, what data support that assertion?

2. When determining if age affects an individual's ability to work or to adjust to other work, what other factors or combination of factors should we consider?

3. Does an individual's educational level affect an individual's ability to do work or to adjust to other work? If so, how? What data support the conclusion that an individual's educational level does or does not affect an individual's ability to do work or to adjust to other work? How does literacy affect an individual's ability to do work or adjust to other work?

4. Does the skill level of an individual's past work affect his or her ability to adjust to other work? If so, how? What data support the conclusion that the skill level of an individual's past work does or does not affect an individual's ability to do work or to adjust to other work? How does the skill level of an individual's past work considered along with an individual's educational level affect this adjustment?

5. Are there other vocational factors or combinations of vocational factors that we should consider when determining an individual's ability to do work or to adjust to other work?

Will we respond to your comments?

We will consider all relevant public comments we receive about this notice, but we will not respond directly to them. If we decide to propose specific revisions to the vocational factors we consider when we determine an individual's ability to do work or to adjust to other work, we will publish a notice of proposed rulemaking in the **Federal Register**, and you will have a chance to comment on any revisions we propose.

References

Library of Congress, "Vocational Factors in the Social Security Disability Decision Process: A Review of the Literature" (December 1998).

American Institutes for Research, "The Impact of Age, Education, and Work Experience on Determining Eligibility for Social Security Disability Insurance: A Synthesis of Recent Literature" (2000).

American Institutes of Research, "Investigation of Non-Medical Factors Used in SSA's Medical-Vocational Process: A Research Review of Age, Education, and Skills as Related to SSA's Disability Determination Process" (August 2002).

Mathematica Center for Studying Disability Policy, "Vocational Factors in the Social Security Disability Determination Process: A Literature Review" (July 2014) (available at: *http://www.mathematica-mpr.com/~/media/publications/pdfs/disability/drc_wp_2014-07_voc_factors_determinations.pdf*)

Social Security Administration, Office of Research, Evaluation, and Statistics, "Evidence Synthesis: The Use of Vocational Factors in the Disability Determination Process" (September 2014).

[13] You can find more information on this effort on the BLS Web site at *http://www.bls.gov/ors/*, and on our Web site at *http://www.ssa.gov/disabilityresearch/occupational_info_systems.html*.

List of Subjects

20 CFR Part 404

Administrative practice and procedure, Blind, Disability benefits, Old-age, Survivors and Disability Insurance, Reporting and recordkeeping requirements, Social security.

20 CFR Part 416

Administrative practice and procedure, Reporting and recordkeeping requirements, Social security.

Dated: July 30, 2015.

Carolyn W. Colvin,

Acting Commissioner of Social Security.

[FR Doc. 2015–22839 Filed 9–11–15; 8:45 am]

BILLING CODE 4191–02–P

DEPARTMENT OF DEFENSE

Department of the Army, Corps of Engineers

33 CFR Part 334

Gulf of Mexico, Apalachicola Bay, East Bay, St. Andrew Bay and St. Andrew Sound at Tyndall Air Force Base, Florida; Restricted Areas

AGENCY: U.S. Army Corps of Engineers, Department of Defense.

ACTION: Notice of proposed rulemaking and request for comments.

SUMMARY: The U.S. Army Corps of Engineers (Corps) is proposing to amend its regulations by revising an existing restricted area regulation and establishing a new restricted area along portions of the Tyndall Air Force Base (AFB) facility shoreline that will be activated on a temporary basis. The duration of temporary restricted area activations will be limited to those periods where it is warranted or required by specific and credible security threats and will be inactive at all other times. The restricted area will be partitioned using 23 pairs of coordinates to facilitate quick geographic recognition. Tyndall AFB is surrounded on three sides by water with approximately 129 miles of unprotected coastline. This includes several areas where the lack of security or lack of restriction on access to these areas leaves Tyndall AFB personnel and resources vulnerable to unauthorized activities. This amendment is necessary to implement an enhanced threat security plan for Tyndall AFB which will allow temporary activation of one or more portions of the restricted area as necessary to provide the appropriate level of security required to address the specific and credible threat triggering

the need for activation. This proposal is an amended version of the proposal published in the **Federal Register** on May 9, 2013 (78 FR 27126).

DATES: Written comments must be submitted on or before October 14, 2015.

ADDRESSES: You may submit comments, identified by docket number COE–2013–0003, by any of the following methods:

Federal Rulemaking Portal: http://www.regulations.gov. Follow the instructions for submitting comments.

Email: david.b.olson@usace.army.mil. Include the docket number, COE–2013–0003, in the subject line of the message.

Mail: U.S. Army Corps of Engineers, Attn: CECW–CO (David B. Olson), 441 G Street NW., Washington, DC 20314–1000.

Hand Delivery/Courier: Due to security requirements, we cannot receive comments by hand delivery or courier.

Instructions: Direct your comments to docket number COE–2013–0003. All comments received will be included in the public docket without change and may be made available on-line at *http://www.regulations.gov,* including any personal information provided, unless the commenter indicates that the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI, or otherwise protected, through regulations.gov or email. The regulations.gov Web site is an anonymous access system, which means we will not know your identity or contact information unless you provide it in the body of your comment. If you send an email directly to the Corps without going through regulations.gov, your email address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, we recommend that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If we cannot read your comment because of technical difficulties and cannot contact you for clarification, we may not be able to consider your comment. Electronic comments should avoid the use of any special characters, any form of encryption, and be free of any defects or viruses.

Docket: For access to the docket to read background documents or comments received, go to *www.regulations.gov.* All documents in the docket are listed. Although listed in the index, some information is not publicly available, such as CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy form.

FOR FURTHER INFORMATION CONTACT: Mr. David Olson, Headquarters, Operations and Regulatory Community of Practice, Washington, DC at 202–761–4922 or Mr. Edward Sarfert, U.S. Army Corps of Engineers, Jacksonville District, Regulatory Division, Pensacola Regulatory Office at 850–439–9533.

SUPPLEMENTARY INFORMATION:

Executive Summary

External reviews of security at Tyndall AFB identified the lack of jurisdiction to respond to threats from the waterways as a major weakness. Tyndall AFB does not currently have the authority to restrict access to the shoreline of Tyndall AFB if needed to respond to a security threat. The purpose of this regulatory action is to establish a restricted area in the waters surrounding portions of Tyndall AFB that would only be activated on a temporary basis in response to specific and credible security threats. Additionally this amendment provides an administrative correction to the existing regulation at 33 CFR 334.660.

The Corps authority to establish the restricted area is Section 7 of the Rivers and Harbors Act of 1917 (40 Stat 266; 33 U.S.C. 1) and Chapter XIX of the Army Appropriations Act of 1919 (40 Stat. 892; 33 U.S.C. 3).

Background

Pursuant to its authorities in Section 7 of the Rivers and Harbors Act of 1917 (40 Stat 266; 33 U.S.C. 1) and Chapter XIX of the Army Appropriations Act of 1919 (40 Stat 892; 33 U.S.C. 3) the Corps is proposing to revise the regulations at 33 CFR part 334 by establishing a restricted area in the waters surrounding Tyndall AFB. This amendment will allow the Installation Commander, Tyndall AFB to temporarily restrict the passage of persons, watercraft, and vessels in waters contiguous to this facility when a specific and credible security threat is identified, providing greater security for personnel and equipment during those periods. The administrative correction at 33 CFR 334.660(b)(3) will clarify who is responsible for enforcing the provisions of § 334.660.

This proposed rule replaces the proposed rule that was originally published in the May 9, 2013, issue of the **Federal Register** (78 FR 27126). The Corps received many comments on that proposed rule, and after those comments were fully considered, Tyndall AFB made substantial changes to its request for a new restricted area. Those changes are incorporated into this proposed rule.

Procedural Requirements

a. *Review Under Executive Order 12866.* The proposed rule is issued with respect to a military function of the Department of Defense and the provisions of Executive Order 12866 do not apply.

b. *Review Under the Regulatory Flexibility Act.* This rule has been reviewed under the Regulatory Flexibility Act (Pub. L. 96–354). The Regulatory Flexibility Act generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to the notice-and-comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities (*i.e.,* small businesses and small governments). Tyndall AFB has approximately 129 miles of unprotected shoreline, including several areas where the lack of security or restriction on access leaves Tyndall AFB personnel and resources vulnerable to unauthorized activities. Therefore, the proposed restricted area regulation is necessary to implement an enhanced threat security plan for Tyndall AFB which will allow for the temporary activation of one or more portions of the restricted area as necessary to provide the appropriate level of security required to address the specific and credible threat triggering the need for the activation. The temporary restrictions in the proposed rule are also necessary to protect the public from potentially hazardous conditions that may develop as a result of military use of the area. When the restricted area is activated, small entities can continue to use the navigable waters surrounding Tyndall AFB that are outside of the restricted area. After considering the economic impacts of this proposed restricted area regulation on small entities, I certify that this action will not have a significant impact on a substantial number of small entities. We are interested in the potential impacts of the proposed regulation on small entities and welcome comments on issues related to such impacts.

c. *Review Under the National Environmental Policy Act.* Due to the administrative nature of this action and because there is no intended change in the use of the area, the Corps expects that this regulation, if adopted, will not have a significant impact on the quality of the human environment and, therefore, preparation of an environmental impact statement will not be required. An environmental assessment will be prepared after the public notice period is closed and all comments have been received and considered.

d. *Unfunded Mandates Act.* This regulation does not impose an enforceable duty among the private sector and, therefore, is not a Federal private sector mandate and is not subject to the requirements of Section 202 or 205 of the Unfunded Mandates Reform Act (Pub. L. 104–4, 109 Stat. 48, 2 U.S.C. 1501 *et seq.*). We have also found under Section 203 of the Act, that small governments will not be significantly or uniquely affected by this regulation.

List of Subjects in 33 CFR Part 334

Danger zones, Navigation (water), Restricted areas, Waterways.

For the reasons set out in the preamble, the Corps proposes to amend 33 CFR part 334 as follows:

PART 334—DANGER ZONE AND RESTRICTED AREA REGULATIONS

■ 1. The authority citation for part 334 continues to read as follows:

Authority: 40 Stat. 266 (33 U.S.C. 1) and 40 Stat. 892 (33 U.S.C. 3).

■ 2. Revise § 334.660(b)(3) to read as follows:

§ 334.660 Gulf of Mexico and Apalachicola Bay south of Apalachicola, Fla., Drone Recovery Area, Tyndall Air Force Base, Fla.

* * * * *

(b) * * *

(3) The federal regulations in this section shall be enforced by the Installation Commander, Tyndall Air Force Base, Florida, and such other agencies as he/she may designate.

■ 3. Add § 334.665 to read as follows:

§ 334.665 East Bay, St. Andrew Bay and St. Andrew Sound, enhanced threat restricted area, Tyndall Air Force Base, Florida.

(a) *The area.* (1) The coordinates provided herein are approximations obtained using a commercial mapping program which utilizes Simple Cylindrical projection with a WGS84 datum for its imagery base and imagery dated February 15 and May 3, 2014.

(2) Each portion of the temporary restricted area described in paragraphs (a)(4)(i) through (xxiii) of this section shall encompass all navigable waters of the United States as defined at 33 CFR part 329 within the area described and includes all contiguous inland navigable waters which lie within the land boundaries of Tyndall AFB.

(3) Because of the dynamic nature of these geographic features near barrier islands, the coordinate points provided may not reflect the current situation regarding the location of a point at the mean high water line or 500 feet waterward of the mean high water line. Even if the landform has shifted through erosion or accretion, the intent of the area description will be enforced from the existing point at the mean high water line that is closest to the shoreline point provided herein out to a point located 500 feet waterward of the mean high water line.

(4) The restricted area will be partitioned using 23 pairs of coordinates to facilitate quick geographic recognition. The first point in each pair of coordinates is located on the shoreline, and the second point is a point 500 feet waterward of the shoreline. From the first point in each pair of coordinates, a line meanders irregularly following the shoreline and connects to the first point in the next pair of coordinates. From the second point in each pair of coordinates, a line beginning 500 feet waterward of the shoreline meanders irregularly following the shoreline at a distance of 500 feet waterward of the shoreline and connects to the second point in the next pair of coordinates. The restricted area shall encompass all navigable waters of the United States as defined at 33 CFR part 329 within the area bounded by lines connecting each of the following pairs of coordinates:

(i) *Farmdale Bayou:* 30°1.156′ N., 85°26.915′ W. to 30°1.238′ N., 85°26.915′ W.

(ii) *Baker Bayou:* 30°1.325′ N., 85°29.008′ W. to 30°1.402′ N., 85°28.977′ W.

(iii) *Blind Alligator Bayou:* 30°2.094′ N., 85°29.933′ W. to 30°2.151′ N., 85°29.864′ W.

(iv) *Little Oyster Bay Point:* 30°3.071′ N., 85°30.629′ W. to 30°3.133′ N., 85°30.568′ W.

(v) *Goose Point South:* 30°3.764′ N., 85°31.874′ W. to 30°3.719′ N., 85°31.795′ W.

(vi) *Goose Point North:* 30°4.599′ N., 85°31.577′ W. to 30° 4.650′ N., 85°31.503′ W.

(vii) *Little Cedar Lake:* 30°4.974′ N., 85°33.476′ W. to 30° 5.024′ N., 85°33.401′ W.

(viii) *Chatters on Bayou:* 30°5.729′ N., 85°34.632′ W. to 30°5.811′ N., 85°34.625′ W.

(ix) *Fred Bayou:* 30° 5.992′ N., 85°35.296′ W. to 30°6.071′ N., 85°35.325′ W.

(x) *Pearl Bayou:* 30°6.039′ N., 85°36.651′ W. to 30°6.043′ N., 85°36.557′ W.

(xi) *Military Point:* 30°7.394′ N., 85°37.153′ W. to 30°7.459′ N., 85°37.096′ W.

(xii) *Freshwater Bayou:* 30°7.425′ N., 85°38.655′ W. to 30°7.473′ N., 85°38.578′ W.

(xiii) *Smack Bayou:* 30°7.826′ N., 85°39.654′ W. to 30°7.838′ N., 85°39.560′ W.

(xiv) *Redfish Point:* 30°8.521′ N., 85°40.147′ W. to 30°8.598′ N., 85°40.113′ W.

(xv) *Davis Point:* 30°7.348′ N., 85°41.224′ W. to 30°7.364′ N., 85°41.317′ W.

(xvi) *Tyndall Marina:* 30°5.827′ N., 85°39.125′ W. to 30°5.762′ N., 85°39.184′ W.

(xvii) *Heritage Bayou:* 30°3.683′ N., 85°35.823′ W. to 30°3.743′ N., 85°35.887′ W.

(xviii) *NCO Beach North:* 30°4.209′ N., 85°37.430′ W. to 30°4.272′ N., 85°37.368′ W. The restricted Area will end on the west side of the land bridge that extends into Shell Island. The Restricted Area resumes on the east side of the land bridge that extends into St. Andrew Sound.

(xix) *St. Andrew Sound west:* 30°1.327′ N., 85°33.756′ W. to 30°1.377′ N., 85°33.681′ W.

(xx) *St. Andrew Sound northwest:* 30° 1.921′ N., 85° 33.244′ W to 30°1.869′ N., 85°33.317′ W.

(xxi) *St. Andrew Sound northeast:* 30°0.514′ N., 85°31.558′ W to 30°0.452′ N., 85°31.619′ W.

(xxii) *Wild Goose Lagoon:* 29°59.395′ N., 85°30.178′ W. to 29°59.319′ N., 85°30.216′ W.

(xxiii) *Crooked Island North:* 29°59.003′ N., 85°30.396′ W. to 29°59.082′ N., 85°30.371′ W.

(b) *The regulations.* (1) Unless one or more portions of the restricted area identified in (a)(4)(i) through (xxiii) of this section is activated, all persons, vessels and other craft are permitted access to all of the navigable waters described in paragraph (a) of this section.

(2) During times when the restricted area defined in paragraphs (a)(4)(i) through (xxiii) of this section is not active, U.S. Air Force boat patrols may operate in the waters adjacent to Tyndall AFB's shoreline to observe the shoreline in order to identify any threats to the installation or personnel. U.S. Air

Force personnel will not have any authority to enforce federal, local or state laws on the water.

(3) Due to the nature of security threats, restricted area activation may occur with little advance notice. Activation will be based on local or national intelligence information related to threats against military installations and/or resources common to Tyndall AFB in concert with evaluations conducted by the Tyndall AFB Threat Working Group and upon direction of the Installation Commander, Tyndall AFB. The Installation Commander activates only those portions of the restricted area identified in paragraphs (a)(4)(i) through (xxiii) of this section necessary to provide the level of security required in response to the specific and credible threat(s) triggering the activation. The duration of activation for any portion(s) of the restricted area defined in paragraph (a) of this section, singularly or in combination, will be limited to those periods where it is warranted or required by security threats. Activated portions of the restricted area will be reevaluated every 48 hours to determine if the threat(s) triggering the activation or related threats warrant continued activation. The activated portion(s) of the restricted area expire if no reevaluation occurs or if the Installation Commander determines that activation is no longer warranted.

(4) Public notification of a temporary restricted area activation will be made via marine VHF broadcasts (channels 13 and 16), local notices to mariners, local news media through Air Force Public Affairs notifications and by on-scene installation personnel. On-scene installation personnel will notify boaters in the restricted area of the restriction and tell them that if they refuse to leave the area they will be trespassing and could be subject to prosecution.

(5) During times when the Installation Commander activates any portion(s) of the temporary restricted area defined in paragraph (a) of this section all entry, transit, drifting, anchoring or attaching any object to the submerged sea-bottom within the activated portion(s) of the restricted area is not allowed without the written permission of the Installation Commander, Tyndall AFB, Florida or his/her authorized representative. Previously affixed mooring balls established to support watercraft during intense weather conditions (*i.e.*, tropical storms, hurricanes, etc.) may remain within the activated portion(s) of the restricted area, however watercraft should not be anchored to the mooring balls without the permission of the Installation Commander, Tyndall AFB, Florida or his/her authorized representative.

(c) *Enforcement.* The regulations in this section shall be enforced by the Installation Commander, Tyndall AFB and/or such persons or agencies as he/she may designate.

Dated: September 4, 2015.

Edward E. Belk, Jr.,

Chief, Operations and Regulatory Division, Directorate of Civil Works.

[FR Doc. 2015–23030 Filed 9–11–15; 8:45 am]

BILLING CODE 3710–58–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[EPA–R08–OAR–2015–0493; FRL–9933–90–Region 8]

Approval and Promulgation of Air Quality Implementation Plans; Colorado; Revisions to Common Provisions and Regulation Number 3; Correction

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) is proposing approval of State Implementation Plan (SIP) revisions submitted by the State of Colorado on March 31, 2010, May 16, 2012, and May 13, 2013. The revisions are to Colorado Air Quality Control Commission (Commission) Regulation Number 3, Parts A, B, and D and Common Provisions Regulation. The revisions include administrative changes to permitting requirements for stationary sources, updates to the fine particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) implementation rules related to the federal New Source Review (NSR) Program, changes to address previous revisions to Air Pollutant Emission Notice (APEN) regulations that EPA disapproved or provided comments on, revisions to definitions, and minor editorial changes. Also in this action, EPA is proposing to correct a final rule pertaining to Colorado's SIP published on April 24, 2014. In our April 24, 2014 action, regulatory text and corresponding "incorporation by reference" (IBR) materials were inadvertently excluded for (1) greenhouse gas permitting revisions to the Common Provisions Regulation, and (2) minor editorial changes to the Common Provisions Regulation and Parts A, B, and D of Regulation Number 3 (adopted October 10, 2010). This action is being taken under section 110 of the Clean Air Act (CAA).

DATES: Written comments must be received on or before October 14, 2015.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–R08–OAR–2015–0493, by one of the following methods:

- *http://www.regulations.gov.* Follow the on-line instructions for submitting comments.
- *Email: dobrahner.jaslyn@epa.gov.*
- *Fax:* (303) 312–6064 (please alert the individual listed in the **FOR FURTHER INFORMATION CONTACT** if you are faxing comments).
- *Mail:* Director, Air Program, Environmental Protection Agency (EPA), Region 8, Mail Code 8P–AR, 1595 Wynkoop Street, Denver, Colorado 80202–1129.
- *Hand Delivery:* Director, Air Program, Environmental Protection Agency (EPA), Region 8, Mail Code 8P–AR, 1595 Wynkoop Street, Denver, Colorado 80202–1129. Such deliveries are only accepted Monday through Friday, 8:00 a.m. to 4:30 p.m., excluding federal holidays. Special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Docket ID No. EPA–R08–OAR–2015–0493. EPA's policy is that all comments received will be included in the public docket without change and may be made available online at *www.regulations.gov,* including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through *www.regulations.gov* or email. The *www.regulations.gov* Web site is an "anonymous access" system, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to EPA, without going through *www.regulations.gov* your email address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment.

Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. For additional information about EPA's public docket visit the EPA Docket Center homepage at *http://www.epa.gov/epahome/dockets.htm.* For additional instructions on submitting comments, go to section I, General Information, of the **SUPPLEMENTARY INFORMATION** section of this document.

Docket: All documents in the docket are listed in the *www.regulations.gov* index. Although listed in the index, some information is not publicly available, *e.g.,* CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available only in hard copy. Publicly available docket materials are available either electronically in *www.regulations.gov* or in hard copy at the Air Program, Environmental Protection Agency (EPA), Region 8, 1595 Wynkoop Street, Denver, Colorado 80202–1129. EPA requests that if at all possible, you contact the individual listed in the **FOR FURTHER INFORMATION CONTACT** section to view the hard copy of the docket. You may view the hard copy of the docket Monday through Friday, 8:00 a.m. to 4:00 p.m., excluding federal holidays.

FOR FURTHER INFORMATION CONTACT: Jaslyn Dobrahner, Air Program, U.S. Environmental Protection Agency (EPA), Region 8, Mail Code 8P–AR, 1595 Wynkoop Street, Denver, Colorado 80202–1129, (303) 312–6252, *dobrahner.jaslyn@epa.gov.*

SUPPLEMENTARY INFORMATION:

I. General Information

What should I consider as I prepare my comments for EPA?

1. *Submitting Confidential Business Information (CBI).* Do not submit CBI to EPA through *http://www.regulations.gov* or email. Clearly mark the part or all of the information that you claim to be CBI. For CBI information on a disk or CD ROM that you mail to EPA, mark the outside of the disk or CD ROM as CBI and then identify electronically within the disk or CD ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 CFR part 2.

2. *Tips for preparing your comments.* When submitting comments, remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, **Federal Register**, date, and page number);
- Follow directions and organize your comments;
- Explain why you agree or disagree;
- Suggest alternatives and substitute language for your requested changes;
- Describe any assumptions and provide any technical information and/or data that you used;
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced;
- Provide specific examples to illustrate your concerns, and suggest alternatives;
- Explain your views as clearly as possible, avoiding the use of profanity or personal threats; and
- Make sure to submit your comments by the comment period deadline identified.

II. Background

A. On March 31, 2010 the State of Colorado submitted a SIP revision containing amendments to the Common Provisions Regulation sections I.A., I.B., I.C., I.D., I.E., I.F., I.G., II.B., II.C., II.E., II.H. and II.J. The amendments update the definition of "negligibly reactive volatile organic compound," add clarification to the definition of "volatile organic compound," and make minor editorial changes. The Commission adopted the amendments on December 17, 2009 (effective January 30, 2010).

B. On May 16, 2012 the State submitted a SIP revision containing amendments to Regulation Number 3, Parts A, B and D. The amendments modify the permitting requirements for stationary sources in Colorado by: (1) Incorporating into state regulations changes to the federal NSR Program related to the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS); (2) revising state regulations to address past rule revisions that were disapproved or commented on by EPA; (3) deferring permitting requirements for biogenic sources of carbon dioxide emissions to ensure consistency with federal greenhouse gas permitting requirements; and (4) making miscellaneous revisions and minor editorial changes. The Commission adopted the amendments on October 20, 2011 (effective December 15, 2011).

C. On May 13, 2013 Colorado submitted a SIP revision containing amendments to Regulation Number 3, Parts A, B and D. The amendments make administrative revisions to the permitting requirements for stationary sources in Colorado and make minor editorial changes. The Commission adopted the amendments on December 20, 2012 (effective February 15, 2013).

D. On April 24, 2014 EPA published a final rule (79 FR 22772) in the **Federal Register** approving Colorado's May 25, 2011 SIP revisions to the Common Provisions Regulation related to greenhouse gas and minor editorial changes to the Common Provisions Regulation and Regulation Number 3 Parts A, B and D (adopted October 10, 2010). This action includes regulatory text and IBR material intended to be a part of EPA's April 24, 2014 final rule but inadvertently excluded.

III. EPA's Review of the State of Colorado's March 31, 2010; May 16, 2012; and May 13, 2013 Submittals, and Regulatory Text/IBR Correction

We evaluated Colorado's March 31, 2010, May 16, 2012 and May 13, 2013 submittals regarding revisions to the State's Common Provisions Regulation and Regulation Number 3, Parts A, B and D. We propose to approve some of the revisions and not act on others.

A. March 31, 2010 SIP Submittal

The State's March 31, 2010 SIP submittal contained amendments to the Common Provisions Regulation and includes the following types of amendments to the State's air quality rules: Adding compounds to the definition of "negligibly reactive volatile compounds" (NRVOC) and clarifying NRVOC and volatile organic compound (VOC) testing methodologies within the definition of "volatile organic compound." In addition, the State subsequently requested [1] a revision to the definition of "incinerator." The revisions also make minor editorial changes.

EPA's policy is that compounds of carbon with a negligible level of reactivity need not be regulated to reduce ozone (42 FR 35314). EPA determines whether a given carbon compound has "negligible" reactivity by comparing the compound's reactivity to the reactivity of ethane. EPA lists these compounds in its regulations at 40 CFR 51.100(s), and excludes them from the definition of a "VOC." The chemicals on this list are often called "negligibly reactive." EPA may periodically revise the list of negligibly reactive volatile compounds or NRVOCs to add or delete compounds from the list. In its March

[1] Refer to docket #EPA–R08–OAR–2015–0493 for documentation.

31, 2010 submission, the State adds the following compounds: "(1)1, 1, 1, 2, 2, 3, 4, 5, 5, 5, -decafluoro-3-methoxy-4-trifluoromethyl-pentane" [2]; "Propylene carbonate"; and "Dimethyl carbonate," as well as the common names or chemical structure: "n-$C_3F_7OCH_3$, HFE–7000"; "HFE–7500"; "HFC 227ea"; "$HCOOCH_3$"; and "HFE–7300" to the list of NRVOCs. Subsequent to the March 31, 2010 submission, the State also requested [3] to add "1, 1, 1, 2, 2, 3, 3, -heptafluoro-3-methoxy-propane"; "3-ethoxy-1, 1, 1, 2, 3, 4, 4, 5, 5, 6, 6, 6-dodecafluoro-2(trifluoromethyl)hexane"; "1, 1, 1, 2, 3, 3, 3-heptafluoropropane"; and "Methyl formate" to the list of NRVOCs [4] in section I.G. EPA is proposing to approve these additions to the State's Common Provisions Regulation list of NRVOCs per our earlier actions (72 FR 2193; 74 FR 3437; 78 FR 9823) updating EPA's listing of organic compounds determined to have negligible photochemical reactivity at 40 CFR 51.100(s)(1).

The March 31, 2010 revision to the Common Provisions Regulation also revises the definition of "VOC" to include test methods specified in the State's SIP, a Title V Permit, 40 CFR part 51, subpart I or appendix S, and 40 CFR part 52. In accordance with 40 CFR 51.100(s)(2) and (4), EPA proposes to approve revisions to the definition of "VOC" in section I.G. of the Common Provisions Regulation.

In addition to modifying the definitions of NRVOC and VOC, the State also subsequently requested revisions to the definition of "incinerator" in section I.G. The revisions exclude from the definition of "incinerator" devices commonly called Air Curtain Destructors used to burn 100% wood waste, clean lumber, or yard waste generated as a result of projects to reduce the risk of wildfire and not operated at a commercial or industrial facility. The revisions also state that any air curtain destructor (also called air curtain incinerator in the federal rule) subject to 40 CFR part 60 incinerator requirements are also considered incinerators under the State's revised Common Provisions Regulation definition of "incinerator" per EPA's final rule (70 FR 74870) for New Source Performance Standards (NSPS) for new and existing "other" solid waste incineration units. We propose to approve these revisions.

The March 2010 submittal also makes minor editorial revisions to the Common Provisions Regulation. We are proposing to approve the minor editorial revisions in sections I.A., I.B., I.C., I.D., I.E., I.F., I.G., II.B., II.C., II.E.2. and II.H as shown in Table 1. We are not acting on the minor editorial revisions in II.J. as they are either already in the approved SIP or in sections that EPA previously disapproved (Table 2). Also, we note that the March 31, 2010 submittal is missing a quotation mark in Section I.B. and contains the incorrect abbreviation for "microgram" in Section I.F. The State is aware of these errors and will make the necessary corrections in a future submittal.[5]

Finally, the March 31, 2010 submission contains text not currently in the Common Provisions section of the SIP yet also not identified by the State as a revision. This text includes the addition of "Tertiary Butyl Acetate (2-Butanone)" to the list of NRVOCs in section I.G. as well as the last sentence in the definition of "VOC" regarding tertiary butyl acetate as a VOC for the purposes of photochemical dispersion monitoring. On November 29, 2004 (69 FR 69298), EPA revised its definition of VOC to exclude tertiary butyl acetate for purposes of VOC emissions limitations or VOC content requirements; however, tertiary butyl acetate continues to be a VOC for purposes of all recordkeeping, emissions reporting, and inventory purposes as reflected in 40 CFR 51.100(s)(1) and (s)(5). Therefore, EPA is not including these State additions with our proposed approval of IBR material.

B. May 16, 2012 SIP Submittal

The State's May 16, 2012 SIP submittal includes the following types of amendments to Regulation Number 3, Parts A, B and D: Revisions to State permitting requirements for stationary sources to incorporate changes to the federal NSR Program related to $PM_{2.5}$; revisions to address past rule revisions that were disapproved or commented on by EPA; and deferral of the permitting requirements for biogenic sources of carbon dioxide emissions to ensure consistency with federal greenhouse gas permitting requirements. The revisions also make several miscellaneous changes along with minor editorial changes.

The May 16, 2012 submittal incorporates into Regulation Number 3, Parts A, B and D changes to the federal NSR Program related to the $PM_{2.5}$ NAAQS. Specifically, the State revised the definition of "criteria pollutants" to address $PM_{2.5}$ precursors in Part A (I.B.17.) and revised the definition of "significant" to address $PM_{2.5}$ in Part D (II.A.42.). We are proposing to approve both of these revisions to definitions to address $PM_{2.5}$. In addition, the State incorporated portions of 40 CFR 51.165(a)(9)(i)–(iv) into the State's Requirements Applicable to Nonattainment Areas for Major Sources in Part D of Regulation Number 3 . (V.A.3.). This section describes the emissions offsets and emissions offset ratios required prior to the date of commencement of operations. We are proposing to approve this revision. We are also proposing to approve the State's revision to the Table of Significance Levels for nonattainment areas in section VI.D.2. of Part D to address $PM_{2.5}$. Finally, the State added $PM_{2.5}$ increments to their ambient air increments in section X.A.1. of Part D and added $PM_{2.5}$ increments to their Class I variances maximum allowable increases in section XIII.D. of Part D. These revisions align with 40 CFR 52.21(b)(58)(c) and 52.21(p)(5), respectively, and we therefore propose to approve these revisions.

The State also revised the definition of "Subject to Regulation" in Part A of Regulation Number 3 in their May 16, 2012 submittal. In section I.B.44.b.(i) the State added language to instruct how to compute greenhouse gas emissions to exclude carbon dioxide emissions resulting from the combustion or decomposition of non-fossilized and biodegradable organic material originating from plants, animals, or micro-organisms. This addition is consistent with EPA's biogenic deferral regulation found at 40 CFR 52.21(b)(49)(a)(ii); therefore, we are proposing to approve the revision.

The May 16, 2012 submission also makes revisions to Regulation Number 3, Part B based on EPA's comments on previous actions (76 FR 6331; 79 FR 8632). These revisions include reverting back to previously approved SIP exemption language for stationary internal combustion engines that have uncontrolled actual emissions of less than five tons per year for construction permit requirements (II.D.1.c.) [6] and clarifying exemptions associated with oil and gas produced wastewater

[2] In 78 FR 9823, EPA amended its definition of VOC at 40 CFR 51.100(s) to make for clarity technical corrections to the current list of exempt compounds at 40 CFR 51.100(s)(1) by removing the erroneous "(1)" notation in "(1) 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-trifluoromethyl-pentane (HFE–7300)" so that it reads "1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-trifluoromethyl-pentane (HFE–7300)."

[3] Refer to docket #EPA–R08–OAR–2015–0493 for documentation.

[4] Refer to docket #EPA–R08–OAR–2015–0493 for documentation.

[5] Refer to docket #EPA–R08–OAR–2015–0493 for documentation.

[6] EPA inadvertently approved a previous version in 79 FR 8632.

impoundments (II.D.1.m). We are proposing to approve these revisions.

Within section VI.B.3. of Part D of the May 16, 2012 submittal, the State revised the PM_{10} surrogate policy for $PM_{2.5}$ based on EPA's previous conclusions that $PM_{2.5}$ implementation issues had been resolved to a degree sufficient for all federal Prevention of Significant Deterioration (PSD) permit reviews to begin direct $PM_{2.5}$ based assessments as of July 15, 2008. In a letter[7] dated January 13, 2011 the State clarified their position on the use of PM_{10} as a surrogate for $PM_{2.5}$ ". . . (CDPHE) now commits to implement $PM_{2.5}$ standards consistent with EPA's latest interpretation of federal case law relevant to the use of the PM_{10} Surrogate Policy . . ." We are proposing to approve this revision, and in doing so, note that as announced in our May 2008 rulemaking to implement preconstruction review provisions for the 1997 $PM_{2.5}$ NAAQS in both attainment and nonattainment areas (73 FR 28321), the 1997 PM_{10} Surrogate Policy ended on May 16, 2011 and can no longer be used for any pending or future State PSD permits.

Also regarding the May 16, 2012 submittal, we are proposing to take no action on several of the State's revisions related to $PM_{2.5}$ implementation in Part D of Regulation Number 3, including section II.A.26.d. describing net emissions increases for $PM_{2.5}$, the introductory paragraph of VI.A.2. and VI.A.2.c. that provide impact levels for $PM_{2.5}$, and VI.B.3.a.(iii) $PM_{2.5}$ monitoring exemption of 4 micrograms/cubic meter over a 24-hour average. We are proposing to not act on these revisions in part due to the January 22, 2013 United States Court of Appeals for the District of Columbia Circuit vacatur of the significant impact levels for $PM_{2.5}$ for attainment areas. Since we are proposing to not take action on the $PM_{2.5}$ monitoring exemption level found at VI.B.3.a.(iii), we also propose to not take action on VI.B.3.d. In absence of a revision to include a $PM_{2.5}$ monitoring exemption level in VI.B.3.a.(iii), $PM_{2.5}$ would be removed from the list of pollutants with monitoring exemption levels contained in VI.B.3.a., therefore exempting $PM_{2.5}$ from monitoring levels completely if we approved VI.B.3.d.

We are also proposing to take no action on several revisions contained in the May 16, 2012 submittal to Definitions in Part D of Regulation Number 3 to address $PM_{2.5}$ in the Baseline Area (II.A.5.a.), Major Source Baseline Date (II.A.23.), Minor Source Baseline Date (II.A.25.) and Regulated NSR Pollutant (II.A.38.) definitions because we already approved these revisions in our September 23, 2013 (78 FR 58186) action. In section II.A.23.c. of Part D, the State also revised the major source baseline date for $PM_{2.5}$ to October 20, 2011. This date is incorrect; the correct major source baseline date for $PM_{2.5}$ is October 20, 2010. In the May 13, 2013 submittal, also part of this action, the State revises the date back to October 20, 2010. The May 13, 2013 submittal supersedes the May 16, 2012 submittal; however, since the current approved SIP already contains the correct date, we are proposing to take no action on either revision.

Additionally, the May 16, 2012 submission addresses EPA's final action on October 3, 2011 (76 FR 61054) partially approving and partially disapproving Colorado's SIP revisions in Regulation Number 3, Part A to Air Pollutant Emission Notice (APEN) and permitting exemptions submitted to EPA in September 1997, June 2003, July 2005, August 2006, and August 2007. In the October 3, 2011 action, EPA partially disapproved APEN exemptions for open burning,[8] mobile sources, stationary internal combustion engines, emergency generators, deaerator/vacuum pump exhaust, and air curtain destructors. In today's action, we are proposing to approve revisions to the open burning APEN requirements (II.D.1.q.) in Regulation Number 3, Part A changing the reference regulation from "9," which is not part of Colorado's SIP, to "1," which is part of Colorado's SIP and clarifying the mobile source APEN (II.D.1.ppp.). Additionally, we are proposing to approve revisions made to the surface water impoundment APEN exemption (II.D.1.uuu.) to include gas production wastewater in addition to oil production wastewater. We are proposing no action on the State's removal of APENs related to stationary internal combustion engines (II.D.1.sss.), emergency power generators (II.D.1.ttt.), deaerator/vacuum pump exhaust (II.D.1.xxx.), and air curtain destructors (II.D.1.ffff.) as these provisions were not approved into the SIP. Finally, we are proposing no action on revisions to identify sections I.B.31.c,[9] and I.B.31.d. as "State-only Requirements" since these are also not part of the SIP.

Finally, the May 16, 2012 submission contains miscellaneous revisions to Parts A, B and D of Regulation Number 3. In Part A, the State clarified the significance level for VOC and NO_X for APEN reporting purposes (II.C.2.b.(ii)). In Part B, section III.G.1., the State changed the timing an applicant must provide notice to the State upon commencement of operation of a source from 30 days prior to startup to 15 days following startup. This revision aligns with 40 CFR 60.7(a)(3) Standards of Performance for New Stationary Sources, Notification and Record Keeping. In Part D, revisions include a correction[10] to move the creditable emissions documentation from II.A.26.d. to II.A.26.c.(iii), remove "total suspended particulate matter" and add NO_X as a precursor to ozone for consistency with federal significant monitoring concentrations requirements in VI.B.3.a.(iii) and VI.B.3.c., respectively. We propose to approve these revisions in addition to minor editorial changes found throughout Parts A, B and D of Regulation Number 3 with exceptions noted in Table 2 because the revisions the State is requesting are already in the SIP.

C. May 13, 2013 SIP Submittal

The State's May 13, 2013 SIP submittal contains amendments to Regulation Number 3 Parts A, B and D and includes administrative revisions to permitting requirements for stationary sources in Colorado and minor editorial changes. The State also updated where materials incorporated by reference are available for public inspection by adding an online web address and deleting reference to the State Publications Depository and Distribution Center in section I.A.

Revisions to section VI.B.5. in Part A of the May 13, 2013 submittal allow the State to issue construction permits prior to receipt of permit processing fees and provide for the option to revoke the permit or assess late fees if such fees are not paid within 90 days of the written request for fees. The purpose of the revisions are to allow applicants to commence construction during the invoicing and payment process; the revisions will not negatively impact permit applicants who pay their permit processing fees on time. A revision to section III.C.1.a. in Part B of the May 13, 2013 submittal clarifies the inclusion of sources in attainment/maintenance areas in the determination of sources

[7] Refer to *January 2011 letter from state_Colorado's Position on the Use of PM_{10} as a Surrogate for $PM_{2.5}$, Relevant to Both the $PM_{2.5}$ Implementation Rules and Interstate Transport* in docket #EPA–R08–OAR–2015–0493 for documentation.

[8] EPA inadvertently approved a previous version in 79 FR 8632.

[9] EPA inadvertently approved a previous version in 79 FR 8632.

[10] Refer to docket #EPA–R08–OAR–2015–0493 for documentation.

subject to public comment. Finally, revisions to Part D of the May 13, 2013 submittal include deleting language EPA previously disapproved (79 FR 8632) in the introductory text for Major Modifications in section II.A.22.[11] and Representative Actual Annual Emissions sections II.A.40.5 and II.A.40.5(a) as well as deleting the associated II.A.40.5(b).[12]

EPA is proposing to approve the revisions in the May 13, 2013 submittal to Parts A, B and D of Regulation Number 3 as well as the minor editorial changes contained throughout, except for sections II.A.22., II.A.40.5 (introductory paragraph), and II.A.40.5(a) in Part D because these are not in the current SIP and the other exceptions noted in Table 2. We are not acting on some of the provisions as listed in Table 2, because they are State-only provisions or because they are not applicable to the current SIP.

Proposed Correction

In our final rule published in the **Federal Register** on April 24, 2014 (79 FR 22772) we inadvertently did not include regulatory text and corresponding IBR materials for our approvals to (1) greenhouse gas permitting revisions to Common Provisions Regulation, and (2) minor editorial changes to the Common Provisions Regulation and Parts A, B and D of Regulation Number 3 (adopted October 10, 2010). EPA is proposing to correct this error with today's action. The IBR material for our April 24, 2014 action is contained within this docket.

IV. What action is EPA taking?

For the reasons expressed above, EPA is proposing to approve revisions to sections I.A., I.B., I.C., I.D., I.E., I.F., I.G., II.B., II.C., II.E.2. and II.H of the State's Common Provisions Regulation from the March 31, 2010 submittal as shown in Table 1 below. We also propose to approve revisions to Parts A, B and D of the State's Regulation Number 3 from the May 16, 2012 and May 13, 2013 submittals (Table 1), except for those revisions we are not taking action on as represented in Table 2 below. Finally, EPA proposes to correct regulatory text and IBR published in the **Federal Register** on April 24, 2014 (79 FR 22772).

A comprehensive summary of the revisions in Colorado's Common Provisions Regulation and Regulation Number 3 Parts A, B and D organized by EPA's proposed rule action, reason for proposed "no action" and submittal date are provided in Table 1 and Table 2 below.

TABLE 1—LIST OF COLORADO REVISIONS THAT EPA IS PROPOSING TO APPROVE

Revised Sections in March 31, 2010; May 16, 2012; and May 13, 2013 Submissions Proposed for Approval
March 31, 2010 submittal—Common Provisions Regulation: I.A., I.B., I.C., I.D., I.E., I.F., I.G., II.B., II.C., II.E.2., II.H.
May 16, 2012 submittal—Regulation Number 3, Part A: I.B.17., I.B.28.c., I.B.44.b.(i), I.B.44.e.(ii)(B), II.C.2.b.(ii), II.D.1.q., II.D.1.ppp., II.D.1.uuu., II.D.1.dddd.
May 13, 2013 submittal—Regulation Number 3, Part A: I.A., I.B.7., I.B.28., I.B.43., II.D.1., II.D.1.dddd., V.I.2., VI.B.5., Appendix B.
May 16, 2012 submittal—Regulation Number 3, Part B: II.D.1.c., II.D.1.m., III.G.1.
May 13, 2013 submittal—Regulation Number 3, Part B: III.C.1.a.
May 16, 2012 submittal—Regulation Number 3, Part D: II.A.24.f., II.A.26.c., II.A.26.e.–II.A.26.k. (re-numbering), II.A.42., III.B., V.A., V.A.3., V.A.4., VI.A.2.a., VI.A.4., VI.B.3.a.(ii) and (iv)–(ix), VI.B.3.a.(iii) in reference to removal of total suspended particulate matter monitoring exemption, VI.B.3.c., VI.B.3.e., VI.D.2., X.A.1., X.A.2., XIII.B., XIII.D.
May 13, 2013 submittal—Regulation Number 3, Part D: I.B.2., I.B.4., I.C., II.A.4.c., II.A.17., II.A.22.d.(ix)(B), II.A.40.5.(b)., V.A.3.b., V.A.6., VI.B.3.d., VI.B.3.e.

TABLE 2—LIST OF COLORADO REVISIONS THAT EPA IS PROPOSING TO TAKE NO ACTION ON

[Revised sections in March 31, 2010; May 16, 2012; and May 13, 2013 submissions proposed for no action]

Revised Section	Reason for Proposed "No Action"				
	Revision in State-only section of SIP	Revision in current section of SIP	Revision in disapproved section of SIP	Revision superseded by revision in February 20, 2015 State submittal (will be reconciled in future rulemaking)	Revision to be made in future State submittal
March 31, 2010 submittal—Common Provisions Regulation:					
II.J.		X	X		
May 16, 2012 submittal—Regulation Number 3, Part A:					
I.B.31.c.	X				
I.B.31.d.	X				
II.D.1.sss.			X		
II.D.1.ttt.			X		

[11] EPA inadvertently approved this language in 79 FR 22772.

[12] Refer to docket #EPA–R08–OAR–2015–0493 for additional documentation.

TABLE 2—LIST OF COLORADO REVISIONS THAT EPA IS PROPOSING TO TAKE NO ACTION ON—Continued

[Revised sections in March 31, 2010; May 16, 2012; and May 13, 2013 submissions proposed for no action]

Revised Section	Reason for Proposed "No Action"				
	Revision in State-only section of SIP	Revision in current section of SIP	Revision in disapproved section of SIP	Revision superseded by revision in February 20, 2015 State submittal (will be reconciled in future rulemaking)	Revision to be made in future State submittal
II.D.1.xxx.			X		
II.D.1.ffff.			X		
May 13, 2013 submittal—Regulation Number 3, Part A:					
I.B.31.d.	X				
May 16, 2012 submittal—Regulation Number 3, Part D:					
II.A.5.a.		X			
II.A.5.b.		X			
II.A.23.		X			
II.A.25.		X			
II.A.26.d. revision to $PM_{2.5}$ net emission increase					X
II.A.38.		X			
VI.A.2. introductory paragraph					X
VI.A.2.c.				X	
VI.B.3.a.(iii) in reference to $PM_{2.5}$ monitoring exemption				X	
VI.B.3.d.				X	
May 13, 2013 submittal—Regulation Number 3, Part D:					
II.A.1.a.			X		
II.A.1.c.			X		
II.A.1.e.			X		
II.A.20.b.			X		
II.A.22.			X		
II.A.23.c.		X			
II.A.26.a.(i)			X		
II.A.26.f.iii.			X		
II.A.38.g.			X		
II.A.40.5. introductory paragraph			X		
II.A.40.5.(a)			X		
VI.A.1.c.			X		

V. Incorporation by Reference

In this rulemaking, the EPA is proposing to include in a final EPA rule regulatory text that includes incorporation by reference. In accordance with requirements of 1 CFR 51.5, the EPA is proposing to incorporate by reference Colorado Air Quality Control Commission regulations discussed in section III, *EPA's Review of the State of Colorado's March 31, 2010; May 16, 2012; and May 13, 2013 Submittals, and Regulatory Text/IBR Correction* of this preamble. The EPA has made, and will continue to make, these documents generally available electronically through *www.regulations.gov* and/or in hard copy at the appropriate EPA office (see the **ADDRESSES** section of this preamble for more information).

VI. Statutory and Executive Orders Review

Under the CAA, the Administrator is required to approve a SIP submission that complies with the provisions of the Act and applicable federal regulations (42 U.S.C. 7410(k), 40 CFR 52.02(a)). Thus, in reviewing SIP submissions, EPA's role is to approve state choices, provided that they meet the criteria of the CAA. Accordingly, this proposed action merely approves some state law as meeting federal requirements; this proposed action does not impose additional requirements beyond those imposed by state law. For that reason, this proposed action:

- Is not a "significant regulatory action" subject to review by the Office of Management and Budget under Executive Order 12866 (58 FR 51735, October 4, 1993);
- Does not impose an information collection burden under the provisions of the Paperwork Reduction Act (44 U.S.C. 3501 *et seq.*);
- Is certified as not having a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*);
- Does not contain any unfunded mandate or significantly or uniquely affect small governments, as described in the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4);
- Does not have federalism implications as specified in Executive Order 13132 (64 FR 43255, August 10, 1999);
- Is not an economically significant regulatory action based on health or safety risks subject to Executive Order 13045 (62 FR 19885, April 23, 1997);
- Is not a significant regulatory action subject to Executive Order 13211 (66 FR 28355, May 22, 2001);
- Is not subject to requirements of section 12(d) of the National

Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note) because application of those requirements would be inconsistent with the CAA; and,

• Does not provide EPA with the discretionary authority to address, as appropriate, disproportionate human health or environmental effects, using practicable and legally permissible methods, under Executive Order 12898 (59 FR 7629, February 16, 1994).

The SIP is not approved to apply on any Indian reservation land or in any other area where EPA or an Indian tribe has demonstrated that a tribe has jurisdiction. In those areas of Indian country, the rule does not have tribal implications and will not impose substantial direct costs on tribal governments or preempt tribal law as specified by Executive Order 13175 (65 FR 67249, November 9, 2000).

List of Subjects in 40 CFR Part 52

Environmental protection, Air pollution control, Carbon monoxide, Incorporation by reference, Intergovernmental relations, Greenhouse gases, Lead, Nitrogen dioxide, Ozone, Particulate matter, Reporting and recordkeeping requirements, Sulfur oxides, Volatile organic compounds.

Authority: 42 U.S.C. 7401 *et seq*

Dated: September 1, 2015.

Debra H. Thomas,

Acting Regional Administrator, Region 8.

[FR Doc. 2015–23075 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 70

[Regional Docket No. II–2012–01; FRL–9933–81–Region 2]

Petition for Objection to State Operating Permit; NY; Seneca Energy II, LLC

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of final action.

SUMMARY: Pursuant to Clean Air Act (CAA) Section 505(b)(2) and 40 CFR 70.8(d), the Environmental Protection Agency (EPA) Administrator signed an Order, dated June 29, 2015, granting in part and denying in part a petition filed by Gary A. Abraham on behalf of Finger Lakes Zero Waste Coalition, Inc. (dated December 22, 2012) asking the EPA to object to the Title V operating permit (Permit No. 8–3244–00040/00002) issued by the New York State Department of Environmental Conservation (DEC) to Seneca Energy II, LLC (Seneca) relating to the Ontario County Landfill Gas-to-Energy Facility (Facility) in western New York. Sections 307(b) and 505(b)(2) of the CAA provide that the petitioner may ask for judicial review by the United States Court of Appeals for the appropriate circuit of those portions of the Order that deny objections raised in the petition.

DATES: Any such petition for review of this Order must be received by November 13, 2015 pursuant to section 307(b) of the CAA.

ADDRESSES: You may review copies of the final Order, the petitions, and other supporting information during normal business hours at EPA Region 2, 290 Broadway, New York, New York. If you wish to examine these documents, you should make an appointment at least 24 hours before the visiting day. Additionally, the final Order is available electronically at: *http://www.epa.gov/region7/air/title5/petitiondb/petitions/seneca_response2012.pdf.*

FOR FURTHER INFORMATION CONTACT: Steven Riva, Chief, Permitting Section, Air Programs Branch, Clean Air and Sustainability Division, EPA, Region 2, 290 Broadway, 25th Floor, New York, New York 10007, telephone (212) 637–4074, email address: *Riva.Steven@epa.gov,* or the above EPA Region 2 address.

SUPPLEMENTARY INFORMATION: The CAA affords the EPA a 45-day period to review, and object to, as appropriate, a title V operating permit proposed by a state permitting authority. Section 505(b)(2) of the CAA authorizes any person to petition the EPA Administrator, within 60 days after the expiration of this review period, to object to a Title V operating permit if the EPA has not done so. Petitions must be based only on objections to the permit that were raised with reasonable specificity during the public comment period provided by the state, unless the petitioner demonstrates that it was impracticable to raise these issues during the comment period or that the grounds for the objection or other issues arose after this period. The claims are described in detail in Section IV of the Order. In summary, the issues raised are that: (1) The Title V permit does not consider the Ontario County Landfill (Landfill) and the Facility a single source even though they together meet the 3-factor source determination test; and (2) the Facility's Title V permit is a "sham permit." The EPA's rationale for partially granting and partially denying the claims raised in the petition are described in the Order.

Dated: August 26, 2015.

Catherine McCabe,

Deputy Regional Administrator.

[FR Doc. 2015–23076 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

[FRL–9933–86–OAR]

40 CFR Part 97

Allocations of Cross-State Air Pollution Rule Allowances From New Unit Set-Asides for 2015 Control Periods

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of data availability (NODA).

SUMMARY: The Environmental Protection Agency (EPA) is providing notice of the availability of preliminary lists of units eligible for allocations of emission allowances under the Cross-State Air Pollution Rule (CSAPR). Under the CSAPR federal implementation plans (FIPs), portions of each covered state's annual emissions budgets for each of the four CSAPR emissions trading programs are reserved for allocation to electricity generating units that commenced commercial operation on or after January 1, 2010 (new units) and certain other units not otherwise obtaining allowance allocations under the FIPs. The quantities of allowances allocated to eligible units from each new unit set-aside (NUSA) under the FIPs are calculated in an annual one- or two-round allocation process. EPA previously completed the first round of NUSA allowance allocations for the 2015 control periods for all four CSAPR trading programs and is now making available preliminary lists of units eligible for allocations in the second round of the NUSA allocation process for the CSAPR NO_X Ozone Season Trading Program. EPA has posted a spreadsheet containing the preliminary lists on EPA's Web site. EPA will consider timely objections to the lists of eligible units contained in the spreadsheet and will promulgate a document responding to any such objections no later than November 15, 2015, the deadline for recording the second-round allocations of CSAPR NO_X Ozone Season allowances in sources' Allowance Management System accounts. This notice of availability may concern CSAPR-affected units in the following states: Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky,

Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

DATES: Objections to the information referenced in this notice of availability must be received on or before October 14, 2015.

ADDRESSES: Submit your objections via email to *CSAPR_NUSA@epa.gov.* Include "2015 NUSA allocations" in the email subject line and include your name, title, affiliation, address, phone number, and email address in the body of the email.

FOR FURTHER INFORMATION CONTACT: Questions concerning this action should be addressed to Robert Miller at (202) 343–9077 or *miller.robertl@epa.gov* or Kenon Smith at (202) 343–9164 or *smith.kenon@epa.gov.*

SUPPLEMENTARY INFORMATION: Under the CSAPR FIPs, the mechanisms by which initial allocations of emission allowances are determined differ for "existing" and "new" units. For "existing" units—that is, units commencing commercial operation before January 1, 2010—the specific amounts of CSAPR FIP allowance allocations for all control periods have been established through rulemaking. EPA has announced the availability of spreadsheets showing the CSAPR FIP allowance allocations to existing units in previous notices of availability.[1]

"New" units—that is, units commencing commercial operation on or after January 1, 2010—as well as certain older units that would not otherwise obtain FIP allowance allocations do not have pre-established allowance allocations. Instead, the CSAPR FIPs reserve a portion of each state's total annual emissions budget for each CSAPR emissions trading program as a new unit set-aside (NUSA)[2] and establish an annual process for allocating NUSA allowances to eligible units. States with Indian country within their borders have separate Indian country NUSAs. The annual process for allocating allowances from the NUSAs and Indian country NUSAs to eligible units is set forth in the CSAPR regulations at 40 CFR 97.411(b) and 97.412 (NO_X Annual Trading Program), 97.511(b) and 97.512 (NO_X Ozone Season Trading Program), 97.611(b) and 97.612 (SO_2 Group 1 Trading Program), and 97.711(b) and 97.712 (SO_2 Group 2 Trading Program). Each NUSA allowance allocation process involves up to two rounds of allocations to new units followed by the allocation to existing units of any allowances not allocated to new units. EPA provides public notice at certain points in the process.

EPA has already completed the first round of allocations of 2015 NUSA allowances for all four CSAPR trading programs, as announced in notices of availability previously published in the **Federal Register**.[3] The first-round NUSA allocation process was discussed in those previous notices of availability.

In the case of second-round allocations of NUSA allowances, the annual allocations for the CSAPR NO_X Ozone Season Trading Program occur before the annual allocations for the other three CSAPR trading programs because of differences in the emissions reporting and compliance deadlines for the various programs. This notice of availability concerns the second round of NUSA allowance allocations for the CSAPR NO_X Ozone Season Trading Program for the 2015 control period.[4]

The units eligible to receive second-round NUSA allocations for the CSAPR NO_X Ozone Season Trading Program are defined in §§ 97.511(a)(1)(iii) and 97.512(a)(9)(i). Generally, eligible units include any CSAPR-affected unit that commenced commercial operation between May 1 of the year before the control period in question and August 31 of the year of the control period in question. In the case of the 2015 control period, an eligible unit therefore must have commenced commercial operation between May 1, 2014 and August 31, 2015 (inclusive).

The total quantity of allowances to be allocated through the 2015 NUSA allowance allocation process for each state and emissions trading program—in the two rounds of the allocation process combined—is generally the state's 2015 emissions budget less the sum of (1) the total of the 2015 CSAPR FIP allowance allocations to existing units and (2) the amount of the 2015 Indian country NUSA, if any.[5] The amounts of CSAPR NO_X Ozone Season NUSA allowances may be increased in certain circumstances as set forth in § 97.512(a)(2).

Second-round NUSA allocations for a given state, trading program, and control period are made only if the NUSA contains allowances after completion of the first-round allocations.

The amounts of second-round CSAPR NO_X Ozone Season allowance allocations to eligible new units from each NUSA are calculated according to the procedures set forth in § 97.512(a)(9), (10) and (12). Generally, the procedures call for each eligible unit to receive a second-round 2015 NUSA allocation equal to the positive difference, if any, between its emissions during the 2015 NO_X ozone season (*i.e.,* May 1, 2015 through September 30, 2015) as reported under 40 CFR part 75 and any first-round allocation the unit received, unless the total of such allocations to all eligible units would exceed the amount of allowances in the NUSA, in which case the allocations are reduced on a pro-rata basis.

Any allowances remaining in the CSAPR NO_X Ozone Season NUSA for a given state and control period after the second round of NUSA allocations to new units will be allocated to the existing units in the state according to the procedures set forth in § 97.512(a)(10) and (12).

EPA notes that an allocation or lack of allocation of allowances to a given EGU does not constitute a determination that CSAPR does or does not apply to the EGU. EPA also notes that allocations are subject to potential correction if a unit to which NUSA allowances have been allocated for a given control period is not actually an affected unit as of the start of that control period.[6]

The preliminary lists of units eligible for second-round 2015 NUSA allocations of CSAPR NO_X Ozone Season allowances are set forth in an Excel spreadsheet titled "CSAPR_NUSA_2015_NOx_OS_2nd_Round_Prelim_Data" available on EPA's Web site at *http://www.epa.gov/crossstaterule/actions.html.* The spreadsheet contains a separate worksheet for each state covered by that program showing each unit preliminarily identified as eligible for a second-round NUSA allocation.

[1] The latest spreadsheet of CSAPR FIP allowance allocations to existing units, updated in 2014 to reflect changes to CSAPR's implementation schedule but with allocation amounts unchanged since June 2012, is available at *http://www.epa.gov/crossstaterule/actions.html. See* Availability of Data on Allocations of Cross-State Air Pollution Rule Allowances to Existing Electricity Generating Units, 79 FR 71674 (December 3, 2014).

[2] The NUSA amounts range from two percent to eight percent of the respective state budgets. The variation in percentages reflects differences among states in the quantities of emission allowances projected to be required by known new units at the time the budgets were set or amended.

[3] 80 FR 30988 (June 1, 2015); 80 FR 44882 (July 28, 2015).

[4] At this time, EPA is not aware of any unit eligible for a second-round allocation from any Indian country NUSA.

[5] The quantities of allowances to be allocated through the NUSA allowance allocation process may differ slightly from the NUSA amounts set forth in §§ 97.410(a), 97.510(a), 97.610(a), and 97.710(a) because of rounding in the spreadsheet of CSAPR FIP allowance allocations to existing units.

[6] *See* 40 CFR 97.511(c).

Each state worksheet also contains a summary showing (1) the quantity of allowances initially available in that state's 2015 NUSA, (2) the sum of the 2015 NUSA allowance allocations that were made in the first-round to new units in that state (if any), and (3) the quantity of allowances in the 2015 NUSA available for distribution in second-round allocations to new units (or ultimately for allocation to existing units).

Objections should be strictly limited to whether EPA has correctly identified the new units eligible for second-round 2015 NUSA allocations of CSAPR NO_X Ozone Season allowances according to the criteria described above and should be emailed to the address identified in **ADDRESSES.** Objections must include: (1) Precise identification of the specific data the commenter believes are inaccurate, (2) new proposed data upon which the commenter believes EPA should rely instead, and (3) the reasons why EPA should rely on the commenter's proposed data and not the data referenced in this notice of availability.

Authority: 40 CFR 97.511(b).

Reid P. Harvey,

Director, Clean Air Markets Division.

[FR Doc. 2015–22943 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[EPA–HQ–OW–2015–0174; FRL–9932–03–OW]

RIN 2040–AF56

Revision of Certain Federal Water Quality Criteria Applicable to Washington

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) proposes to revise the current federal Clean Water Act (CWA) human health criteria applicable to waters under the state of Washington's jurisdiction to ensure that the criteria are set at levels that will adequately protect Washington residents, including tribes with treaty-protected rights, from exposure to toxic pollutants. EPA promulgated Washington's existing criteria for the protection of human health in 1992 as part of the National Toxics Rule (NTR), (amended in 1999 for Polychlorinated Biphenyls (PCBs)) using the Agency's recommended criteria values at the time. EPA derived those criteria using a fish consumption rate (FCR) of 6.5 grams per day (g/day) based on national surveys. However, the best available data now demonstrate that fish consumers in Washington, including tribes with treaty-protected rights, consume much more fish than 6.5 g/day. There are also new data and scientific information available to update the toxicity and exposure parameters used to calculate human health criteria. Therefore, EPA proposes to revise the federal human health criteria applicable to waters under Washington's jurisdiction to take into account the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, to protect human health.

DATES: Comments must be received on or before November 13, 2015.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–HQ–OW–2015–0174, to the *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or withdrawn. EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.* on the web, cloud, or other file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *http://www2.epa.gov/dockets/commenting-epa-dockets.*

FOR FURTHER INFORMATION CONTACT: Erica Fleisig, Office of Water, Standards and Health Protection Division (4305T), Environmental Protection Agency, 1200 Pennsylvania Avenue NW., Washington, DC 20460; telephone number: (202) 566–1057; email address: *fleisig.erica@epa.gov.*

SUPPLEMENTARY INFORMATION: This proposed rule is organized as follows:

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I. General Information

Does this action apply to me?

Entities such as industries, stormwater management districts, or publicly owned treatment works (POTWs) that discharge pollutants to waters of the United States under the state of Washington's jurisdiction could be indirectly affected by this rulemaking, because federal water quality standards (WQS) promulgated by EPA would be applicable to CWA regulatory programs, such as National Pollutant Discharge Elimination System (NPDES) permitting. Citizens concerned with water quality in Washington could also be interested in this rulemaking. Categories and entities that could potentially be affected include the following:

Category	Examples of potentially affected entities
Industry	Industries discharging pollutants to waters of the United States in Washington.
Municipalities	Publicly owned treatment works or other facilities discharging pollutants to waters of the United States in Washington.
Stormwater Management Districts.	Entities responsible for managing stormwater runoff in the state of Washington.

This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities that could be indirectly affected by this action. Any parties or entities who depend upon or contribute to the water quality of Washington's waters could be affected by this proposed rule. To determine whether your facility or activities could be affected by this action, you should carefully examine this proposed rule. If you have questions regarding the applicability of this action to a particular entity, consult the person listed in the **FOR FURTHER INFORMATION CONTACT** section.

II. Background

A. Statutory and Regulatory Background

CWA section 101(a)(2) establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the CWA. EPA interprets "fishable" uses to include, at a minimum, designated uses providing for the protection of aquatic communities and human health related to consumption of fish and shellfish.[1]

CWA section 303(c) (33 U.S.C. 1313(c)) directs states to adopt WQS for their waters subject to the CWA. CWA section 303(c)(2)(A) and EPA's implementing regulations at 40 CFR part 131 require, among other things, that a state's WQS specify appropriate designated uses of the waters, and water quality criteria that protect those uses. EPA's regulations at 40 CFR 131.11(a)(1) provide that such criteria "must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use." In addition, 40 CFR 131.10(b) provides that "[i]n designating uses of a water body and the appropriate criteria for those uses, the state shall take into consideration the water quality standards of downstream waters and ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."

States are required to review applicable WQS at least once every three years and, if appropriate, revise or adopt new standards (CWA section 303(c)(1)). Any new or revised WQS must be submitted to EPA for review and approval or disapproval (CWA section 303(c)(2)(A) and (c)(3)). CWA section 303(c)(4)(B) authorizes the Administrator to determine, even in the absence of a state submission, that a new or revised standard is needed to meet CWA requirements.

Under CWA section 304(a), EPA periodically publishes criteria recommendations for states to consider when adopting water quality criteria for particular pollutants to meet the CWA section 101(a)(2) goals. In 2015, EPA updated its 304(a) recommended criteria for human health for 94 pollutants.[2] Where EPA has published recommended criteria, states should consider adopting water quality criteria based on EPA's CWA section 304(a) criteria, section 304(a) criteria modified to reflect site-specific conditions, or other scientifically defensible methods (40 CFR 131.11(b)(1)). Ultimately, however, criteria must protect the designated use and be based on sound scientific rationale (40 CFR 131.11(a)(1)). CWA section 303(c)(2)(B) requires states to adopt numeric criteria for all toxic pollutants listed pursuant to CWA section 307(a)(1) for which EPA has published 304(a) criteria, as necessary to support the states' designated uses.

In 1992, EPA promulgated the NTR at 40 CFR 131.36, establishing chemical-specific, numeric criteria for 85 priority toxic pollutants for 14 states and territories (states), including Washington, that were not in compliance with the requirements of CWA section 303(c)(2)(B). When states covered by the NTR subsequently adopted their own criteria for toxic pollutants that EPA approved as consistent with the CWA and EPA's implementing regulations, EPA amended the NTR to remove those states. Half of the original 14 states and territories remain covered for one or more criteria in the NTR. Washington has not yet adopted its own criteria for the protection of human health and, therefore, the Federal human health criteria that EPA promulgated in the NTR remain applicable to waters throughout the state.[3]

B. General Recommended Approach for Deriving Human Health Criteria

Human health criteria are designed to minimize the risk of adverse cancer and non-cancer effects occurring from lifetime exposure to pollutants through the ingestion of drinking water and consumption of fish/shellfish obtained from inland and nearshore waters. EPA's practice is to establish a human health 304(a) criterion for both drinking water and consumption of fish/shellfish from inland and nearshore waters combined and a separate human health criterion based on ingestion of fish/shellfish from inland and nearshore waters alone. This latter criterion applies in cases where the designated uses of a waterbody include supporting fish/shellfish for human consumption but not drinking water supply sources (*e.g.,* in non-potable estuarine waters).

The criteria are based on two types of biological endpoints: (1) Carcinogenicity and (2) systemic toxicity (*i.e.,* all adverse effects other than cancer). EPA takes an integrated approach and considers both cancer and non-cancer effects when deriving human health criteria. Where sufficient data are available, EPA derives criteria using both carcinogenic and non-carcinogenic toxicity endpoints and recommends the lower value. Human health criteria for carcinogenic effects are calculated using the following input parameters: Cancer slope factor, cancer risk level, body weight, drinking water intake rate, fish consumption rate, and a bioaccumulation factor(s). Human health criteria for non-carcinogenic and nonlinear carcinogenic effects are calculated using a reference dose in place of a cancer slope factor and cancer risk level, as well as a relative source contribution (RSC), which is intended to ensure that an individual's total exposure from all sources does not exceed the criteria. Each of these inputs is discussed in more detail below and in

[1] USEPA. 2000. Memorandum #WQSP–00–03. U.S. Environmental Protection Agency, Office of Water, Washington, DC *http://water.epa.gov/scitech/swguidance/standards/upload/2000_10_31_standards_shellfish.pdf.*

[2] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[3] Washington adopted criteria for the protection of aquatic life from toxic pollutants at WAC 173–201A–240. On January 12, 2015, Washington proposed statewide human health criteria and new and revised implementation provisions. In July 2015, Governor Inslee directed Washington to reconsider its proposed human health criteria and implementation tool revisions. See *http://www.ecy.wa.gov/programs/wq/ruledev/wac173201A/1203ov.html.*

EPA's 2000 Human Health Methodology.[4]

a. Cancer Risk Level

EPA's 304(a) national recommended human health criteria generally assume that carcinogenicity is a "non-threshold phenomenon," which means that there are no "safe" or "no-effect" levels because even extremely small doses are assumed to cause a finite increase in the incidence of cancer. Therefore, EPA calculates 304(a) human health criteria for carcinogenic effects as pollutant concentrations corresponding to lifetime increases in the risk of developing cancer.[5] EPA calculates its 304(a) human health criteria values at a 10^{-6} (one in one million) cancer risk level and recommends cancer risk levels of 10^{-6} or 10^{-5} (one in one hundred thousand) for the general population.[6] EPA notes that states and authorized tribes can also choose a more stringent risk level, such as 10^{-7} (one in ten million), when deriving human health criteria.

If the pollutant is not considered to have the potential for causing cancer in humans (*i.e.,* systemic toxicants), EPA assumes that the pollutant has a threshold below which a physiological mechanism exists within living organisms to avoid or overcome the adverse effects of the pollutant.

b. Cancer Slope Factor and Reference Dose

A dose-response assessment is required to understand the quantitative relationships between the amount of exposure to a pollutant and the onset of human health effects. EPA evaluates dose-response relationships derived from animal toxicity and human epidemiological studies to derive dose-response metrics for regulatory purposes. To evaluate carcinogenic effects, the dose-response metric used to characterize a chemical's human cancer-causing potential is referred to as a cancer slope factor (CSF). For non-carcinogenic effects, EPA uses the reference dose (RfD) to calculate human health criteria. Doses that are below the RfD are less likely to be associated with health risks. EPA's Integrated Risk Information System (IRIS)[7] was the primary source of toxicity values (*i.e.,* RfD and CSF) for EPA's 2015 updated 304(a) human health criteria.[8] For some pollutants, however, more recent peer-reviewed and publicly available toxicological data were available from other EPA program offices (*e.g.,* Office of Pesticide Programs, Office of Water, Office of Solid Waste and Emergency Response), other national and international programs, and state programs.

c. Exposure Assumptions

Per EPA's latest 304(a) national human health criteria, EPA uses a default drinking water intake rate of 2.4 liters per day (L/day) and default rate of 22 g/day for consumption of fish and shellfish from inland and nearshore waters, multiplied by pollutant-specific bioaccumulation factors (BAFs) to account for the amount of the pollutant in the edible portions of the ingested species. EPA's methodology for deriving human health criteria emphasizes using, when possible, measured or estimated BAFs, which account for chemical accumulation in aquatic organisms from all potential exposure routes.[9] In the 2015 national 304(a) human health criteria update, EPA primarily used field-measured BAFs and laboratory-measured bioconcentration factors (BCFs) available from peer-reviewed, publicly available databases to develop national BAFs for three trophic levels of fish.[10] If this information was not available, EPA selected octanol-water partition coefficients (K_{ow} values) from peer-reviewed sources for use in calculating national BAFs.

EPA's national default drinking water intake rate of 2.4 L/day represents the per capita estimate of combined direct and indirect community water ingestion at the 90th percentile for adults ages 21 and older.[11] EPA's national FCR of 22 g/day represents the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the U.S. adult population 21 years of age and older, based on National Health and Nutrient Examination Survey (NHANES) data from 2003 to 2010.[12] [13] EPA calculates human health criteria using a default body weight of 80 kilograms (kg), the average weight of a U.S. adult age 21 and older, based on NHANES data from 1999 to 2006.

Although EPA uses these values to calculate national 304(a) recommended criteria, EPA's methodology notes a preference for the use of local data to calculate human health criteria (*e.g.,* locally derived FCRs, drinking water intake rates and body weights, and waterbody-specific bioaccumulation rates) over national default values, to better represent local conditions.[14] EPA also generally recommends, where sufficient data are available, selecting a FCR that reflects consumption that is not suppressed by fish availability or concerns about the safety of available fish.[15] Deriving criteria using an unsuppressed FCR furthers the restoration goals of the CWA, and ensures protection of human health as pollutant levels decrease, fish habitats

[4] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–822–B–00–004. *http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.*

[5] As noted above, EPA recommends the criteria derived for non-carcinogenic effects if it is more protective (lower) than that derived for carcinogenic effects.

[6] EPA's 2000 Human Health Methodology also states: "Criteria based on a 10^{-5} risk level are acceptable for the general population as long as states and authorized tribes ensure that the risk to more highly exposed subgroups (sport fishers or subsistence fishers) does not exceed the 10^{-4} level." Since EPA is proposing criteria to protect the target general population in Washington (tribes with reserved rights in Washington waters), the applicable EPA-recommended cancer risk levels are those for the general population. See section IV for additional discussion.

[7] USEPA. Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. *www.epa.gov/iris.*

[8] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[9] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–822–B–00–004. *http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.*

[10] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[11] USEPA. 2011. EPA Exposure Factors Handbook. 2011 edition (EPA 600/R–090/052F). *http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.*

[12] USEPA. 2014. Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003–2010). United States Environmental Protection Agency, Washington, DC, USA. EPA 820–R–14–002.

[13] EPA's national FCR is based on the total rate of consumption of fish and shellfish from inland and nearshore waters (including fish and shellfish from local, commercial, aquaculture, interstate, and international sources). This is consistent with a principle that each state does its share to protect people who consume fish and shellfish that originate from multiple jurisdictions. USEPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions. http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf.*

[14] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–822–B–00–004. *http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.*

[15] USEPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions. http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/upload/hhfaqs.pdf.*

are restored, and fish availability increases. While EPA encourages doing so in general, where tribal treaty or other reserved fishing rights apply, selecting a FCR that reflects unsuppressed fish consumption could be necessary in order to satisfy such rights. If sufficient data regarding unsuppressed fish consumption levels are unavailable, consultation with tribes is important in deciding which fish consumption data should be used. See section IV.C.a.

d. Relative Source Contribution

When deriving human health criteria for non-carcinogens and nonlinear carcinogens, EPA recommends including a RSC factor to account for sources of exposure other than drinking water and fish and shellfish from inland and nearshore waters, so that the pollutant effect threshold (*i.e.*, RfD) is not apportioned to drinking water and fish consumption alone. These other exposures include exposure to a particular pollutant from ocean fish consumption (which is not included in EPA's default national FCR), non-fish food consumption (*e.g.*, fruits, vegetables, grains, meats, poultry), dermal exposure, and respiratory exposure. EPA's guidance includes a procedure for determining an appropriate RSC for a given pollutant ranging in value from 0.2 to 0.8.

III. Necessity Determination for Washington

A. Existing Criteria Are Not Protective of Designated Uses of Waters in the State of Washington

In the NTR, 40 CFR 131.36(d)(14), EPA stated that the federal human health criteria applied to all waters assigned to Washington's use classifications identified at WAC 173–201–045, including fish and shellfish, fish, water supply (domestic), and recreation. As currently defined in Washington's WQS (WAC 173–201A–600 and WAC 173–201A–610), the uses subject to federal human health criteria in Washington include the following: Fresh waters—Harvesting (fish harvesting), Domestic Water (domestic water supply), and Recreational Uses; Marine waters—Shellfish Harvesting (shellfish—clam, oyster, and mussel—harvesting), Harvesting (salmonid and other fish harvesting, and crustacean and other shellfish—crabs, shrimp, scallops, etc.—harvesting), and Recreational Uses.

Per EPA's regulations at § 131.11(a), water quality criteria must contain sufficient parameters or constituents to protect the designated use, and for waters with multiple use designations, the criteria must support the most sensitive use. In determining whether WQS comply with the CWA and EPA's regulations, when setting criteria to support the most sensitive use in Washington, it is necessary to consider other applicable laws, including federal treaties.[16] In Washington, many tribes hold reserved rights to take fish for subsistence, ceremonial, religious, and commercial purposes, including treaty-reserved rights to fish at all usual and accustomed fishing grounds and stations in waters under state jurisdiction, which cover the majority of waters in the state. Such rights include not only a right to take those fish, but necessarily include an attendant right to not be exposed to unacceptable health risks by consuming those fish.

In 1992, EPA selected input values based on available national data to derive protective human health criteria in the NTR. To ensure protection of human health in waters where fish and shellfish are caught and consumed, EPA used data available at the time on the average per-capita consumption rate of fish from inland and nearshore waters for the U.S. population. This average rate was 6.5 g/day.

Surveys of local residents in the Pacific Northwest, including tribes and recreational anglers, reflect high consumption levels of fish and shellfish—much higher than the 6.5 g/day rate that EPA used in 1992 to derive Washington's human health criteria in the NTR. Since that time, data have become available that better represent regional and local fish consumption in Washington, including:

- *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission (CRITFC), 1994).
- *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region* (Toy et al., 1996).
- *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region* (Suquamish Tribe, 2000).
- *Asian and Pacific Islander Seafood Consumption Study* (Sechena et al., 1999).

The average FCRs[17] from these surveys range from 63 to 214 g/day, far in excess of 6.5 g/day. The 90th percentile FCRs from these surveys range from 113 to 489 g/day, also far in excess of EPA's current national FCR of 22 g/day, which represents the 90th percentile national FCR (see section II.B.c). The 6.5 g/day FCR that EPA used to derive the current human health criteria applicable to Washington does not account for these more recent local data, nor suppression in fish consumption (as discussed earlier).[18] In addition, the 6.5 g/day FCR does not account for EPA's 2000 recommendation to use an upper percentile of fish consumption data for the target general population (as with EPA's current national FCR of 22 g/day) rather than an average. EPA considered the fish consumption data cited above, in conjunction with Washington's current designated uses as informed by tribal reserved rights in Washington (as discussed in section IV.A), and determined that the federal human health criteria in the NTR as applied to Washington no longer protect the relevant designated uses of Washington's waters.

B. CWA 303(c)(4)(B) Determination of Necessity

Because Washington's existing human health criteria, as promulgated by EPA in the NTR, are no longer protective of the applicable designated uses per the CWA and EPA's regulations at 40 CFR 131.11, EPA determines under CWA section 303(c)(4)(B) that new or revised WQS for the protection of human health are necessary to meet the requirements of the CWA for Washington. EPA, therefore, proposes the revised human health criteria for Washington in this rule in accordance with this 303(c)(4)(B) determination. EPA's determination is not itself a final action, nor part of a final action, at this time. After consideration of comments on the

[16] In addition to treaties, executive orders and federal statutes, such as land claim settlement acts, could also apply.

[17] Cited FCRs are based on total fish consumption regardless of source.

[18] Historical or heritage FCRs could be of relevance to establishing unsuppressed FCRs for Washington tribes. Extensively researched historical average FCRs for the Columbia River Basin Tribes range from 401 to 995 g/day (Craig and Hacker (1940) & Hewes (1947); Swindell (1942); Marshall (1977); Walker (1967)). More limited average historic FCRs for Washington Tribes range from 454 to 746 g/day (Hewes 1973). In *United States* v. *Washington* (1974), the court accepted a heritage FCR of 620 g/day. A number of factors could cause these FCRs to be underestimates (Schalk 1986), including the fact that, with the exception of Craig and Hacker (1940), they only include consumption of salmon. Upper percentile values are not reported in these historical studies but would be higher than the reported average values. The highest estimated current FCRs in Washington come from the Suquamish Tribal survey (Suquamish 2000), with a reported FCR as high as 1,600 g/day (Table C5). The 95th percentile Suquamish FCR is 767 g/day (Ecology 2013). Recent publications by Harper and Walker (2015) comprehensively summarize and further support these heritage and contemporary fish consumption rates.

proposed rule, EPA will take final agency action on this rulemaking. It is at that time that any change to the water quality standards applicable to Washington would occur.

IV. Derivation of Human Health Criteria for Washington

A. Tribal Reserved Fishing Rights and Washington's Designated Uses

A majority of waters under Washington's jurisdiction are covered by reserved rights, including tribal treaty-reserved rights (see section III.A). Many areas where reserved rights are exercised cannot be directly protected or regulated by the tribal governments and, therefore, the responsibility falls to the state and federal governments to ensure their protection.[19] In order to effectuate and harmonize these reserved rights, including treaty rights, with the CWA, EPA determined that such rights appropriately must be considered when determining which criteria are necessary to adequately protect Washington's fish and shellfish harvesting designated uses (see sections IV.C.a and IV.C.b).

Protecting Washington's fish and shellfish harvesting designated uses, which include consumption of such fish and shellfish, necessitates protecting the population exercising those uses. Where a population exercising such uses has a legal right to do so, the criteria protecting such uses must be consistent with such right. Thus, EPA proposes to consider the tribal population exercising their reserved fishing rights in Washington as the target general population for the purposes of deriving protective criteria that allow the tribes to harvest and consume fish consistent with their reserved rights.

Although treaties do not cover all waters in Washington, they cover the vast majority of the state's waters. Additionally, where treaty and non-treaty reserved rights apply on waters downstream of waters without reserved fishing rights, upstream WQS must provide for the attainment and maintenance of downstream WQS in accordance with EPA's regulations at 40 CFR 131.10(b). For any remaining waters in Washington where reserved rights do not apply and that are not upstream of waters with such rights or waters in Oregon (see section IV.C.a), it would be administratively burdensome and difficult to implement separate criteria because it would create a patchwork of protection among these areas leading to potential difficulties in administering the WQS, NPDES permitting, and other programs. In addition, delineating the precise boundaries could itself be complicated. Therefore, EPA proposes to apply these criteria to all waters under Washington's jurisdiction.

B. Scope of EPA's Proposal

In 1992, EPA did not establish human health criteria in the NTR for some priority toxic pollutants for reasons articulated in the preamble to the final rule at 57 FR 60848, December 22, 1992. EPA had no 304(a) recommendations for those pollutants at the time. EPA now has 304(a) recommendations for 99 priority toxic pollutants listed pursuant to CWA section 307(a)(1) (85 for which EPA established criteria in the NTR, plus 14 additional pollutants). Therefore, EPA proposes to derive Washington-specific criteria for all 99 priority toxic pollutants in this rule. For those priority pollutants for which EPA does not have 304(a) national recommended criteria, and are thus not included in this proposed rule, EPA expects that Washington will continue to apply their existing narrative toxics criterion in the state's WQS at WAC 173–201A–260(2)(a).

This rule proposes to change the criteria that EPA promulgated for Washington in the NTR and establish new human health criteria for the 14 additional chemicals for which EPA now has 304(a) recommended criteria: Copper, Selenium, Zinc, 1,2-Dichloropropane, 1,2-Trans-Dichloroethylene, 2-Chlorophenol, 2,4-Dimethylphenol, Acenaphthene, Butylbenzyl Phthalate, 2-Chloronaphthalene, N-Nitrosodi-n-Propylamine, 1,1,1-Trichloroethane, 3-Methyl-4-Chlorophenol, and 1,2,4-Trichlorobenzene. Since 1992, EPA replaced its recommended human health criteria for mercury with a fish tissue-based human health criterion for methylmercury. EPA proposes to replace the criteria for mercury that EPA promulgated for Washington in the NTR with a methylmercury fish tissue criterion, adjusted for the FCR that EPA proposes to use to derive human health criteria in Washington.[20] This proposed rule would not change or supersede any criteria that EPA previously promulgated for other states in the NTR, nor does it change any other elements of the NTR such as EPA's original basis for promulgation. EPA proposes to remove Washington from the NTR at 40 CFR 131.36 and incorporate the Washington-specific criteria proposed in this rule into proposed 40 CFR 131.45 so there is a single comprehensive rule for Washington.

This proposed rule would apply to waters under the state of Washington's jurisdiction, and not to waters within Indian Country[21], unless otherwise specified in federal law. Some waters located within Indian Country already have CWA-effective human health criteria, while others do not.[22] Several tribes are working with EPA to either revise their existing CWA-effective WQS, or obtain treatment in a similar manner as a state (TAS) status in order to adopt their own WQS in the near future. EPA will continue to work closely with tribes in Washington to ensure that they adopt human health criteria that are scientifically supported and protective of designated uses, in accordance with the CWA and EPA's regulations.

C. Washington-Specific Human Health Criteria Inputs

a. Fish Consumption Rate

EPA proposes to derive human health criteria for Washington using a FCR of 175 g/day as this FCR accounts for local data (consistent with EPA's methodology), reflects input received during consultation with tribes, and appropriately addresses protection of Oregon's downstream WQS, per EPA's regulations at 40 CFR 131.10(b).

EPA considered the input received during consultation with tribes when selecting which fish consumption data would be used to estimate a FCR for calculating human health criteria to protect the designated uses. A FCR of 175 g/day approximates the 95th percentile consumption rate of surveyed tribal members from the CRITFC study.[23] Although EPA's national default FCR only includes consumption of fish from inland and nearshore waters, 175 g/day in this case includes anadromous fish, which is appropriate given that anadromous species reside in

[19] Note that for formal and informal reservation lands, eligible tribes can obtain treatment in a similar manner as a state (TAS) status and set their own WQS under the CWA, including human health criteria.

[20] USEPA. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–823–R–01–001. *http://water.epa.gov/scitech/swguidance/standards/criteria/health/upload/2009_01_15_criteria_methylmercury_mercury-criterion.pdf.*

[21] *See* 18 U.S.C. 1151 for definition of Indian Country.

[22] Indian Country waters with CWA-effective WQS are (a) those Indian Country waters where EPA explicitly found that a tribe has jurisdiction to adopt WQS under the CWA, and where the tribe adopted standards in accordance with EPA regulations, and (b) where EPA promulgated federal WQS.

[23] *Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission (CRITFC), 1994)

Washington's nearshore waters, especially Puget Sound, and accumulate pollutants discharged to these waters.[24] A FCR of 175 g/day, therefore, accounts for local fish consumption data. Additionally, Oregon, much of which is downstream from Washington, used this FCR to derive statewide human health criteria, which EPA approved in 2011. Use of this FCR to derive Washington's criteria should thus help provide for the attainment and maintenance of downstream WQS in Oregon.

After consideration of the full range of available local fish consumption data and after consultation with Washington tribes and Columbia River Basin tribes in Oregon and Idaho, EPA determined that a FCR of 175 g/day very likely does not reflect unsuppressed consumption rates of tribes within the state (see section II.B.c). EPA considered this fact as well as tribal input in selecting a cancer risk level of 10^{-6} to account for this uncertainty and ensure that EPA's proposed criteria protect Washington's fishing uses, including the tribes' reserved fishing rights. See discussion in section IV.C.b.

b. Cancer Risk Level

Based on Washington's longstanding use of a cancer risk level of 10^{-6}, along with EPA's consideration of tribal reserved rights, EPA guidance, and downstream protection, EPA proposes to derive human health criteria for carcinogens in Washington using a 10^{-6} cancer risk level.

To derive final human health criteria for each state in the NTR, EPA selected a cancer risk level based on each state's policy or practice regarding what risk level should be used when regulating carcinogens in surface waters. In its official comments on EPA's proposed NTR, Washington asked EPA to promulgate human health criteria using a cancer risk level of 10^{-6}, stating, "The State of Washington supports adoption of a risk level of one in one million for carcinogens. If EPA decides to promulgate a risk level below one in one million, the rule should specifically address the issue of multiple contaminants so as to better control overall site risks." (57 FR 60848, December 22, 1992). Accordingly, in the NTR, EPA used a cancer risk level of 10^{-6} (one in one million) to derive human health criteria for Washington. Subsequently, Washington adopted and EPA approved a provision in the state's WQS that reads: "Risk-based criteria for carcinogenic substances shall be selected such that the upper-bound excess cancer risk is less than or equal to one in a million" (WAC 173–201A–240(6)). This provision has been in effect in Washington's WQS since 1993.

In order to effectuate reserved fishing rights, including the rights that federal treaties afford to tribes in Washington, EPA proposes to derive criteria that will protect the tribe's reserved fishing rights in Washington, treating the tribal population exercising those rights as the target general population (see section IV.A). EPA's selection of a 10^{-6} cancer risk level for the tribal target general population is consistent with EPA's 2000 Human Health Methodology, which states that when promulgating water quality criteria for states and tribes, EPA intends to use the 10^{-6} level, which reflects an appropriate risk for the general population.[25] EPA's 2000 Human Health Methodology did not consider how CWA decisions should account for applicable reserved fishing rights, including treaty-reserved rights. As discussed in section IV.C.a, because a FCR of 175 g/day very likely does not reflect unsuppressed consumption, using a cancer risk level of 10^{-6} ensures protection of tribal members' unsuppressed consumption. Independently, the treaties themselves could require higher levels of protection. The treaties themselves could be interpreted to require a certain level of risk; *e.g.*, a *de minimis* level of risk that would most reasonably approximate conditions at the time the treaties were signed and the fishing rights were reserved. In policy development regarding management of cancer risks, EPA often uses 10^{-6} as a *de minimis* risk level.[26] In this case, EPA considers 10^{-6} to be sufficiently protective, and the tribes have supported this during consultation.

Finally, many of Washington's rivers are in the Columbia River basin, upstream of Oregon's portion of the Columbia River. Oregon's criteria are based on a FCR of 175 g/day and a cancer risk level of 10^{-6}. EPA's proposal to derive human health criteria for Washington using a cancer risk level of 10^{-6} along with a FCR of 175 g/day helps ensure that Washington's criteria will provide for the attainment and maintenance of Oregon's downstream WQS as required by 40 CFR 131.10(b).

c. Relative Source Contribution

EPA recommends using a RSC for non-carcinogens and nonlinear carcinogens to account for sources of exposure other than drinking water and consumption of inland and nearshore fish and shellfish (see section II.B.d). In 2015, after evaluating information on chemical uses, properties, occurrences, releases to the environment and regulatory restrictions, EPA developed chemical-specific RSCs for non-carcinogens and nonlinear carcinogens ranging from 0.2 (20 percent) to 0.8 (80 percent) following the Exposure Decision Tree approach described in EPA's 2000 Human Health Methodology.[27] [28] EPA proposes to use these same RSCs to derive human health criteria for Washington. Where EPA did not update the nationally recommended criteria for certain pollutants in 2015, EPA proposes to use a RSC of 0.2 to derive human health criteria for those pollutants in Washington to ensure protectiveness. See Table 1, column B2 for a list of EPA's proposed RSCs by pollutant.

d. Body Weight

EPA proposes to calculate human health criteria for Washington using a body weight of 80 kg, which represents the average weight of a U.S. adult. In 2015, EPA updated its national adult body weight to 80 kg based on national survey data (see section II.B.c).[29] Local

[24] O'Neill, S.M., and J.E. West. 2009. Marine distribution, life history traits, and the accumulation of polychlorinated biphenyls in Chinook salmon from Puget Sound, Washington. Transactions of the American Fisheries Society 138: 616–632.

O'Neill, S.M., G.M. Ylitalo, J.E. West, J. Bolton, C.A. Sloan, and M.M. Krahn. 2006. Regional patterns of persistent organic pollutants in five Pacific salmon species (*Oncorhynchus spp*) and their contributions to contaminant levels in northern and southern resident killer whales (*Orcinus orca*). 2006 Southern Resident Killer Whale Symposium, NOAA Fisheries Service Northwest Regional Office April 3–5, 2006. Seattle, WA. Extended Abstract. 5pp.

[25] EPA 2000 Human Health Methodology, pages 2–6. The Methodology recommends that states set human health criteria cancer risk levels for the target general population at either 10^{-5} or 10^{-6} (pages 2–6) and also notes that states and authorized tribes can always choose a more stringent risk level, such as 10^{-7} (pages 1–12).

[26] *See* Castorina, Rosemary and Tracey J. Woodruff. *Assessment of Potential Risk Levels Associated with the U.S. EPA Reference Values.* Environmental Health Perspectives, Vol. 111, No. 10, page 1318. August 2003. *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241613/pdf/ehp0111-001318.pdf.*

[27] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–822–B–00–004. *http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.*

[28] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[29] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health

tribal survey data relevant to Washington are consistent with EPA's national adult body weight of 80 kg.[30]

e. Drinking Water Intake

EPA proposes to calculate human health criteria for Washington using a rate of 2.4 L/day. In 2015, EPA updated its national default drinking water intake rate to 2.4 L/day based on national survey data (see section II.B.c).[31] EPA is not aware of any local data applicable to Washington that suggest a more appropriate rate.

f. Pollutant-Specific Reference Doses and Cancer Slope Factors

As part of EPA's 2015 updates to its 304(a) recommended human health criteria, EPA conducted a systematic search of eight peer-reviewed, publicly available sources to obtain the most current toxicity values for each pollutant (RfDs for non-carcinogenic effects and CSFs for carcinogenic effects).[32] EPA proposes to calculate human health criteria for Washington using the same toxicity values that EPA used in its 2015 304(a) criteria updates, to ensure that the resulting criteria are based on a sound scientific rationale. Where EPA did not update criteria for certain pollutants in 2015, EPA proposes to use the toxicity values that the Agency used the last time it updated its 304(a) criteria for those pollutants as the best available scientific information. See Table 1, columns B1 and B3 for a list of EPA's proposed toxicity factors by pollutant.

g. Pollutant-Specific Bioaccumulation Factors

For the 2015 national 304(a) human health criteria update, EPA estimated chemical-specific BAFs using a framework for deriving national BAFs described in EPA's 2000 Human Health Methodology.[33] Because the surveyed population upon which the 175 g/day FCR is based consumed almost exclusively trophic level four fish (*i.e.,* predator fish species), EPA proposes to apply the trophic level four BAF from the 2015 304(a) human health criteria updates in conjunction with the 175 g/day FCR, in order to ensure protectiveness.[34] Where EPA did not update criteria for certain pollutants in 2015, EPA proposes to use the BCFs that the Agency used the last time it updated its 304(a) criteria for those pollutants as the best available scientific information. See Table 1, columns B4 and B5 for a list of EPA's proposed bioaccumulation factors by pollutant.

D. Proposed Human Health Criteria for Washington

EPA proposes 195 human health criteria for 99 different pollutants (97 organism-only criteria and 98 water-plus-organism criteria) to protect the applicable designated uses of Washington's waters (see Table 1). The water-plus-organism criteria in column C1 of Table 1 are the applicable criteria for any waters that include the Domestic Water (domestic water supply) use defined in Washington's WQS (WAC 173–201A–600). The organism-only criteria in column C2 of Table 1 apply to waters that do not include the Domestic Water (domestic water supply) use and that Washington defines at WAC 173–201A–600 and 173–201A–610 as the following: Fresh waters—Harvesting (fish harvesting), and Recreational Uses; Marine waters—Shellfish Harvesting (shellfish—clam, oyster, and mussel—harvesting), Harvesting (salmonid and other fish harvesting, and crustacean and other shellfish—crabs, shrimp, scallops, etc.—harvesting), and Recreational Uses.

EPA solicits comment on the criteria, the inputs EPA used to derive these criteria, and specifically solicits additional Washington-specific information such as data from local fish or drinking water consumption rate studies, or bioaccumulation field studies from Washington waters.

TABLE 1—PROPOSED HUMAN HEALTH CRITERIA FOR WASHINGTON

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (–) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor for trophic level 4 (L/kg tissue) (B4)	Bio-concentration factor L1≤(L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
1. 1,1,1-Trichloroethane	71556	.....	0.20	2	10	.....	8,000	20,000
2. 1,1,2,2-Tetrachloroethane	79345	0.2	.....	.....	8.4	.....	0.1	0.3
3. 1,1,2-Trichloroethane	79005	0.057	.....	.....	8.9	.....	0.35	0.90
4. 1,1-Dichloroethylene	75354	.....	0.20	0.05	2.6	.....	300	2,000
5. 1,2,4-Trichlorobenzene	120821	0.029	.....	.....	430	.....	0.036	0.037
6. 1,2-Dichlorobenzene	95501	.....	0.20	0.3	82	.....	300	300
7. 1,2-Dichloroethane	107062	0.0033	.....	.....	1.9	.....	8.9	73
8. 1,2-Dichloropropane	78875	0.036	.....	.....	3.9	.....	0.72	3.3
9. 1,2-Diphenylhydrazine	122667	0.8	.....	.....	27	.....	0.01	0.02
10. 1,2-Trans-Dichloroethylene	156605	.....	0.20	0.02	4.7	.....	100	400
11. 1,3-Dichlorobenzene	541731	.....	0.20	0.002	190	.....	0.9	1
12. 1,3-Dichloropropene	542756	0.122	.....	.....	3.0	.....	0.22	1.2
13. 1,4-Dichlorobenzene	106467	.....	0.20	0.07	84	.....	70	80
14. 2,3,7,8-TCDD (Dioxin)	1746016	156,000	.....	.....	.....	5,000	5.8E–10	5.9E–10

Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[30] USEPA Region 10. August 2007. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. Appendix B. *http://yosemite.epa.gov/r10/CLEANUP.NSF/7780249be8f25153882565f0070bd8b/e12918970debc8e488256da6005c428e/$FILE/Tribal%20Shellfish%20Framework.pdf.*

[31] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[32] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *http://water.epa.gov/scitech/swguidance/standards/criteria/current/hhfinal.cfm.*

[33] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *http://www.epa.gov/waterscience/criteria/humanhealth/method/complete.pdf.*

[34] *Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission (CRITFC), 1994).

TABLE 1—PROPOSED HUMAN HEALTH CRITERIA FOR WASHINGTON—Continued

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (–) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor for trophic level 4 (L/kg tissue) (B4)	Bio-concentration factor LI≤(L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
15. 2,4,6-Trichlorophenol	88062	0.011			150		0.25	0.28
16. 2,4-Dichlorophenol	120832		0.20	0.003	48		4	6
17. 2,4-Dimethylphenol	105679		0.20	0.02	7		90	300
18. 2,4-Dinitrophenol	51285		0.20	0.002		4.4	10	40
19. 2,4-Dinitrotoluene	121142	0.667			3.9		0.039	0.18
20. 2-Chloronaphthalene	91587		0.80	0.08	240		100	100
21. 2-Chlorophenol	95578		0.20	0.005	5.4		20	80
22. 2-Methyl-4,6-Dinitrophenol	534521		0.20	0.0003	10		1	3
23. 3,3′-Dichlorobenzidine	91941	0.45			69		0.012	0.015
24. 3-Methyl-4-Chlorophenol	59507		0.20	0.1	39		200	200
25. 4,4′-DDD	72548	0.24			240,000		7.9E–06	7.9E–06
26. 4,4′-DDE	72559	0.167			3,100,000		8.8E–07	8.8E–07
27. 4,4′-DDT	50293	0.34			1,100,000		1.2E–06	1.2E–06
28. Acenaphthene	83329		0.20	0.06		510	10	10
29. Acrolein	107028		0.20	0.0005	1.0		3	50
30. Acrylonitrile	107131	0.54			1.0		0.058	0.85
31. Aldrin	309002	17			650,000		4.1E–08	4.1E–08
32. alpha-BHC	319846	6.3			1,500		4.8E–05	4.8E–05
33. alpha-Endosulfan	959988		0.20	0.006	200		3	3
34. Anthracene	120127		0.20	0.3		610	40	40
35. Antimony	7440360		0.20	0.0004		1	2.5	37
36. Arsenic	7440382	1.75				44	[a] 0.0045	[a] 0.0059
37. Asbestos	1332214						[b] 7,000,000 (fibers/L)	
38. Benzene	71432	[c] 0.055			5.0		[c] 0.44	[c] 1.7
39. Benzidine	92875	230			1.7		0.00013	0.0012
40. Benzo(a) Anthracene	56553	0.73				3,900	0.00016	0.00016
41. Benzo(a) Pyrene	50328	7.3				3,900	1.6E–05	1.6E–05
42. Benzo(b) Fluoranthene	205992	0.73				3,900	0.00016	0.00016
43. Benzo(k) Fluoranthene	207089	0.073				3,900	0.0016	0.0016
44. beta-BHC	319857	1.8			180		0.0013	0.0014
45. beta-Endosulfan	33213659		0.20	0.006	130		4	4
46. Bis(2-Chloroethyl) Ether	111444	1.1			1.7		0.027	0.24
47. *Bis(2-Chloro-1-Methylethyl) Ether	108601		0.20	0.04	10		200	400
48. Bis(2-Ethylhexyl) Phthalate	117817	0.014				710	0.045	0.046
49. Bromoform	75252	0.0045			8.5		4.6	12
50. Butylbenzyl Phthalate	85687	0.0019				19,000	0.013	0.013
51. Carbon Tetrachloride	56235	0.07			14		0.2	0.5
52. Chlordane	57749	0.35			60,000		2.2E–05	2.2E–05
53. Chlorobenzene	108907		0.20	0.02	22		50	80
54. Chlorodibromomethane	124481	0.04			5.3		0.60	2.2
55. Chloroform	67663		0.20	0.01	3.8		50	200
56. Chrysene	218019	0.0073				3,900	0.016	0.016
57. Copper	7440508						[d] 1300	
58. Cyanide	57125		0.20	0.0006		1	4	50
59. Dibenzo(a,h) Anthracene	53703	7.3				3,900	1.6E–05	1.6E–05
60. Dichlorobromomethane	75274	0.034			4.8		0.73	2.8
61. Dieldrin	60571	16			410,000		7.0E–08	7.0E–08
62. Diethyl Phthalate	84662		0.20	0.8		920	80	80
63. Dimethyl Phthalate	131113		0.20	10		4,000	200	200
64. Di-n-Butyl Phthalate	84742		0.20	0.1		2,900	3	3
65. Endosulfan Sulfate	1031078		0.20	0.006	140		4	4
66. Endrin	72208		0.80	0.0003	46,000		0.002	0.002
67. Endrin Aldehyde	7421934		0.80	0.0003	850		0.1	0.1
68. Ethylbenzene	100414		0.20	0.022	160		12	13
69. Fluoranthene	206440		0.20	0.04		1,500	2	2
70. Fluorene	86737		0.20	0.04	710		5	5
71. gamma-BHC; Lindane	58899		0.50	0.0047	2,500		0.43	0.43
72. Heptachlor	76448	4.1			330,000		3.4E–07	3.4E–07
73. Heptachlor Epoxide	1024573	5.5			35,000		2.4E–06	2.4E–06
74. Hexachlorobenzene	118741	1.02			90,000		5.0E–06	5.0E–06
75. Hexachlorobutadiene	87683	0.04			1,100		0.01	0.01
76. Hexachlorocyclopentadiene	77474		0.20	0.006	1,300		0.4	0.4
77. Hexachloroethane	67721	0.04			600		0.02	0.02
78. Indeno(1,2,3-cd) Pyrene	193395	0.73				3,900	0.00016	0.00016
79. Isophorone	78591	0.00095			2.4		30	200
80. Methyl Bromide	74839		0.20	0.02	1.4		100	1,000
81. Methylene Chloride	75092	0.002			1.6		10	100
82. Methylmercury	22967926		2.7E–05	0.0001				[e] 0.033 (mg/kg)
83. Nickel	7440020		0.20	0.02		47	30	39
84. Nitrobenzene	98953		0.20	0.002	3.1		10	60
85. N-Nitrosodimethylamine	62759	51				0.026	0.00065	0.34

TABLE 1—PROPOSED HUMAN HEALTH CRITERIA FOR WASHINGTON—Continued

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (−) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor for trophic level 4 (L/kg tissue) (B4)	Bio-concentration factor Lis(L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
86. N-Nitrosodi-n-Propylamine	621647	7				1.13	0.0044	0.058
87. N-Nitrosodiphenylamine	86306	0.0049				136	0.62	0.69
88. Pentachlorophenol (PCP)	87865	0.4			520		0.002	0.002
89. Phenol	108952		0.20	0.6	1.9		4,000	30,000
90. Polychlorinated Biphenyls (PCBs)		2				31,200	[f]7.3E−06	[f]7.3E−06
91. Pyrene	129000		0.20	0.03		860	3	3
92. Selenium	7782492		0.20	0.005		4.8	25	95
93. Tetrachloroethylene	127184	0.0021			76		2.4	2.9
94. Thallium	7440280		0.20	0.000068		116	0.048	0.054
95. Toluene	108883		0.20	0.0097	17		29	52
96. Toxaphene	8001352	1.1			6,300		6.6E−05	6.6E−05
97. Trichloroethylene	79016	0.05			13		0.3	0.7
98. Vinyl Chloride	75014	1.5			1.7		0.020	0.18
99. Zinc	7440666		0.20	0.3		47	450	580

[a] This criterion refers to the inorganic form of arsenic only.
[b] This criterion is expressed as fibers per liter (fibers/L). The criterion for asbestos is the Maximum Contaminant Level Goal (MCLG) developed under the Safe Drinking Water Act (SDWA) (56 FR 3526, January 30, 1991).
[c] EPA's national 304(a) recommended criteria for benzene use a CSF range of 0.015 to 0.055 per mg/kg-day. EPA proposes to use the higher end of the CSF range (0.055 per mg/kg-day) to derive the proposed benzene criteria for Washington.
[d] The criterion for copper is the Maximum Contaminant Level Goal (MCLG) developed under the Safe Drinking Water Act (SDWA) (40 CFR 141.80, June 7, 1991).
[e] This criterion is expressed as the fish tissue concentration of methylmercury (mg methylmercury/kg fish). See *Water Quality Criterion for the Protection of Human Health: Methylmercury* (EPA–823–R–01–001, January 3, 2001) for how this value is calculated using the criterion equation in EPA's 2000 Human Health Methodology rearranged to solve for a protective concentration in fish tissue rather than in water.
[f] This criterion applies to total PCBs (*e.g.,* the sum of all congener or isomer or homolog or Aroclor analyses).
* Bis(2-Chloro-1-Methylethyl) Ether was previously listed as Bis(2-Chloroisopropyl) Ether.

E. Applicability of Criteria When Final

The EPA does not propose to revise or replace any existing criteria (related to human health or otherwise) that were already adopted and submitted to EPA by Washington (and for those adopted after May 30, 2000, approved by EPA), such as the state's narrative toxics criteria statement at WAC 173–201A–260(2)(a). Rather, EPA proposes to revise the current federal human health criteria applicable to waters in the state of Washington, as promulgated in the NTR, and establish new criteria for 14 additional priority pollutants. These new and revised human health criteria would apply for CWA purposes in addition to any existing criteria already applicable to Washington's waters.

EPA proposes to replicate in 40 CFR 131.45 the same general rules of applicability for human health criteria as in 40 CFR 131.36(c), with one exception. For waters suitable for the establishment of low flow return frequencies (*i.e.,* streams and rivers), EPA proposes that Washington must not use a low flow value below which numeric standards can be exceeded that is less stringent than the harmonic mean flow (a long-term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows). Per 65 FR 66444, November 3, 2000, EPA now recommends harmonic mean flow be used to implement human health criteria for both carcinogens and non-carcinogens.[35]

Under the CWA, Congress gave states primary responsibility for developing and adopting WQS for their navigable waters (CWA section 303(a)–(c)). Although EPA proposes human health criteria for Washington to update the existing federally promulgated criteria, Washington continues to have the option to adopt and submit to EPA human health criteria for the state's waters consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131. EPA encourages Washington to expeditiously adopt protective human health criteria. Consistent with CWA section 303(c)(4), if Washington adopts and submits human health criteria and EPA approves such criteria before finalizing this proposed rule, EPA would not proceed with the final rulemaking for those waters and/or pollutants for which EPA approves Washington's criteria.

If EPA finalizes this proposed rule, and Washington subsequently adopts and submits human health criteria, EPA proposes that once EPA approves Washington's WQS, the pollutant-specific or site-specific EPA-approved criteria in Washington's WQS would become effective for CWA purposes and EPA's promulgated criteria for those pollutants or for that site would no longer apply. EPA would still undertake a rulemaking to withdraw the federal criteria for those pollutants, but any delay in that process would not delay Washington's approved criteria from becoming the sole applicable criteria for CWA purposes. EPA solicits comment on this approach.

F. Alternative Regulatory Approaches and Implementation Mechanisms

Once finalized, Washington will have considerable discretion to implement these revised federal human health criteria through various water quality control programs including the NPDES program, which limits discharges to waters except in compliance with a NPDES permit. EPA's regulations at 40 CFR 131.14, once effective, authorize states and authorized tribes to adopt WQS variances to provide time to achieve the applicable WQS. 40 CFR part 131 defines WQS variances at 131.3(o) as time-limited designated uses and supporting criteria for a specific pollutant(s) or water quality parameter(s) that reflect the highest attainable conditions during the term of the WQS variance. WQS variances adopted in accordance with 40 CFR part 131 allow states and authorized tribes to

[35] See also USEPA. 2014. Water Quality Standards Handbook—Chapter 5: General Policies. U.S. Environmental Protection Agency. Office of Water. Washington, D.C. EPA–820–B–14–004. *http://water.epa.gov/scitech/swguidance/standards/handbook/chapter05.cfm#section52.*

address water quality challenges in a transparent and predictable way. Variances help states and authorized tribes focus on making incremental progress in improving water quality, rather than pursuing a downgrade of the underlying water quality goals through a designated use change, when the current designated use is difficult to attain. EPA's regulations at 40 CFR 122.47 and 40 CFR 131.15, once effective, allow states and authorized tribes to include permit compliance schedules in their NPDES permits if dischargers need additional time to meet their water quality based limits based on the applicable WQS. EPA's updated regulations at 40 CFR part 131 also include provisions authorizing the use of permit compliance schedules to ensure that a decision to allow permit compliance schedules includes public engagement and transparency. (80 FR 51022, August 21, 2015).

40 CFR 131.10 specifies how states and authorized tribes establish, modify or remove designated uses for their waters. 40 CFR 131.11 specifies the requirements for establishing criteria to protect designated uses, including criteria modified to reflect site-specific conditions. In the context of this rulemaking, a site-specific criterion (SSC) is an alternative value to the federal human health criteria that would be applied on a watershed, area-wide, or waterbody-specific basis that meets the regulatory test of protecting the designated use, being scientifically defensible, and ensuring the protection and maintenance of downstream WQS. A SSC may be more or less stringent than the otherwise applicable federal criteria. A SSC may be appropriate when further scientific data and analyses can bring added precision to express the concentration of a particular pollutant that protects the human health-related designated use in a particular waterbody.

EPA does not propose to change any of the flexibilities afforded to Washington by EPA's regulations to modify or remove designated uses, adopt variances, issue compliance schedules or establish site-specific criteria. Washington may continue to use any of these regulatory flexibilities when implementing the revised federal human health criteria.

a. Designating Uses

EPA's proposed human health criteria apply to waters that Washington has designated for the following: Fresh waters—Harvesting (fish harvesting), Domestic Water (domestic water supply), and Recreational Uses; Marine waters—Shellfish Harvesting (shellfish—clam, oyster, and mussel—harvesting), Harvesting (salmonid and other fish harvesting, and crustacean and other shellfish—crabs, shrimp, scallops, etc.—harvesting), and Recreational Uses (see WAC 173–201A–600 and WAC 173–201A–610). If Washington removes the Domestic Water use but retains any of the other above designated uses for any particular waterbody ultimately affected by this rule, and EPA finds that removal to be consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131, then the federal organism-only criteria would apply in place of the federal water-plus-organism criteria. If Washington removes designated uses such that none of the above uses apply to any particular waterbody ultimately affected by this rule and adopts the highest attainable use, as defined by 40 CFR 131.3(m), consistent with 40 CFR 131.10(g), and EPA finds that removal to be consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131, then the federal human health criteria would no longer apply to that waterbody. Instead, any criteria associated with the newly designated highest attainable use would apply to that waterbody.

b. Variances and Compliance Schedules

EPA is proposing human health criteria that apply to use designations that Washington has already established. Washington has sufficient authority to use variances when implementing the human health criteria as long as such variances are adopted consistent with 40 CFR 131.14. Washington may use its currently EPA-approved variance procedures with respect to a temporary modification of its uses as it pertains to any federal criteria (see WAC 173–201A–420) when adopting such variances. Similarly, Washington already has an EPA-approved regulation authorizing the use of permit compliance schedules (see WAC 173–201A–510), consistent with 40 CFR 131.15. That state regulation is not affected by this rule, and Washington is authorized to grant compliance schedules, as appropriate, based on the federal criteria.

c. Site-Specific Criteria

As discussed in section IV.E, EPA proposes that once EPA approves human health criteria that Washington adopts and submits after EPA finalizes this proposed rule, the pollutant-specific or site-specific EPA-approved criteria in Washington's WQS would become effective for CWA purposes and EPA's promulgated criteria for those pollutants or for that site would no longer apply.

V. Economic Analysis

These WQS may serve as a basis for development of NPDES permit limits. Washington has NPDES permitting authority, and retains considerable discretion in implementing standards. EPA evaluated the potential costs to NPDES dischargers associated with state implementation of EPA's proposed criteria. This analysis is documented in "Economic Analysis for the Revision of Certain Federal Water Quality Criteria Applicable to Washington," which can be found in the record for this rulemaking.

Any NPDES-permitted facility that discharges pollutants for which the revised human health criteria are more stringent than the applicable aquatic life criteria (or for which human health criteria are the only applicable criteria) could potentially incur compliance costs. The types of affected facilities could include industrial facilities and POTWs discharging wastewater to surface waters (*i.e.*, point sources). Once in compliance with water quality-based effluent limitations (WQBELs) reflective of existing federal human health criteria applicable to Washington (hereafter referred to as "baseline criteria"), EPA expects that dischargers will continue to use the same types of controls to come into compliance with the revised criteria; EPA did not attribute compliance with WQBELs reflective of baseline criteria to the proposed rule. EPA did not fully evaluate the potential for costs to nonpoint sources, such as agricultural runoff, for this preliminary analysis.

EPA recognizes that the permitting authority may require controls for nonpoint sources (*e.g.*, agricultural runoff). However, it is difficult to model and evaluate the potential cost impacts of this proposed rule to nonpoint sources because they are intermittent, variable, and occur under hydrologic or climatic conditions associated with precipitation events. Also, data on instream and discharge levels of the pollutants of concern after dischargers have implemented controls to meet current WQS, total maximum daily loads (TMDLs) for impaired waters, or other water quality improvement plans, are not available. Therefore, trying to determine which sources would not achieve WQS based on the revised human health criteria after complying with existing regulations and policies may not be possible.

Finally, legacy contamination (*e.g.*, in sediment) may be a source of ongoing loading. Atmospheric deposition may

also contribute loadings of the pollutants of concern (*e.g.*, mercury). EPA did not estimate sediment remediation costs, or air pollution controls costs, for this preliminary analysis.

A. Identifying Affected Entities

EPA identified 406 point source facilities that could ultimately be affected by this proposed rule. Of these potentially affected facilities, 73 are major dischargers and 333 are minor dischargers. EPA did not include general permit facilities in its analysis because data for such facilities are limited, and flows are usually negligible. Of the potentially affected facilities, EPA evaluated a sample of 17 major facilities. Minor facilities are unlikely to incur costs as a result of implementation of the rule. Minor facilities are typically those that discharge less than 1 million gallons per day (mgd) and do not discharge toxics in toxic amounts. Although lower human health criteria could potentially change this categorization, EPA did not have effluent data on toxic pollutants to evaluate minor facilities for this preliminary analysis. Table 2 summarizes these potentially affected facilities by type and category.

TABLE 2—POTENTIALLY AFFECTED FACILITIES

Category	Minor	Major	All
Municipal	184	48	232
Industrial	149	25	174
Total	333	73	406

B. Method for Estimating Costs

EPA evaluated the 2 major municipal facilities with design flows greater than 100 mgd and the largest industrial facility, to attempt to capture the facilities with the potential for the largest costs. For the remaining major facilities, EPA evaluated a random sample of facilities to represent discharger type and category. For all sample facilities, EPA evaluated existing baseline permit conditions, reasonable potential to exceed human health criteria based on the proposed rule, and potential to exceed projected effluent limitations based on the last three years of effluent monitoring data (if available). In instances of baseline effluent limitations not being reflective of baseline criteria, EPA estimated baseline effluent limitations, compliance actions, and costs. In instances of exceedances of projected effluent limitations under the proposed criteria, EPA determined the likely compliance scenarios and costs. Only compliance actions and costs that would be needed above the baseline level of controls are attributable to the proposed rule.

EPA assumed that dischargers will pursue the least cost means of compliance with WQBELs. Incremental compliance actions attributable to the proposed rule may include pollution prevention, end-of-pipe treatment, and alternative compliance mechanisms (*e.g.*, variances). EPA annualized capital costs, including study (*e.g.*, variance) and program (*e.g.*, pollution prevention) costs, over 20 years using a 7% discount rate to obtain total annual costs per facility. For the random sample, EPA extrapolated the annualized costs based on the sampling weight for each sample facility. To obtain an estimate of total costs to point sources, EPA added the results for the certainty sample to the extrapolated random sample costs.

C. Results

Based on the results for 17 sample facilities across 8 industrial and municipal categories,[36] EPA estimated a total annual cost of approximately $13.0 million to $13.1 million for all major dischargers in the state. The low end of the range reflects the assumption that the compliance actions will result in compliance with projected effluent limits through pollution prevention programs and end-of-pipe treatment, whereas the high scenario reflects the assumption that these actions will not result in compliance with very low limits and dischargers will also need to apply for variances. All of the incremental costs are attributable to industrial dischargers, primarily for treatment of arsenic. Overall, compliance with revised human health criteria for arsenic accounts for 99% of the costs, while compliance with revised human health criteria for mercury accounts for the remaining 1% of costs.

If the revised criteria result in an incremental increase in impaired waters, resulting in the need for TMDL development, there could also be some costs to nonpoint sources of pollution. Using available ambient monitoring data, EPA compared pollutant concentrations to the baseline and proposed criteria, identifying waterbodies that may be incrementally impaired (*i.e.*, impaired under the proposed criteria but not under the baseline). For the 26 parameters and stations for which EPA had sufficient monitoring data available to evaluate, there were 205 impairments under the baseline criteria and 254 under the proposed criteria, for a total of 49 potential incremental impairments (or a 24% increase relative to the baseline; including for mercury and DDT). This increase indicates the potential for nonpoint sources to bear some compliance costs, although data are not available to estimate the magnitude of these costs. The control of nonpoint sources such as in the context of a TMDL could result in less stringent requirements, and thus lower costs, for point sources.

[36] Seven industrial categories (mining, food and kindred products, paper and allied products, chemicals and allied products, petroleum refining and related industries, primary metal industries, and transportation and public utilities (except POTWs)) and municipal POTWs.

VI. Statutory and Executive Order Reviews

A. Executive Order 12866 (Regulatory Planning and Review) and Executive Order 13563 (Improving Regulation and Regulatory Review)

It has been determined that this proposed rule is not a "significant regulatory action" under the terms of Executive Order 12866 (58 FR 51735, October 4, 1993) and is, therefore, not subject to review under Executive Orders 12866 and 13563 (76 FR 3821, January 21, 2011). The proposed rule does not establish any requirements directly applicable to regulated entities or other sources of toxic pollutants. However, these WQS may serve as a basis for development of NPDES permit limits. Washington has NPDES permitting authority, and retains considerable discretion in implementing standards. In the spirit of Executive Order 12866, EPA evaluated the potential costs to NPDES dischargers associated with state implementation of EPA's proposed criteria. This analysis,

Economic Analysis for the Revision of Certain Federal Water Quality Criteria Applicable to Washington, is summarized in section V of the preamble and is available in the docket.

B. Paperwork Reduction Act

This action does not impose any direct new information collection burden under the provisions of the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* Actions to implement these WQS could entail additional paperwork burden. Burden is defined at 5 CFR 1320.3(b). This action does not include any information collection, reporting, or record-keeping requirements.

C. Regulatory Flexibility Act

This action will not have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (RFA). Small entities, such as small businesses or small governmental jurisdictions, are not directly regulated by this rule. This proposed rule will thus not impose any requirements on small entities. We continue to be interested, however, in the potential impacts of the proposed rule on small entities and welcome comments on issues related to such impacts.

D. Unfunded Mandates Reform Act

This action contains no federal mandates under the provisions of Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), 2 U.S.C. 1531–1538 for state, local, or tribal governments or the private sector. As these water quality criteria are not self-implementing, EPA's action imposes no enforceable duty on any state, local or tribal governments or the private sector. Therefore, this action is not subject to the requirements of sections 202 or 205 of the UMRA.

This action is also not subject to the requirements of section 203 of UMRA because it contains no regulatory requirements that could significantly or uniquely affect small governments.

E. Executive Order 13132 (Federalism)

This action does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government. This rule does not alter Washington's considerable discretion in implementing these WQS, nor would it preclude Washington from adopting WQS that EPA concludes meet the requirements of the CWA, either before or after promulgation of the final rule, which would eliminate the need for federal standards. Thus, Executive Order 13132 does not apply to this action.

In the spirit of Executive Order 13132 and consistent with EPA policy to promote communications between EPA and state and local governments, EPA specifically solicits comments on this proposed action from state and local officials.

F. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)

This action has tribal implications. However, it will neither impose substantial direct compliance costs on federally recognized tribal governments, nor preempt tribal law. In the state of Washington, there are 29 federally recognized Indian tribes. To date, nine of these Indian tribes have been approved for TAS for CWA sections 303 and 401.[37] Of these nine tribes, seven have EPA-approved WQS in their respective jurisdictions.[38] This rule could affect federally recognized Indian tribes in Washington because the numeric criteria for Washington will apply to waters adjacent to (or upstream or downstream of) the tribal waters, and because the proposed Washington criteria are informed by tribal reserved rights. Additionally, there are ten federally recognized Indian tribes in the Columbia River Basin located in the states of Oregon and Idaho that this rule could affect because their waters could affect or be affected by the water quality of Washington's downstream or upstream waters.

EPA consulted with federally recognized tribal officials under EPA's Policy on Consultation and Coordination with Indian tribes early in the process of developing this proposed rule to permit them to have meaningful and timely input into its development. In February and March 2015, EPA held tribes-only technical staff and leadership consultation sessions to hear their views and answer questions of all interested tribes on the proposed rule. Representatives from approximately 23 tribes and four tribal consortia participated in two leadership meetings held in March 2015. EPA and tribes have also met regularly since November 2012 to discuss Washington's human health criteria at both the tribal leadership level and technical staff level. The tribes have repeatedly asked EPA to promulgate federal human health criteria for Washington if the state did not do so in a timely and protective manner. At these meetings, the tribes consistently emphasized that the human health criteria should be derived using at least a minimum FCR value of 175 g/day, a cancer risk level of 10^{-6}, and the latest scientific information from EPA's 304(a) recommended criteria. EPA considered the input received during consultation with tribes when developing this proposal (see section IV for additional discussion of how EPA considered tribal input).

G. Executive Order 13045 (Protection of Children From Environmental Health and Safety Risks)

This rule is not subject to Executive Order 13045, because it is not economically significant as defined in Executive Order 12866, and because the environmental health or safety risks addressed by this action do not present a disproportionate risk to children.

The public is invited to submit comments or identify peer-reviewed studies and data that assess effects of early life exposure.

H. Executive Order 13211 (Actions That Significantly Affect Energy Supply, Distribution, or Use)

This action is not a "significant energy action" because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy.

I. National Technology Transfer and Advancement Act of 1995

This proposed rulemaking does not involve technical standards.

J. Executive Order 12898 (Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations)

This action will not have disproportionately high and adverse human health or environmental effects on minority or low-income populations. Conversely, this action identifies and ameliorates disproportionately high and adverse human health effects on minority populations and low-income populations in Washington. EPA developed the human health criteria included in this proposed rule specifically to protect Washington's designated uses, using the most current science, including local and regional information on fish consumption. Applying these criteria to waters in the state of Washington will afford a greater

[37] *http://water.epa.gov/scitech/swguidance/standards/wqslibrary/approvtable.cfm.*

[38] *http://yosemite.epa.gov/r10/water.nsf/34090d07b77d50bd88256b79006529e8/dd2a4df00fd7ae1a88256e0500680e86!OpenDocument.* Note that this number does not include the Confederated Tribes of the Colville Reservation, which has federally-promulgated WQS from 1989. EPA is currently reviewing the Colville Tribe's application for TAS.

level of protection to both human health and the environment.

List of Subjects in 40 CFR Part 131

Environmental protection, Indians-lands, Intergovernmental relations, Reporting and recordkeeping requirements, Water pollution control.

Dated: August 31, 2015.

Gina McCarthy,

Administrator.

For the reasons set forth in the preamble, EPA proposes to amend 40 CFR part 131 as follows:

PART 131—WATER QUALITY STANDARDS

■ 1. The authority citation for part 131 continues to read as follows:

Authority: 33 U.S.C. 1251 *et seq.*

Subpart D—Federally Promulgated Water Quality Standards

§ 131.36 [Amended]

■ 2. In § 131.36, remove paragraph (d)(14).

■ 3. Add § 131.45 to read as follows:

§ 131.45 Revision of certain Federal water quality criteria applicable to Washington.

(a) *Scope.* This section promulgates human health criteria for priority toxic pollutants in surface waters in Washington.

(b) *Criteria for priority toxic pollutants in Washington.* The applicable human health criteria are shown in Table 1.

TABLE 1—PROPOSED HUMAN HEALTH CRITERIA FOR WASHINGTON

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (−) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor for trophic level 4 (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
1. 1,1,1-Trichloroethane	71556	.....	0.20	2	10	.....	8,000	20,000
2. 1,1,2,2-Tetrachloroethane	79345	0.2	.....	.....	8.4	.....	0.1	0.3
3. 1,1,2-Trichloroethane	79005	0.057	.....	.....	8.9	.....	0.35	0.90
4. 1,1-Dichloroethylene	75354	.....	0.20	0.05	2.6	.....	300	2,000
5. 1,2,4-Trichlorobenzene	120821	0.029	.....	.....	430	.....	0.036	0.037
6. 1,2-Dichlorobenzene	95501	.....	0.20	0.3	82	.....	300	300
7. 1,2-Dichloroethane	107062	0.0033	.....	.....	1.9	.....	8.9	73
8. 1,2-Dichloropropane	78875	0.036	.....	.....	3.9	.....	0.72	3.3
9. 1,2-Diphenylhydrazine	122667	0.8	.....	.....	27	.....	0.01	0.02
10. 1,2-Trans-Dichloroethylene	156605	.....	0.20	0.02	4.7	.....	100	400
11. 1,3-Dichlorobenzene	541731	.....	0.20	0.002	190	.....	0.9	1
12. 1,3-Dichloropropene	542756	0.122	.....	.....	3.0	.....	0.22	1.2
13. 1,4-Dichlorobenzene	106467	.....	0.20	0.07	84	.....	70	80
14. 2,3,7,8-TCDD (Dioxin)	1746016	156,000	.....	.....	.....	5,000	5.8E−10	5.9E−10
15. 2,4,6-Trichlorophenol	88062	0.011	.....	.....	150	.....	0.25	0.28
16. 2,4-Dichlorophenol	120832	.....	0.20	0.003	48	.....	4	6
17. 2,4-Dimethylphenol	105679	.....	0.20	0.02	7	.....	90	300
18. 2,4-Dinitrophenol	51285	.....	0.20	0.002	.....	4.4	10	40
19. 2,4-Dinitrotoluene	121142	0.667	.....	.....	3.9	.....	0.039	0.18
20. 2-Chloronaphthalene	91587	.....	0.80	0.08	240	.....	100	100
21. 2-Chlorophenol	95578	.....	0.20	0.005	5.4	.....	20	80
22. 2-Methyl-4,6-Dinitrophenol	534521	.....	0.20	0.0003	10	.....	1	3
23. 3,3′-Dichlorobenzidine	91941	0.45	.....	.....	69	.....	0.012	0.015
24. 3-Methyl-4-Chlorophenol	59507	.....	0.20	0.1	39	.....	200	200
25. 4,4′-DDD	72548	0.24	.....	.....	240,000	.....	7.9E−06	7.9E−06
26. 4,4′-DDE	72559	0.167	.....	.....	3,100,000	.....	8.8E−07	8.8E−07
27. 4,4′-DDT	50293	0.34	.....	.....	1,100,000	.....	1.2E−06	1.2E−06
28. Acenaphthene	83329	.....	0.20	0.06	.....	510	10	10
29. Acrolein	107028	.....	0.20	0.0005	1.0	.....	3	50
30. Acrylonitrile	107131	0.54	.....	.....	1.0	.....	0.058	0.85
31. Aldrin	309002	17	.....	.....	650,000	.....	4.1E−08	4.1E−08
32. alpha-BHC	319846	6.3	.....	.....	1,500	.....	4.8E−05	4.8E−05
33. alpha-Endosulfan	959988	.....	0.20	0.006	200	.....	3	3
34. Anthracene	120127	.....	0.20	0.3	.....	610	40	40
35. Antimony	7440360	.....	0.20	0.0004	.....	1	2.5	37
36. Arsenic	7440382	1.75	.....	.....	.....	44	[a]0.0045	[a]0.0059
37. Asbestos	1332214	.....	.....	.....	.....	.....	[b]7,000,000 (fibers/L)	.....
38. Benzene	71432	[c]0.055	.....	.....	5.0	.....	[c]0.44	[c]1.7
39. Benzidine	92875	230	.....	.....	1.7	.....	0.00013	0.0012
40. Benzo(a) Anthracene	56553	0.73	.....	.....	.....	3,900	0.00016	0.00016
41. Benzo(a) Pyrene	50328	7.3	.....	.....	.....	3,900	1.6E−05	1.6E−05
42. Benzo(b) Fluoranthene	205992	0.73	.....	.....	.....	3,900	0.00016	0.00016
43. Benzo(k) Fluoranthene	207089	0.073	.....	.....	.....	3,900	0.0016	0.0016
44. beta-BHC	319857	1.8	.....	.....	160	.....	0.0013	0.0014
45. beta-Endosulfan	33213659	.....	0.20	0.006	130	.....	4	4
46. Bis(2-Chloroethyl) Ether	111444	1.1	.....	.....	1.7	.....	0.027	0.24
47. *Bis(2-Chloro-1-Methylethyl) Ether	108601	.....	0.20	0.04	10	.....	200	400
48. Bis(2-Ethylhexyl) Phthalate	117817	0.014	.....	.....	.....	710	0.045	0.046
49. Bromoform	75252	0.0045	.....	.....	8.5	.....	4.6	12
50. Butylbenzyl Phthalate	85687	0.0019	.....	.....	.....	19,000	0.013	0.013
51. Carbon Tetrachloride	56235	0.07	.....	.....	14	.....	0.2	0.5
52. Chlordane	57749	0.35	.....	.....	60,000	.....	2.2E−05	2.2E−05
53. Chlorobenzene	108907	.....	0.20	0.02	22	.....	50	80
54. Chlorodibromomethane	124481	0.04	.....	.....	5.3	.....	0.60	2.2

TABLE 1—PROPOSED HUMAN HEALTH CRITERIA FOR WASHINGTON—Continued

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (–) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor for trophic level 4 (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
55. Chloroform	67663	.....	0.20	0.01	3.8	.....	50	200
56. Chrysene	218019	0.0073	.....	.....	.....	3,900	0.016	0.016
57. Copper	7440508	.....	.....	.....	.....	.....	[d] 1300	.....
58. Cyanide	57125	.....	0.20	0.0006	.....	1	4	50
59. Dibenzo(a,h) Anthracene	53703	7.3	.....	.....	.....	3,900	1.6E–05	1.6E–05
60. Dichlorobromomethane	75274	0.034	.....	.....	4.8	.....	0.73	2.8
61. Dieldrin	60571	16	.....	.....	410,000	.....	7.0E–08	7.0E–08
62. Diethyl Phthalate	84662	.....	0.20	0.8	.....	920	80	80
63. Dimethyl Phthalate	131113	.....	0.20	10	.....	4,000	200	200
64. Di-n-Butyl Phthalate	84742	.....	0.20	0.1	.....	2,900	3	3
65. Endosulfan Sulfate	1031078	.....	0.20	0.006	140	.....	4	4
66. Endrin	72208	.....	0.80	0.0003	46,000	.....	0.002	0.002
67. Endrin Aldehyde	7421934	.....	0.80	0.0003	850	.....	0.1	0.1
68. Ethylbenzene	100414	.....	0.20	0.022	160	.....	12	13
69. Fluoranthene	206440	.....	0.20	0.04	.....	1,500	2	2
70. Fluorene	86737	.....	0.20	0.04	710	.....	5	5
71. gamma-BHC; Lindane	58899	.....	0.50	0.0047	2,500	.....	0.43	0.43
72. Heptachlor	76448	4.1	.....	.....	330,000	.....	3.4E–07	3.4E–07
73. Heptachlor Epoxide	1024573	5.5	.....	.....	35,000	.....	2.4E–06	2.4E–06
74. Hexachlorobenzene	118741	1.02	.....	.....	90,000	.....	5.0E–06	5.0E–06
75. Hexachlorobutadiene	87683	0.04	.....	.....	1,100	.....	0.01	0.01
76. Hexachlorocyclopentadiene	77474	.....	0.20	0.006	1,300	.....	0.4	0.4
77. Hexachloroethane	67721	0.04	.....	.....	600	.....	0.02	0.02
78. Indeno(1,2,3-cd) Pyrene	193395	0.73	.....	.....	.....	3,900	0.00016	0.00016
79. Isophorone	78591	0.00095	.....	.....	2.4	.....	30	200
80. Methyl Bromide	74839	.....	0.20	0.02	1.4	.....	100	1,000
81. Methylene Chloride	75092	0.002	.....	.....	1.6	.....	10	100
82. Methylmercury	22967926	.....	2.7E–05	0.0001	.....	.....	.....	[e] 0.033 (mg/kg)
83. Nickel	7440020	.....	0.20	0.02	.....	47	30	39
84. Nitrobenzene	98953	.....	0.20	0.002	3.1	.....	10	60
85. N-Nitrosodimethylamine	62759	51	.....	.....	.....	0.026	0.00065	0.34
86. N-Nitrosodi-n-Propylamine	621647	7	.....	.....	.....	1.13	0.0044	0.058
87. N-Nitrosodiphenylamine	86306	0.0049	.....	.....	.....	136	0.62	0.69
88. Pentachlorophenol (PCP)	87865	0.4	.....	.....	520	.....	0.002	0.002
89. Phenol	108952	.....	0.20	0.6	1.9	.....	4,000	30,000
90. Polychlorinated Biphenyls (PCBs)	.....	2	.....	.....	.....	31,200	[f] 7.3E–06	[f] 7.3E–06
91. Pyrene	129000	.....	0.20	0.03	.....	860	3	3
92. Selenium	7782492	.....	0.20	0.005	.....	4.8	25	95
93. Tetrachloroethylene	127184	0.0021	.....	.....	76	.....	2.4	2.9
94. Thallium	7440280	.....	0.20	0.000068	.....	116	0.048	0.054
95. Toluene	108883	.....	0.20	0.0097	17	.....	29	52
96. Toxaphene	8001352	1.1	.....	.....	6,300	.....	6.6E–05	6.6E–05
97. Trichloroethylene	79016	0.05	.....	.....	13	.....	0.3	0.7
98. Vinyl Chloride	75014	1.5	.....	.....	1.7	.....	0.020	0.18
99. Zinc	7440666	.....	0.20	0.3	.....	47	450	580

[a] This criterion refers to the inorganic form of arsenic only.
[b] This criterion is expressed as fibers per liter (fibers/L). The criterion for asbestos is the Maximum Contaminant Level Goal (MCLG) developed under the Safe Drinking Water Act (SDWA) (56 FR 3526, January 30, 1991).
[c] EPA's national 304(a) recommended criteria for benzene use a CSF range of 0.015 to 0.055 per mg/kg-day. EPA proposes to use the higher end of the CSF range (0.055 per mg/kg-day) to derive the proposed benzene criteria for Washington.
[d] The criterion for copper is the Maximum Contaminant Level Goal (MCLG) developed under the Safe Drinking Water Act (SDWA) (40 CFR 141.80, June 7, 1991).
[e] This criterion is expressed as the fish tissue concentration of methylmercury (mg methylmercury/kg fish). See *Water Quality Criterion for the Protection of Human Health: Methylmercury* (EPA–823–R–01–001, January 3, 2001) for how this value is calculated using the criterion equation in EPA's 2000 Human Health Methodology rearranged to solve for a protective concentration in fish tissue rather than in water.
[f] This criterion applies to total PCBs (*e.g.*, the sum of all congener or isomer or homolog or Aroclor analyses).
* Bis(2-Chloro-1-Methylethyl) Ether was previously listed as Bis(2-Chloroisopropyl) Ether.

(c) *Applicability.* (1) The criteria in paragraph (b) of this section apply to waters with Washington's designated uses cited in paragraph (d) of this section and apply concurrently with any water quality criteria adopted by the state, except where pollutant- or waterbody-specific state human health criteria regulations determined by EPA to meet the requirements of Clean Water Act section 303(c) and 40 CFR part 131 apply, in which case Washington's pollutant- or waterbody-specific criteria will apply and not the criteria in paragraph (b) of this section.

(2) The criteria established in this section are subject to Washington's general rules of applicability in the same way and to the same extent as are other federally promulgated and state-adopted numeric criteria when applied to the same use classifications in paragraph (d) of this section.

(i) For all waters with mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the waterbody including at the end of any discharge pipe, conveyance or other discharge point.

(ii) The state must not use a low flow value below which numeric non-carcinogen and carcinogen human health criteria can be exceeded that is less stringent than the harmonic mean flow for waters suitable for the establishment of low flow return frequencies (*i.e.*, streams and rivers). Harmonic mean flow is a long-term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

(iii) If the state does not have such a low flow value for numeric criteria, then none will apply and the criteria in paragraph (b) of this section herein apply at all flows.

(d) *Applicable use designations.* (1) All waters in Washington assigned to the following use classifications are subject to the criteria identified in paragraph (d)(2) of this section:

(i) Fresh waters—

(A) Miscellaneous uses: Harvesting (Fish harvesting);

(B) Recreational uses;

(C) Water supply uses: Domestic water (Domestic water supply);

(ii) Marine waters—

(A) Miscellaneous uses: Harvesting (Salmonid and other fish harvesting, and crustacean and other shellfish (crabs, shrimp, scallops, etc.) harvesting);

(B) Recreational uses;

(C) Shellfish harvesting: Shellfish harvest (Shellfish (clam, oyster, and mussel) harvesting)

Note to paragraph (d)(1): The source of these uses is Washington Administrative Code 173–201A–600 for Fresh waters and 173–201A–610 for Marine waters.

(2) For Washington waters that include the use classification of Domestic Water, the criteria in column C1 of Table 1 in paragraph (b) of this section apply. For Washington waters that include any of the following use classifications but do not include the use classification of Domestic Water, the criteria in column C2 of Table 1 in paragraph (b) of this section apply: Harvesting (fresh and marine waters), Recreational Uses (fresh and marine waters), and Shellfish Harvesting.

[FR Doc. 2015–22592 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 271

[EPA–R06–RCRA 2015–0070; FRL–9933–78–Region 6]

Louisiana: Final Authorization of State Hazardous Waste Management Program Revisions

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The State of Louisiana has applied to the Environmental Protection Agency (EPA) for Final authorization of the changes to its hazardous waste program under the Resource Conservation and Recovery Act (RCRA). EPA proposes to grant Final authorization to the State of Louisiana. In the "Rules and Regulations" section of this **Federal Register**, EPA is authorizing the changes by direct final rule. EPA did not make a proposal prior to the direct final rule because we believe this action is not controversial and do not expect comments that oppose it. We have explained the reasons for this authorization in the preamble to the direct final rule. Unless we get written comments which oppose this authorization during the comment period, the direct final rule will become effective 60 days after publication and we will not take further action on this proposal. If we receive comments that oppose this action, we will withdraw the direct final rule and it will not take effect. We will then respond to public comments in a later final rule based on this proposal. You may not have another opportunity for comment. If you want to comment on this action, you must do so at this time.

DATES: Send your written comments by October 14, 2015.

ADDRESSES: Submit any comments identified by Docket ID No. EPA–R06–RCRA–2015–0070, by one of the following methods:

1. *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the on-line instructions for submitting comments.

2. *Email: patterson.alima@epa.gov.*

3. *Mail:* Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733.

4. *Hand Delivery or Courier:* Deliver your comments to Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733.

Instructions: Do not submit information that you consider to be CBI or otherwise protected through regulations.gov, or email. Direct your comment to Docket No. EPA–R06–RCRA–2015–0070. The Federal regulations.gov Web site is an "anonymous access" system, which means the EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to the EPA without going through regulations.gov, your email address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, the EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If the EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, the EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. You can view and copy Louisiana's application and associated publicly available materials from 8:30 a.m. to 4 p.m. Monday through Friday at the following locations: Louisiana Department of Environmental Quality, 602 N. Fifth Street, Baton Rouge, Louisiana 70884–2178, phone number (225) 219–3559 and EPA, Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733, phone number (214) 665–8533. Interested persons wanting to examine these documents should make an appointment with the office at least two weeks in advance.

FOR FURTHER INFORMATION CONTACT: Alima Patterson, Region 6, Regional Authorization Coordinator, State/Tribal Oversight Section (6PD–O), Multimedia Planning and Permitting Division, EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733, (214) 665–8533) and Email address *patterson.alima@epa.gov.*

SUPPLEMENTARY INFORMATION: For additional information, please see the direct final published in the "Rules and Regulations" section of this **Federal Register**.

Dated: August 21, 2015.

Ron Curry,

Regional Administrator, Region 6.

[FR Doc. 2015–23072 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 85

[Docket No: FWS–HQ–WSR–2015–0006; FVWF94100900000–XXX–FF09W11000]

RIN 1018–AW66

Clean Vessel Act Grant Program

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Advance notice of proposed rulemaking; notice of intent.

SUMMARY: The U.S. Fish and Wildlife Service (Service) is seeking comments to assist us in developing a proposed rule for the Clean Vessel Act Grant Program (CVA). The proposed rule will use plain language to clarify topics that have led to varying interpretations and will incorporate changes in legislation and technology. We seek public input to advise us on topics of interest to the boating community in regard to projects funded through CVA. We ask for response from anyone having an interest in CVA and associated topics, but particularly from members of the public having experience, expertise, or both in administering CVA; entities receiving services from CVA-funded facilities; entities manufacturing, selling, or installing CVA-funded facilities and equipment; or persons possessing other professional or practical knowledge of the subjects we present in this document. We present topics of interest, but encourage comments on any topic relevant to CVA and the proposed rulemaking. The terms *you* or *your* in this document refer to those members of the public from whom we seek response. The terms *we, us,* and *our* refer to the U.S. Fish and Wildlife Service.

DATES: Submit comments on or before November 13, 2015.

ADDRESSES: You may submit comments, identified by docket number FWS–R9–WSR–2015–0006, by any of the following methods:

- Federal eRulemaking Portal: *http://www.regulations.gov.* Follow the instructions for submitting comments.
- U.S. mail: Public Comments Processing, Attn: Docket No. FWS–R9–WSR–2015–0006; U.S. Fish and Wildlife Service; Division of Policy, Performance, and Management Programs; MS: BPHC; 5275 Leesburg Pike, Falls Church, VA 22041–4501.
- Hand Delivery/Courier: U.S. Fish and Wildlife Service; Division of Policy, Performance, and Management Programs; 5275 Leesburg Pike, Falls Church, VA 22041–4501.

We will not accept email or faxes. All submissions received must include the agency name and docket number for this rulemaking. We will post all comments received without change to *http://www.regulations.gov,* including any personal information provided. For detailed instructions on submitting comments and other information on the rulemaking process, see the "Public Participation" heading in **SUPPLEMENTARY INFORMATION.**

Docket: For access to the docket to read background documents or comments received, go to *http://www.regulations.gov* and search for FWS–R9–WSR–2015–0006.

FOR FURTHER INFORMATION CONTACT: Lisa E. Van Alstyne, Wildlife and Sport Fish Restoration Program, Division of Policy and Programs, U.S. Fish and Wildlife Service, 703–358–1942.

SUPPLEMENTARY INFORMATION:

Background

The Clean Vessel Act of 1992 (Act) (Pub. L. 102–587, title V, subtitle F) amends the Sport Fish Restoration Act (16 U.S.C. 777c) and establishes a program that provides matching grants to States for projects that address septic waste from recreational vessels. Grants may be used to conduct coastal surveys and establish plans; construct, renovate, operate, and maintain pumpout and other waste reception facilities for recreational vessels; and conduct programs to educate boaters about the environmental and health issues associated with improperly disposing of human waste. Priority consideration was established in the Act for projects that are in coastal States, include public/private partnerships, and include innovative ways to increase project availability and use. The Sportfishing and Recreational Boating Safety Act of 2005 (SAFETEA–LU) (Pub. L. 109–59, Title X, section 10131) amends the Clean Vessel Act to remove the preference for projects in coastal States.

Since inception, the Clean Vessel Act grant program (CVA) has awarded more than $246 million. The projects funded have helped States to build an infrastructure that links services within and between States and raised awareness of the benefits of properly disposing of septic waste. As a result, States have experienced a reduction in beach and shellfish bed closures, enhanced boater awareness and satisfaction, and improved water quality in recreational areas.

In the 1990s, we published in the **Federal Register** three documents related to CVA: Clean Vessel Act Pumpout Grant Program, Final rule (59 FR 11204, March 10, 1994); Clean Vessel Act: Pumpout Station and Dump Station Technical Guidelines, Notice of final guidelines (59 FR 11290, March 10, 1994); and Clean Vessel Act Pumpout Symbol, Slogan, and Program Crediting, Final rule (62 FR 45344, August 27, 1997). The CVA regulations are located in title 50 of the Code of Federal Regulations (CFR) in part 85 (50 CFR part 85).

As we move forward in the program, we propose not only to build on the success of CVA to date, but also to seek new and innovative ways to serve the boating public into the future. We hosted four open forum discussions between October 2014 and February 2015 in which we asked States and other stakeholders to share their knowledge and opinions on topics associated with implementing CVA nationally. Participants informed us on challenges to implementation and consistency that have arisen since the program began, changes in focus that have evolved as the program has matured, and successful approaches they would like to continue. These discussions prompted us to seek input on certain topics from a larger audience.

Information Requested

With this advance notice of proposed rulemaking (ANPR), the Service is seeking information, comments, and suggestions that will help us to consider how best to address updating the CVA regulations and Technical Guidelines. We ask for your help in identifying significant issues that interfere with participation in CVA, administration of CVA, services provided under CVA, or successful implementation of CVA projects. We ask for your responses on successful approaches or foundational benefits that you suggest we should preserve in future rulemaking. We intend to use your input to develop updated regulations and guidelines in one location at 50 CFR part 85. After receiving and considering your responses to our requests in this ANPR, we will publish a proposed rule in the **Federal Register** for public review and comment. In particular, we encourage you to give comments and suggestions on the issues described in the body of the ANPR. When commenting, please indicate which of the listed issues your comment addresses and to which question you are responding. If your comments cover issues outside of those listed, please identify them as *Other.*

There are several topics where your response may reference a State or local law, regulation, standard, or other legal

reference. When your comments include a legal reference, please specifically cite the legal document. We recommend you use citation formats in *Association of Legal Writing Directors (ALWD) Guide to Legal Citation* or *Bluebook: A Uniform System of Citation* as your guide. If possible, please give a location where we may access the document electronically.

Issue 1: Technical information

(a) The Technical Guidelines (Guidelines) issued on March 10, 1994, reflect a collaborative effort between the Service and various entities that have expertise or interest in boating, clean water, waste disposal equipment, and other associated topics. We consulted with the Environmental Protection Agency (EPA), the U.S. Coast Guard (USCG), and the National Oceanic and Atmospheric Administration (NOAA) when developing the guidelines. We also asked for advice and input from States, local municipalities, boat users, manufacturers of pumpout equipment, marina operators, conservation groups, interest organizations, and the public. The resulting document reflects the best available knowledge at that time and informs the public on basic principles that were foundational to the grant program in the beginning stages of development.

(b) We are aware that advances have been made in technology, technique, and approach since we published the Guidelines. Through this notice, we ask for those same groups and any new user and interest groups, technical experts, and practitioners to advise us on some specific and some general technology issues. When responding to a topic, please address to the extent possible the following regarding the technology, technique, or approach:

(1) For technology, if it is currently available or would need to be developed;

(2) Cost;

(3) Expertise needed;

(4) Supporting infrastructure or other technology needed;

(5) Long-term personnel investment; and

(6) Any known obstacles.

(c) We ask that if you have knowledge of such advancements, you discuss developments that have been made since 1994, or are anticipated in the next few years, that improve, support, or otherwise affect CVA. Discuss how you suggest we should use this information to inform new guidelines.

(d) We ask your comments on these specific topics:

(1) States that experience seasonal cold weather likely have pumpout facility operators that choose to close for the season, winterize their pumpout equipment, or both. However, boaters may travel to those areas seeking pumpout services. What technology, technique, or approach would address the need to provide pumpout services in cold weather areas?

(2) How important is it for States to monitor the amount of waste removed through pumpouts? Should the guidelines strongly recommend meters or other "add-on" equipment to accomplish this? Should the regulations require it? If so, when should the new requirement be effective?

(3) Floating restrooms are eligible for CVA funding. However, with the emphasis of the program on providing facilities that benefit boaters, the current regulations state they cannot be connected to land or anything else that is connected to land, restricting floating restrooms to water-only access. Therefore, floating restrooms connected to an attached dock cannot be funded through CVA. (Land-based restrooms are currently ineligible.) We have received requests to revisit this restriction and consider the possibility of allowing floating restrooms to be attached to a dock and to allow piping to run directly from the floating restroom to a land connection for waste disposal. We ask you to comment on:

(i) Whether we should allow floating restrooms to be connected to land or docks. What are the advantages and disadvantages? Should there be limitations?

(ii) Are you aware of legal issues that affect floating restrooms, such as State or local regulations, permit restrictions, or building standards? If so, please discuss the effect and cite the regulation, code, or standard.

(iii) There are concerns with protecting floating restrooms from vandalism and other damage. If floating restrooms are allowed to be connected to land or docks, the potential for vandalism may increase with easier land-side access. Do you have any suggestions for how to address these concerns?

(iv) Is it important to maintain the emphasis on floating restrooms serving only the boating public? If we were to allow floating restrooms to be connected to docks, what approaches would restrict use to serve only the boating public?

(v) What approaches would ensure that floating restrooms are designed to limit land-side access and potential over-use by the non-boating public?

(vi) Should we participate in efforts to develop standards or best management practices for floating restrooms?

Issue 2: State Participation in Offering Operation and Maintenance (O&M) Funds for CVA Projects

(a) Some States offer CVA O&M, and some do not. We suggest that offering O&M greatly benefits CVA by:

(1) Increasing the number of pumpout facilities by supporting operators that otherwise might not be able to financially support ongoing service;

(2) Providing a mechanism to reimburse operators when they respond to equipment failures, increasing pumpout facility availability and functionality; and

(3) Helping to extend the useful life of the investment.

(b) The Service does not have a comprehensive list of how many and which States do not participate in offering O&M for pumpout projects, or the reasons why these States have chosen this approach. We would like to know more about those States that participate, and those that do not, in order to identify if changes in regulations or guidelines could improve this aspect of CVA. We ask States to respond telling us:

(1) Does your State offer O&M grant funding to subgrantees and operators?

(2) If your State does offer O&M funding, describe your program, including:

(i) Any restrictions on the type of projects that may receive O&M funds;

(ii) Any limits on O&M funds;

(iii) How you administer O&M processing; and

(iv) Any obstacles you currently experience that you suggest we may alleviate either through regulation or other means.

(3) If your State does not offer O&M funding, describe the reasons why your State has chosen not to offer O&M funding. If the reasons include laws or regulations, please cite as directed under Information Requested. Include in your comments changes you suggest we consider that might assist your State to begin a CVA O&M program.

Issue 3: Do any existing or proposed State or local laws affect CVA?

(a) Please cite, as directed under Information Requested, and discuss any State or local laws or regulations that either support or impede CVA projects. When available, include web links to the law or regulation.

(b) Discuss specifically how the law or regulation affects CVA projects. If it is a positive effect, tell us if you believe the Service should consider adopting similar principles. If it is a negative effect, tell us how it restricts your ability to complete successful projects. Please

suggest any changes in the CVA regulation that would increase your ability to complete successful projects within the parameters of current or proposed State and local laws and regulations.

Issue 4: User Fees

(a) The current regulations at 50 CFR 85.44 allow operators of facilities constructed, operated, or maintained with CVA grant funds to charge users a maximum $5 fee, with no justification. If an operator chooses to charge a higher fee, it must be justified. The proceeds must be accounted for and used by the operator to defray the operation and maintenance costs of the facility as long as the facility is needed and serves its intended purpose. The Service was to evaluate the maximum fee each year for inflation and other potential considerations. The Service has not taken this action to date.

(b) During an open forum discussion at the States Organization for Boating Access Conference on October 6, 2014, we asked States to comment on the following questions:

(1) Should the maximum fee be increased? Decreased?

(2) What are the pros and cons of higher fees?

(3) What alternatives do you suggest other than a maximum fee (Ex: sliding scale)?

(4) Should fees correspond to usage (Ex: gallons pumped, holding tank size)?

(5) Should the method of service influence the fees charged (Ex: self-serve vs. pumpout assistance)?

(c) We received a range of responses that fall into five general categories:

(1) Support no change to the current regulations. The $5 maximum fee works well, and boaters are used to it.

(2) Suggest the regulations be changed to mandate or encourage free pumpout services. Offering free pumpout services increases the number of boaters using pumpouts, decreases the amount of inappropriately disposed boater septic waste, and reduces the burden for operators in States that offer CVA O&M funding.

(3) Suggest the regulations be changed to allow a sliding scale with a $5 maximum for boats with smaller holding tanks, increasing fees with the size of the holding tank. An issue with this option is that not all pumpout equipment is installed with monitoring capability to gauge the number of gallons pumped.

(4) Address the fee issue by maintaining a similar approach as in the current regulations, but increase the fee.

(5) Allow operators to charge a fee according to the prevailing market rate for the area they serve.

(d) We are interested in comments from States, boaters, operators, and interest organizations that address the questions and responses above. When responding, please consider:

(1) The maximum fee that boaters will accept as reasonable for the service they receive;

(2) How the fee schedule may influence boater usage;

(3) How the fee schedule may affect water quality;

(4) If we need to consider State and local laws or codes when establishing a fee schedule; and

(5) How reduced fees may affect operators that incur additional costs for:

(i) Removing septic waste via a waste hauler from an on-site holding tank where municipal sewer service is not available;

(ii) Disposing of boater waste via municipal sewer connections where the municipality charges an additional fee for boater waste (Ex: hazardous waste disposal fee); or

(iii) Other actions to process or dispose of boater waste.

Issue 5: Defining "Recreational Vessel" and Access to CVA-Funded Services

(a) We have received many comments requesting clarity on how to define "recreational vessel" in the context of CVA and whether we should consider allowing CVA-funded facilities to be available to non-recreational vessels (Ex: house boats, commercial vessels). We ask your comments on the following:

(1) How should we define "recreational vessel" for CVA? Should the term include vessels that are not for personal use, but that transport the public to recreational opportunities? (Ex: dive boats, fishing charters)

(2) What criteria might we use that would clearly separate a recreational vessel from a non-recreational vessel?

(b) We have considered that the ultimate benefit of CVA is clean recreational waters that benefit all users. We have engaged in discussions that ask us to consider allowing CVA-funded pumpouts to be available for use by other than what we define as a "recreational vessel." We ask for comments on the following:

(1) Should CVA-funded facilities be available to serve all vessels, regardless of their designation as recreational or non-recreational? What are the advantages and disadvantages?

(2) If CVA-funded facilities are used to service other than non-recreational vessels, should operators be allowed to charge a higher fee for non-recreational use? (The rationale is that the higher fees would help pay for replacement/repairs of the equipment that will have a reduced useful life due to the additional burden on the equipment.)

(3) Are there any user groups or vessel types that should be fully excluded from consideration for expanding availability of CVA-funded pumpouts? Why or why not?

(4) If we choose to expand eligible use, what restrictions, if any, should be imposed on non-recreational vessels using CVA-funded pumpouts?

Issue 6: Definition of "Useful Life"

(a) The term "useful life" as used in the current CVA regulations was intended to relate to the functional longevity of the equipment. Using this approach, there are multiple considerations that could influence the useful life of a pumpout project, such as environmental effects (marine vs. freshwater environment, weather), biological effects (quagga mussels), amount and type of usage, adequate maintenance, boater education on proper use, and equipment components that are more vulnerable to wear or failure. In addition, it is likely that more than one of these considerations are present at one time, compounding potential impacts. Many States indicate that they have moved away from looking at the operational longevity of the equipment and instead have set a contractual requirement for the number of years the operator must maintain the equipment.

The above information has led us to reconsider our regulatory approach for how long a pumpout facility must be maintained and operational for its intended purpose. We also consider that a primary goal of CVA is to have sufficient available and functional pumpout facilities and that they contribute to a network of pumpout facilities for continued boater access and use.

(b) We typically employ useful life consideration for capital improvements. We define a "capital improvement" as: (1) a new structure that costs at least $25,000 to build; or (2) altering, renovating, or repairing an existing structure if it increases the structure's useful life by 10 years or if it costs at least $25,000. The focus is on structures attached to real property.

The cost of a typical land-based pumpout facility is below the threshold for a capital improvement. Mobile or movable pumpout facilities, such as boats and floating restrooms, we consider personal property and not a capital improvement. We, therefore, must consider that using useful life to

measure obligation for a pumpout facility may not benefit the consistency and viability of the CVA program mission.

We suggest the alternative approach of applying in regulation an obligation for a minimum number of years that an operator must maintain an operational pumpout for its intended purpose. After this time, an operator may choose to continue the obligation for another period under the CVA grant program, continue operation outside the CVA grant program, or cease operation of the pumpout facility.

The majority of States responding to an inquiry suggested 10 years, but other suggestions ranged from 4 to 20 years.

(c) We ask for your comments on the following:

(1) Which approach do you suggest is the best for the continued success of CVA, and why do you prefer it?

(2) What obligation do you suggest an operator assume when participating in CVA, including how long an operator must maintain a CVA-funded pumpout facility?

(3) If a State offers O&M funding for existing facilities, should participation in O&M extend the obligation to maintain and operate the facility? For example, if we assume a fixed-year obligation for maintaining a pumpout facility, for each year that the operator receives O&M funding should it extend the obligation an additional year?

(4) What CVA-funded actions would you suggest we identify that, if completed, will restart the fixed-year obligation period? (Ex: replacement, major renovation, etc.)

(5) We discussed in Issue 5 the possibility of expanding the type of vessels that could be serviced by CVA-funded facilities. If we choose the approach to require a fixed-year obligation for a CVA-funded facility, the CVA-funded facility would be obligated to be maintained and functional for the designated period regardless of use, so additional wear and tear would be the responsibility of the operator to address during that period. What advantages, disadvantages, or other effects should we consider regarding this combined approach?

Public Participation

We seek comments from you in response to the topics and questions above. We also seek any relevant comments on other issues related to this proposed rulemaking. We especially seek recommendations for effective and efficient approaches to CVA. After analyzing the comments received from this ANPR, we will proceed with a proposed rulemaking.

All submissions received must include the Service docket number for this notice. Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal information—may be made publicly available. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

The Service supports a collaborative process as we develop the proposed rule. After the comment period ends for the ANPR, we will post information on other opportunities to comment prior to the proposed rule, background, and past comments received at: *http://fawiki.fws.gov/display/CR5C8/CVA+Review+50+CFR+85+Home.*

Dated: August 31, 2015.

Karen Hyun,

Acting Principal Deputy Assistant Secretary for Fish and Wildlife and Parks.

[FR Doc. 2015–22723 Filed 9–11–15; 8:45 am]

BILLING CODE 4310–55–P

Notices

Federal Register
Vol. 80, No. 177
Monday, September 14, 2015

This section of the FEDERAL REGISTER contains documents other than rules or proposed rules that are applicable to the public. Notices of hearings and investigations, committee meetings, agency decisions and rulings, delegations of authority, filing of petitions and applications and agency statements of organization and functions are examples of documents appearing in this section.

DEPARTMENT OF AGRICULTURE

Forest Service

Ketchikan Resource Advisory Committee

AGENCY: Forest Service, USDA.

ACTION: Notice of meeting.

SUMMARY: The Ketchikan Resource Advisory Committee (RAC) will meet in Ketchikan, Alaska. The committee is authorized under the Secure Rural Schools and Community Self-Determination Act (the Act) and operates in compliance with the Federal Advisory Committee Act. The purpose of the committee is to improve collaborative relationships and to provide advice and recommendations to the Forest Service concerning projects and funding consistent with title II of the Act. The meeting is open to the public. Additional RAC information, including the meeting agenda and the meeting summary/minutes can be found at the following Web site: *https://www.fs.usda.gov/main/pts.*

DATES: The meeting will be held October 14, 2015, at 4:00 p.m. All RAC meetings are subject to cancellation. For status of meeting prior to attendance, please contact the person listed under **FOR FURTHER INFORMATION CONTACT.**

ADDRESSES: The meeting will be held at the Ketchikan Misty Fiords Ranger District, 3031 Tongass Avenue, Ketchikan, Alaska. A conference line has been set up for those wishing to listen in by telephone, for the conference call number, please contact the person listed under **FOR FURTHER INFORMATION CONTACT.**

Written comments may be submitted as described under **SUPPLEMENTARY INFORMATION** All comments, including names and addresses when provided, are placed in the record and are available for public inspection and copying. The public may inspect comments received at Ketchikan Misty Fiords Ranger District. Please call ahead to facilitate entry into the building.

FOR FURTHER INFORMATION CONTACT: Diane L. Olson, RAC Coordinator, by phone at 907–228–4105 or via email at *dianelolson@fs.fedus.*

Individuals who use telecommunication devices for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 1–800–877–8339 between 8:00 a.m. and 8:00 p.m., Eastern Standard Time, Monday through Friday.

SUPPLEMENTARY INFORMATION: The purpose of the meeting is:

1. To update members on past RAC projects, and
2. Propose new RAC projects.

The meeting is open to the public. The agenda will include time for people to make oral statements of three minutes or less. Individuals wishing to make an oral statement should request in writing by October 9, 2015, to be scheduled on the agenda. Anyone who would like to bring related matters to the attention of the committee may file written statements with the committee staff before or after the meeting. Written comments and requests for time to make oral comments must be sent to Diane L. Olson, RAC Coordinator, Ketchikan Misty Fiords Ranger District, 3031 Tongass Avenue, Ketchikan, Alaska 99901; by email to *dianelolson@fsled.us,* or via facsimile to 907–225–8738.

Meeting Accommodations: If you are a person requiring reasonable accommodation, please make requests in advance for sign language interpreting, assistive listening devices or other reasonable accomodation for access to the facility or proceedings by contacting the person listed in the section titled **FOR FURTHER INFORMATION CONTACT.** All reasonable accommodation requests are managed on a case by case basis.

Dated: September 1, 2015.

Jeffrey DeFreest,

District Ranger.

[FR Doc. 2015–22786 Filed 9–11–15; 8:45 am]

BILLING CODE M

COMMISSION ON CIVIL RIGHTS

Agenda and Notice of Public Meeting of the Delaware Advisory Committee

AGENCY: Commission on Civil Rights.

ACTION: Announcement of meeting.

SUMMARY: Notice is hereby given, pursuant to the provisions of the rules and regulations of the U.S. Commission on Civil Rights (Commission), and the Federal Advisory Committee Act (FACA) that a briefing meeting of the Delaware Advisory Committee to the Commission will convene at 1:00 p.m. (EDT) on Thursday, October 8, 2015, by teleconference. The purpose of the meeting is to hear from experts who will share information about the impact that discriminatory public school disciplinary practices and policies have on children of color. This presentation will inform the DE Advisory Committee's civil rights review of discriminatory school discipline in the state's public schools and whether the Supportive School Discipline Initiative is employed by Delaware schools.

Interested members of the public may listen to the discussion by calling the following toll-free conference call number 1–888–359–3624 and conference call code: 2977026#. Please be advised that before placing them into the conference call, the conference call operator will ask callers to provide their names, their organizational affiliations (if any), and email addresses (so that callers may be notified of future meetings). Callers can expect to incur charges for calls they initiate over wireless lines, and the Commission will not refund any incurred charges. Callers will incur no charge for calls they initiate over land-line connections to the toll-free telephone number.

Persons with hearing impairments may also follow the discussion by first calling the Federal Relay Service at 1–800–977–8339 and providing the operator with the above conference call number and conference call code.

Members of the public are invited to submit written comments; the comments must be received in the regional office by Monday, October 9, 2015. Written comments may be mailed to the Eastern Regional Office, U.S. Commission on Civil Rights, 1331 Pennsylvania Avenue, Suite 1150, Washington, DC 20425, faxed to (202) 376–7548, or emailed to Evelyn Bohor at *ero@usccr.gov.* Persons who desire additional information may contact the Eastern Regional Office at (202) 376–7533.

The activities of this advisory committee, including records and

documents discussed during the meeting, will be available for public viewing, as they become available at: *https://database.faca.gov/committee/meetings.aspx?cid=240.* Records generated from this meeting may also be inspected and reproduced at the Eastern Regional Office, as they become available, both before and after the meeting. Persons interested in the work of this advisory committee are advised to go to the Commission's Web site, *www.usccr.gov,* or to contact the Eastern Regional Office at the above phone number, email or street address.

Agenda

Administrative Matters

Ivy L. Davis, Director, Eastern Regional Office and Designated Federal Official

Welcome and Introductions

Enid Wallace-Simms, Vice Chair

Expert Presentations and Discussion

DE State Advisory Committee

Open Comment

DATES: Thursday, October 8, 2015 at 1:00 p.m. (EDT).

ADDRESSES: The meeting will be held via teleconference:

Public Call Information

Conference Call-in Number: 1–888–359–3624; Conference Call ID code: 2977026.

TDD: Dial Federal Relay Service 1–800–977–8339 and give the operator the above conference call-in number and conference call code.

FOR FURTHER INFORMATION CONTACT: Ivy L. Davis at *ero@usccr.gov,* or 202–376–7533.

Dated: September 8, 2015.

David Mussatt,

Chief, Regional Programs Unit.

[FR Doc. 2015–22954 Filed 9–11–15; 8:45 am]

BILLING CODE 6335–01–P

COMMISSION ON CIVIL RIGHTS

Agenda and Notice of Public Meeting of the Virginia Advisory Committee

AGENCY: Commission on Civil Rights.

ACTION: Announcement of meeting.

SUMMARY: Notice is hereby given, pursuant to the provisions of the rules and regulations of the U.S. Commission on Civil Rights (Commission), and the Federal Advisory Committee Act (FACA) that both an orientation and planning meeting of the Virginia Advisory Committee to the Commission will convene at 2:00 p.m. (EDT) on Thursday, October 1, 2015, by teleconference. The purpose of the orientation meeting is to inform the newly appointed members about the rules of operation for the advisory committee. The purpose of the planning meeting is to begin discussing possible topics for the advisory committee's expected civil rights review.

Interested members of the public may listen to the discussion by calling the following toll-free conference call number 1–888–437–9445 and conference call code: 8116017#. Please be advised that before placing them into the conference call, the conference call operator will ask callers to provide their names, their organizational affiliations (if any), and email addresses (so that callers may be notified of future meetings). Callers can expect to incur charges for calls they initiate over wireless lines, and the Commission will not refund any incurred charges. Callers will incur no charge for calls they initiate over land-line connections to the toll-free telephone number.

Persons with hearing impairments may also follow the discussion by first calling the Federal Relay Service at 1–800–977–8339 and providing the operator with the above conference call number and conference call code.

Members of the public are invited to submit written comments; the comments must be received in the regional office by Monday, November 2, 2015. Written comments may be mailed to the Eastern Regional Office, U.S. Commission on Civil Rights, 1331 Pennsylvania Avenue, Suite 1150, Washington, DC 20425, faxed to (202) 376–7548, or emailed to Evelyn Bohor at *ero@usccr.gov.* Persons who desire additional information may contact the Eastern Regional Office at (202) 376–7533.

The activities of this advisory committee, including records and documents discussed during the meeting, will be available for public viewing, as they become available at: *https://database.faca.gov/committee/meetings.aspx?cid=279.* Records generated from this meeting may also be inspected and reproduced at the Eastern Regional Office, as they become available, both before and after the meeting. Persons interested in the work of this advisory committee are advised to go to the Commission's Web site, *www.usccr.gov,* or to contact the Eastern Regional Office at the above phone number, email or street address.

Agenda

Administrative Matters

Ivy L. Davis, Director, Eastern Regional Office and Designated Federal Official

Welcome and Introductions

K. Shiek Pal, Chair

Orientation Meeting

VA State Advisory Committee

Planning Meeting

VA State Advisory Committee

DATES: Thursday, October 1, 2015 at 2:00 p.m. (EDT).

ADDRESSES: The meeting will be held via teleconference:

Public Call Information

Conference Call-in Number: 1–888–437–9445; Conference Call ID code: 8116017#.

TDD: Dial Federal Relay Service 1–800–977–8339 and give the operator the above conference all-in number and conference call code.

FOR FURTHER INFORMATION CONTACT: Ivy L. Davis at *ero@usccr.gov,* or 202–376–7533.

Dated: September 8, 2015.

David Mussatt,

Chief, Regional Programs Unit.

[FR Doc. 2015–22955 Filed 9–11–15; 8:45 am]

BILLING CODE 6335–01–P

DEPARTMENT OF COMMERCE

Submission for OMB Review; Comment Request

The Department of Commerce will submit to the Office of Management and Budget (OMB) for clearance the following proposal for collection of information under the provisions of the Paperwork Reduction Act (44 U.S.C. Chapter 35).

Agency: Bureau of Economic Analysis (BEA).

Title: Annual Survey of U.S. Direct Investment Abroad.

OMB Control Number: 0608–0053.

Form Number: BE–11.

Type of Request: Regular submission.

Number of Respondents: An estimated 1,900 U.S. parents will file data for their U.S. operations on the A form; 21,800 foreign affiliates, which include 20,500 B forms, 1,150 C forms, and 150 D forms; and 500 Claim for Exemption forms.

Estimated Total Annual Burden Hours: 262,250 hours. Total annual burden is calculated by multiplying the estimated number of submissions of each form by the average hourly burden

per form, which is 7 hours for the A form, 12 hours for the B form, 2 hours for the C form, 1 hour for the D form, and 1 hour for the Claim for Exemption forms.

Estimated Time per Respondent: 138.0 hours per respondent (262,250 hours/1,900 U.S. parents) is the average, but may vary considerably among respondents because of differences in company structure, size, and complexity.

Needs and Uses: The Annual Survey of U.S. Direct Investment Abroad (Form BE–11) collects financial and operating data covering the operations of U.S. parents and their foreign affiliates, including their balance sheets, income statements, property, plant, and equipment, employment and employee compensation, merchandise trade, sales of goods and services, taxes, and research and development activity. The survey is a sample survey that covers all foreign affiliates above a size-exemption level and their U.S. parents. The sample data are used to derive universe estimates in nonbenchmark years by extrapolating forward similar data reported in the BE–10, Benchmark Survey of U.S. Direct Investment Abroad, which is conducted every five years. The data are needed to measure the size and economic significance of direct investment abroad, measure changes in such investment, and assess its impact on the U.S. and foreign economies.

The data from the survey are primarily intended as general purpose statistics. They should be readily available to answer any number of research and policy questions related to U.S. direct investment abroad.

Affected Public: Businesses or other for-profit organizations.

Frequency: Annual.

Respondent's Obligation: Mandatory.

This information collection request may be viewed at *www.reginfo.gov.* Follow the instructions to view Department of Commerce collections currently under review by OMB.

Written comments and recommendations for the proposed information collection should be sent within 30 days of publication of this notice to *OIRASubmission@omb.eop.gov* or fax to (202) 395–5806.

Dated: September 9, 2015.

Glenna Mickelson,

Management Analyst, Office of the Chief Information Officer.

[FR Doc. 2015–23014 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–06–P

DEPARTMENT OF COMMERCE

Submission for OMB Review; Comment Request

The Department of Commerce will submit to the Office of Management and Budget (OMB) for clearance the following proposal for collection of information under the provisions of the Paperwork Reduction Act (44 U.S.C. chapter 35).

Agency: U.S. Census Bureau.

Title: 2016 Government Units Survey.

OMB Control Number: 0607–0930.

Form Number(s): GUS–1.

Type of Request: Reinstatement, with change, of an expired collection.

Number of Respondents: 77,000.

Average Hours per Response: 15 minutes.

Burden Hours: 19,250.

Needs and Uses: This information request covers the questionnaire needed to conduct the directory survey component of the 2017 Census of Governments. The 2016 Government Units Survey (GUS) will be used to update the universe list of public sector entities for the 2017 Census of Governments. Each of the estimated 77,000 non-school governments will be sent a questionnaire. Respondents will be encouraged to respond to the survey on the Internet but will have the option to answer the questions and return the questionnaire by paper mail. Respondents will be asked to verify or correct the name and mailing address of the government and answer five questions to complete the survey.

The GUS is mailed to all municipalities, townships, counties, and special districts. The 2011 GUS, conducted in advance of the 2012 Census of Governments, consisted of nine broad content areas: Background information, debt, license and permit fees, taxes, retirement/pension plan, government activity, public services, judicial or legal activities, and finance. The 2016 GUS will differ from the former version by shortening the number of content areas. The 2016 GUS consists of only two broad content areas: Background and employee information. Both the 2011 and 2016 GUS also include(d) both remarks and contact information sections. The first content area for the 2016 GUS consists predominately of yes/no questions and is designed to determine the existence of a government. The employees section of the questionnaire requests the number of paid employees of a government. A notice published in the **Federal Register** on April 1, 2015 stated our intent to ask respondents detailed questions on defined-contribution plans, defined-benefit and post-employment healthcare plans. However, we will not be asking these questions for this collection.

The GUS serves multiple purposes. The GUS will be used to obtain descriptive information on the basic characteristics of governments; to identify and delete inactive units from the official list of public entities maintained by the Census Bureau; to identify file duplicates and units that were dependent on other governments; to update and verify the mailing addresses of governments; and to produce the official count of non-school government units in the United States.

Federal legislation relevant to the American workforce, the Fair Labor Standards Act (FLSA) and the Family Medical Leave Act, refer to the list of governments maintained by the Census Bureau for purposes of administering provisions of these laws. The Bureau of Justice Statistics maintains an interest in the list of active governments and their activities for purposes of administering grant programs. The Bureau of Economic Analysis (BEA) uses the products of the Census of Governments including the counts of state and local governments; and state and local government employment and payroll data. BEA also uses revenue, expenditures, debt, and financial assets data from the Census of Governments for principal inputs to the local government portion of their Gross Domestic Product publication. In addition, users from academia, research organizations, governments, public interest groups, and various businesses provide evidence of their interest through requests for information and requests for assistance in accessing universe information available on the Census Bureau Internet Web site.

Affected Public: State, local or tribal government.

Frequency: Every 5 years.

Respondent's Obligation: Voluntary.

Legal Authority: Title 13 U.S.C., Sections 161 and 193.

This information collection request may be viewed at *www.reginfo.gov.* Follow the instructions to view Department of Commerce collections currently under review by OMB.

Written comments and recommendations for the proposed information collection should be sent within 30 days of publication of this notice to *OIRA_Submission@omb.eop.gov* or fax to (202) 395–5806.

Dated: September 8, 2015.

Glenna Mickelson,

Management Analyst, Office of the Chief Information Officer.

[FR Doc. 2015–22958 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–07–P

DEPARTMENT OF COMMERCE

Census Bureau

Submission for OMB Review; Comment Request

The Department of Commerce will submit to the Office of Management and Budget (OMB) for clearance the following proposal for collection of information under the provisions of the Paperwork Reduction Act (44 U.S.C. chapter 35).

Agency: U.S. Census Bureau, Commerce.

Title: Geographic Partnership Programs.

OMB Control Number: 0607–0795.

Form Number(s): Not applicable.

Type of Request: Regular Submission.

Number of Respondents: 9,900.

Fiscal Year (FY) 2015: 1,900.

FY 2016: 4,000.

FY 2017: 4,000.

Average Hours per Response: 13.5.

Burden Hours: 133,650.

FY 2015: 25,650.

FY 2016: 54,000.

FY 2017: 54,000.

Needs and Uses: The mission of GEO within the U.S. Census Bureau is to plan, coordinate, and administer all geographic and cartographic activities needed to facilitate Census Bureau statistical programs throughout the United States and its territories. GEO manages programs to continuously update geographic data including addresses, spatial features, boundaries, and geographic entities in the Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) System. GEO also conducts research into geographic concepts, methods, and standards needed to facilitate Census Bureau data collection and dissemination programs. Geographic Partnership Programs (GPPs) encourages participants, following Census Bureau guidelines, to review, update, and suggest modifications to geographic data to maintain MAF/TIGER and to ensure the accurate reporting of data from censuses and surveys. Because state, local, and tribal governments have geographic data and current knowledge about where growth and change are occurring in their jurisdictions, their input into the overall development of a continually maintained address list for censuses and surveys makes a vital contribution. The Census Bureau recognizes that state, local, and tribal governments have authoritative geographic data for their jurisdictions. The benefits to local governments in sharing that information as part of the Census Bureaus GPPs are realized with quality data for more accurate results of censuses and surveys. This notice is for a generic clearance that will cover a number of activities required for updating MAF/TIGER with participant-provided address and other geographic information, or obtain address and spatial data for research and evaluation purposes. The information collected in these programs in cooperation with state, local, and tribal governments and other partners is essential to the mission of the Census Bureau and directly contributes to the successful outcome of censuses and surveys conducted by the Census Bureau. The generic clearance allows the Census Bureau to focus its resources on actual operational planning, development of procedures, and implementation of programs to update and improve the geographic data maintained in MAF/TIGER.

Geographic Support System Initiative (GSS–I)

The GSS–I is an integrated program designed to improve geographic data and enhance the quality assessment and measurement for MAF/TIGER. The GSS–I builds on the accomplishments of the last decade's MAF/TIGER Enhancement Program (MTEP), which redesigned MAF/TGER, improved the positional accuracy of TIGER spatial features, and emphasized quality measurement. The Census Bureau plans on a continual update process for MAF/TIGER throughout the decade to support current surveys, including the American Community Survey (ACS). Major participants are the Census Bureau with state, local, and tribal governments. The Census Bureau will contact state, local, and tribal governments to obtain files containing their geographic data to explore data exchange opportunities, and share best practices on maintaining quality geographic data. Governments can provide a file of their geographic data or provide data through a web-based application sponsored by the Census Bureau. Governments can choose the format and medium to provide their data directly to the Census Bureau, or may elect to standardize their data using Community TIGER.

Affected Public: State, local, and tribal governments.

Frequency: Annually.

Respondent's Obligation: Voluntary.

Legal Authority: Title 13 U.S.C. Sections 16, 141, and 193.

This information collection request may be viewed at *www.reginfo.gov.* Follow the instructions to view Department of Commerce collections currently under review by OMB.

Written comments and recommendations for the proposed information collection should be sent within 30 days of publication of this notice to *OIRA_Submission@omb.eop.gov* or fax to (202) 395–5806.

Dated: September 8, 2015.

Glenna Mickelson,

Management Analyst, Office of the Chief Information Officer.

[FR Doc. 2015–22952 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–07–P

DEPARTMENT OF COMMERCE

Economic Development Administration

Notice of Petitions by Firms for Determination of Eligibility To Apply for Trade Adjustment Assistance

AGENCY: Economic Development Administration, Department of Commerce.

ACTION: Notice and opportunity for public comment.

Pursuant to Section 251 of the Trade Act 1974, as amended (19 U.S.C. 2341 *et seq.*), the Economic Development Administration (EDA) has received petitions for certification of eligibility to apply for Trade Adjustment Assistance from the firms listed below. Accordingly, EDA has initiated investigations to determine whether increased imports into the United States of articles like or directly competitive with those produced by each of these firms contributed importantly to the total or partial separation of the firm's workers, or threat thereof, and to a decrease in sales or production of each petitioning firm.

LIST OF PETITIONS RECEIVED BY EDA FOR CERTIFICATION ELIGIBILITY TO APPLY FOR TRADE ADJUSTMENT ASSISTANCE
(9/1/2015 through 9/8/2015)

Firm name	Firm address	Date accepted for investigation	Product(s)
Northridge Gardens, Inc. d/b/a PUREfactory Naturals.	3380 Town Point Drive, #330, Kennesaw, GA 30144	9/4/2015	The firm manufactures lotion bars, hand cream, lip balm, body wash and other body care products.
United Lens	259 Worcester Street, Southbridge, MA 01550	9/3/2015	The firm manufactures finished mirrors, prisms, windows, and other optical components.
The Old Wood Company, LLC	99 Riverside Drive, Asheville, NC 28801	9/3/2015	The firm manufactures tabletops, tables with bases, stools, and other furniture items.
Machining Concepts, Inc.	1304 Industrial Drive, Erie, PA 16505	9/8/2015	The firm manufactures precision component parts comprised of stainless steel and other metals.
Palmetto Plating Company, Inc..	510 Saco Lowell Road Easley SC 29640	9/8/2015	The firm manufactures protective metal coatings and finishes.

Any party having a substantial interest in these proceedings may request a public hearing on the matter. A written request for a hearing must be submitted to the Trade Adjustment Assistance for Firms Division, Room 71030, Economic Development Administration, U.S. Department of Commerce, Washington, DC 20230, no later than ten (10) calendar days following publication of this notice.

Please follow the requirements set forth in EDA's regulations at 13 CFR 315.9 for procedures to request a public hearing. The Catalog of Federal Domestic Assistance official number and title for the program under which these petitions are submitted is 11.313, Trade Adjustment Assistance for Firms.

Dated: September 8, 2015.

Michael S. DeVillo,

Eligibility Examiner.

[FR Doc. 2015–23019 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–WH–P

DEPARTMENT OF COMMERCE

Foreign-Trade Zones Board

[B–31–2015]

Foreign-Trade Zone 44—Mount Olive, New Jersey, Authorization of Production Activity, Robertet, Inc., (Fragrance Compounds), Mount Olive, New Jersey

On May 6, 2015, Robertet, Inc. submitted a notification of proposed production activity to the Foreign-Trade Zones (FTZ) Board for its facility within FTZ 44-Site 1 in Mount Olive, New Jersey.

The notification was processed in accordance with the regulations of the FTZ Board (15 CFR part 400), including notice in the **Federal Register** inviting public comment (80 FR 27628–27631, 05–14–2015). The FTZ Board has determined that no further review of the activity is warranted at this time. The production activity described in the notification is authorized, subject to the FTZ Act and the Board's regulations, including Section 400.14.

Dated: September 4, 2015.

Andrew McGilvray,

Executive Secretary.

[FR Doc. 2015–23077 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

DEPARTMENT OF COMMERCE

Foreign-Trade Zones Board

[B–34–2015]

Authorization of Production Activity; Foreign-Trade Subzone 29F; Hitachi Automotive Systems Americas, Inc. (Automotive Battery Management Systems); Harrodsburg, Kentucky

On May 5, 2015, the Louisville and Jefferson County Riverport Authority, grantee of FTZ 29, submitted a notification of proposed production activity to the Foreign-Trade Zones (FTZ) Board on behalf of Hitachi Automotive Systems Americas, Inc., operator of Subzone 29F in Harrodsburg, Kentucky.

The notification was processed in accordance with the regulations of the FTZ Board (15 CFR part 400), including notice in the **Federal Register** inviting public comment (80 FR 30434–30435, May 28, 2015). The FTZ Board has determined that no further review of the activity is warranted at this time. The production activity described in the notification is authorized, subject to the FTZ Act and the FTZ Board's regulations, including Section 400.14.

Dated: September 3, 2015.

Andrew McGilvray,

Executive Secretary.

[FR Doc. 2015–23079 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

DEPARTMENT OF COMMERCE

Foreign-Trade Zones Board

[B–59–2015]

Foreign-Trade Zone (FTZ) 29—Louisville, Kentucky; Notification of Proposed Production Activity; Custom Quality Services (Liquor Kitting); Louisville, Kentucky

Custom Quality Services submitted a notification of proposed production activity to the FTZ Board for its facility in Louisville, Kentucky within FTZ 29. The notification conforming to the requirements of the regulations of the FTZ Board (15 CFR 400.22) was received on September 2, 2015.

The Custom Quality Services facility is located within Site 1 of FTZ 29. The facility is used for the warehousing, distribution and kitting of liquor and glassware. Pursuant to 15 CFR 400.14(b), FTZ activity would be limited to the specific foreign-status materials and components and specific finished products described in the submitted notification (as described below) and subsequently authorized by the FTZ Board.

Production under FTZ procedures could exempt Custom Quality Services from customs duty payments on the foreign status components used in export production. On its domestic sales, Custom Quality Services would be able to choose the duty rates during customs entry procedures that apply to: Whiskey liquor kits; vodka kits; tequila kits; and, wine kits (duty rate ranges from duty-free to 6.3¢/liter) for the foreign status inputs noted below. Customs duties also could possibly be deferred or reduced on foreign status production equipment.

The components and materials sourced from abroad include: Whiskey, bourbon; tequila; wine; whiskey and cola; vodka; liqueur; specialty-tempered glassware; cut or engraved glassware;

lead crystal glasses; non-lead crystal glasses; and, drinking glasses (duty rate ranges from duty-free to 28.5%).

Public comment is invited from interested parties. Submissions shall be addressed to the Board's Executive Secretary at the address below. The closing period for their receipt is October 26, 2015.

A copy of the notification will be available for public inspection at the Office of the Executive Secretary, Foreign-Trade Zones Board, Room 21013, U.S. Department of Commerce, 1401 Constitution Avenue NW., Washington, DC 20230–0002, and in the "Reading Room" section of the Board's Web site, which is accessible via *www.trade.gov/ftz.*

For further information, contact Elizabeth Whiteman at *Elizabeth.Whiteman@trade.gov* or (202) 482–0473.

Dated: September 4, 2015.

Andrew McGilvray,

Executive Secretary.

[FR Doc. 2015–23078 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

DEPARTMENT OF COMMERCE

Foreign-Trade Zones Board

[B–60–2015]

Foreign-Trade Zone (FTZ) 84—Houston, Texas; Notification of Proposed Production Activity; Mitsubishi Caterpillar Forklift America Inc. (Forklift Trucks); Houston, Texas

Mitsubishi Caterpillar Forklift America Inc. (MCFA), an operator of FTZ 84, submitted a notification of proposed production activity to the FTZ Board for its facility in Houston, Texas. The notification conforming to the requirements of the regulations of the FTZ Board (15 CFR 400.22) was received on August 13, 2015.

MCFA already has authority to produce forklift trucks (Class I through Class V) powered by gasoline, propane or electric motors within Site 27 of FTZ 84. The current request would add certain foreign-status components to the scope of authority. Pursuant to 15 CFR 400.14(b), additional FTZ authority would be limited to the specific foreign-status materials and components and specific finished products described in the submitted notification (as described below) and subsequently authorized by the FTZ Board.

Production under FTZ procedures could exempt MCFA from customs duty payments on the foreign status components used in export production. On its domestic sales, MCFA would be able to choose the duty rates during customs entry procedures that apply to forklift trucks (free) for the foreign status materials and components noted below and in the existing scope of authority. Customs duties also could possibly be deferred or reduced on foreign status production equipment.

The components sourced from abroad include: Acrylonitrile-butadiene rubber sheets; alloy/non-alloy steel angles/shapes/sections/pipes/tubes; steel liquid/compressed petroleum gas tanks and cylinders; steel wires; and, liquid crystal display video monitors (duty rate ranges from free to 5.0%).

Public comment is invited from interested parties. Submissions shall be addressed to the FTZ Board's Executive Secretary at the address below. The closing period for their receipt is October 26, 2015.

A copy of the notification will be available for public inspection at the Office of the Executive Secretary, Foreign-Trade Zones Board, Room 21013, U.S. Department of Commerce, 1401 Constitution Avenue NW., Washington, DC 20230–0002, and in the "Reading Room" section of the FTZ Board's Web site, which is accessible via *www.trade.gov/ftz.*

For further information, contact Pierre Duy at *Pierre.Duy@trade.gov* or (202) 482–1378.

Dated: September 2, 2015.

Andrew McGilvray,

Executive Secretary.

[FR Doc. 2015–23082 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

DEPARTMENT OF COMMERCE

Bureau of Industry and Security

[Docket No. 150902803–5803–01]

Effects of Extending Foreign Policy-Based Export Controls

AGENCY: Bureau of Industry and Security, Commerce.

ACTION: Request for comments.

SUMMARY: The Bureau of Industry and Security (BIS) is seeking public comments on the effect of existing foreign policy-based export controls in the Export Administration Regulations. Section 6 of the Export Administration Act requires BIS to consult with industry on the effect of such controls and to report the results of the consultations to Congress. BIS is conducting the consultations through this request for public comments. Comments from all interested persons are welcome. All comments will be made available for public inspection and copying and included in a report to be submitted to Congress.

DATES: Comments must be received by October 14, 2015.

ADDRESSES: Comments may be submitted through the Federal e-Rulemaking portal (*www.regulations.gov*). The regulations.gov ID for this notice is: BIS–2015–0029. Comments may also be sent by email to *publiccomments@bis.doc.gov* or on paper to Regulatory Policy Division, Bureau of Industry and Security, Department of Commerce, 14th Street & Pennsylvania Avenue NW., Room 2099B, Washington, DC 20230. Include the phrase "FPBEC Comment" in the subject line of the email message or on the envelope if submitting comments on paper. All comments must be in writing (either submitted to regulations.gov, by email or on paper). All comments, including Personal Identifying Information (*e.g.,* name, address) voluntarily submitted by the commenter will be a matter of public record and will be available for public inspection and copying. Do not submit Confidential Business Information or otherwise sensitive or protected information.

FOR FURTHER INFORMATION CONTACT: Elan Mitchell, Foreign Policy Division, Office of Nonproliferation Controls and Treaty Compliance, Bureau of Industry and Security, telephone 202–482–4777. Copies of the current Annual Foreign Policy Report to the Congress are available at *http://www.bis.doc.gov/index.php/about-bis/newsroom/archives/27-about-bis/502-foreign-policy-reports,* and copies may also be requested by calling the Office of Nonproliferation and Treaty Compliance at the number listed above.

SUPPLEMENTARY INFORMATION: Foreign policy-based controls in the Export Administration Regulations (EAR) are implemented pursuant to section 6 of the Export Administration Act of 1979, as amended, (50 U.S.C. app. sections 2401–2420 (2000)) (EAA). The current foreign policy-based export controls maintained by the Bureau of Industry and Security (BIS) are set forth in the EAR (15 CFR parts 730–774), including in parts 742 (CCL Based Controls), 744 (End-User and End-Use Based Controls) and 746 (Embargoes and Other Special Controls). These controls apply to a range of countries, items, activities and persons, including:

- Entities acting contrary to the national security or foreign policy interests of the United States (§ 744.11);

- Certain general purpose microprocessors for "military end-uses" and "military end-users" (§ 744.17);
- Significant items (SI): Hot section technology for the development, production, or overhaul of commercial aircraft engines, components, and systems (§ 742.14);
- Encryption items (§ 742.15);
- Crime control and detection items (§ 742.7);
- Specially designed implements of torture (§ 742.11);
- Certain firearms and related items based on the Organization of American States Model Regulations for the Control of the International Movement of Firearms, their Parts and Components and Ammunition included within the Inter-American Convention Against the Illicit Manufacturing of and Trafficking in Firearms, Ammunition, Explosives, and Other Related Materials (§ 742.17);
- Regional stability items (§ 742.6);
- Equipment and related technical data used in the design, development, production, or use of certain rocket systems and unmanned air vehicles (§§ 742.5 and 744.3);
- Chemical precursors and biological agents, associated equipment, technical data, and software related to the production of chemical and biological agents (§§ 742.2 and 744.4) and various chemicals included on the list of those chemicals controlled pursuant to the Chemical Weapons Convention (§ 742.18);
- Communication intercepting devices, software and technology (§ 742.13);
- Nuclear propulsion (§ 744.5);
- Aircraft and vessels (§ 744.7);
- Restrictions on exports and reexports to certain persons designated as proliferators of weapons of mass destruction (§ 744.8);
- Certain cameras to be used by military end-users or incorporated into a military commodity (§ 744.9);
- Countries designated as Supporters of Acts of International Terrorism (§§ 742.8, 742.9, 742.10, 742.19, 746.4, 746.7, and 746.9);
- Certain entities in Russia (§ 744.10);
- Individual terrorists and terrorist organizations (§§ 744.12, 744.13 and 744.14);
- Certain persons designated by Executive Order 13315 ("Blocking Property of the Former Iraqi Regime, Its Senior Officials and Their Family Members") (§ 744.18);
- Certain sanctioned entities (§ 744.20);
- Embargoed countries (Part 746); and
- U.S. and U.N. arms embargoes (§ 746.1 and Country Group D:5 of Supplement No. 1 to Part 740).

In addition, the EAR impose foreign policy-based export controls on certain nuclear related commodities, technology, end-uses and end-users (§§ 742.3 and 744.2), in part, implementing section 309(c) of the Nuclear Non-Proliferation Act (42 U.S.C. 2139a).

Under the provisions of section 6 of the EAA, export controls maintained for foreign policy purposes require annual extension. Section 6 of the EAA requires a report to Congress when foreign policy-based export controls are extended. The EAA expired on August 20, 2001. Executive Order 13222 of August 17, 2001 (3 CFR, 2001 Comp., p. 783 (2002)), as amended by Executive Order 13637 of March 8, 2013, 78 FR 16129 (March 13, 2013), which has been extended by successive Presidential Notices, the most recent being that of August 7, 2015 (80 FR 48233 (Aug. 11, 2015)), continues the EAR and, to the extent permitted by law, the provisions of the EAA, in effect under the International Emergency Economic Powers Act (50 U.S.C. 1701–1706 (2000)). The Department of Commerce, as appropriate, follows the provisions of section 6 of the EAA by reviewing its foreign policy-based export controls, conducting consultations with industry on such controls through public comments and preparing a report to be submitted to Congress. In January 2015, the Secretary of Commerce, on the recommendation of the Secretary of State, extended for one year all foreign policy-based export controls then in effect. BIS is now soliciting public comment on the effects of extending the existing foreign policy-based export controls from January 21, 2016 to January 20, 2017. Among the criteria considered in determining whether to extend U.S. foreign policy-based export controls are the following:

1. The likelihood that such controls will achieve their intended foreign policy purposes, in light of other factors, including the availability from other countries of the goods, software or technology proposed for such controls;

2. Whether the foreign policy objective of such controls can be achieved through negotiations or other alternative means;

3. The compatibility of the controls with the foreign policy objectives of the United States and with overall U.S. policy toward the country subject to the controls;

4. Whether the reaction of other countries to the extension of such controls is not likely to render the controls ineffective in achieving the intended foreign policy objective or be counterproductive to U.S. foreign policy interests;

5. The comparative benefits to U.S. foreign policy objectives versus the effect of the controls on the export performance of the United States, the competitive position of the United States in the international economy, the international reputation of the United States as a supplier of goods and technology; and

6. The ability of the United States to effectively enforce the controls.

BIS is particularly interested in receiving comments on the economic impact of proliferation controls. BIS is also interested in industry information relating to the following:

1. Information on the effect of foreign policy-based export controls on sales of U.S. products to third countries (*i.e.*, those countries not targeted by sanctions), including the views of foreign purchasers or prospective customers regarding U.S. foreign policy-based export controls.

2. Information on controls maintained by U.S. trade partners. For example, to what extent do U.S. trade partners have similar controls on goods and technology on a worldwide basis or to specific destinations?

3. Information on licensing policies or practices by our foreign trade partners that are similar to U.S. foreign policy based export controls, including license review criteria, use of conditions, and requirements for pre- and post-shipment verifications (preferably supported by examples of approvals, denials and foreign regulations).

4. Suggestions for bringing foreign policy-based export controls more into line with multilateral practice.

5. Comments or suggestions to make multilateral controls more effective.

6. Information that illustrates the effect of foreign policy-based export controls on trade or acquisitions by intended targets of the controls.

7. Data or other information on the effect of foreign policy-based export controls on overall trade at the level of individual industrial sectors.

8. Suggestions for measuring the effect of foreign policy-based export controls on trade.

9. Information on the use of foreign policy-based export controls on targeted countries, entities, or individuals. BIS is also interested in comments relating generally to the extension or revision of existing foreign policy-based export controls.

Parties submitting comments are asked to be as specific as possible. All comments received before the close of the comment period will be considered by BIS in reviewing the controls and in

developing the report to Congress. All comments received in response to this notice will be displayed on BIS's Freedom of Information Act (FOIA) Web site at *http://efoia.bis.doc.gov/* and on the Federal e-Rulemaking portal at *www.Regulations.gov.* All comments will also be included in a report to Congress, as required by section 6 of the EAA, which directs that BIS report to Congress the results of its consultations with industry on the effects of foreign policy-based controls.

Dated: September 8, 2015.

Kevin J. Wolf,

Assistant Secretary for Export Administration.

[FR Doc. 2015–22982 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–33–P

DEPARTMENT OF COMMERCE

International Trade Administration

[A–427–818]

Low-Enriched Uranium From France: Final Results of Antidumping Duty Administrative Review; 2013–2014

AGENCY: Enforcement and Compliance, International Trade Administration, Department of Commerce.

SUMMARY: On March 9, 2015, the Department of Commerce (the Department) published the preliminary results of the administrative review of the antidumping duty order on low-enriched uranium (LEU) from France.[1] The review covers one producer or exporter of the subject merchandise, Eurodif S.A., AREVA NC, and AREVA NC, Inc. (collectively AREVA). The Department determines that AREVA made no shipments of subject merchandise during the POR. The Department also determines that we will issue revised certifications required from the importer and end-user.

DATES: *Effective Date:* September 14, 2015.

FOR FURTHER INFORMATION CONTACT: Andrew Huston, AD/CVD Operations, Office VII, Enforcement and Compliance, International Trade Administration, U.S. Department of Commerce, 14th Street and Constitution Avenue NW., Washington, DC 20230; telephone: (202) 482–4261.

SUPPLEMENTARY INFORMATION:

Background

For a complete description of the events that followed the *Preliminary Results,* see the Issues and Decision Memorandum.[2] The Issues and Decision Memorandum is a public document and is available electronically via Enforcement and Compliance's Antidumping and Countervailing Duty Centralized Electronic Services System (ACCESS). ACCESS is available to registered users at *http://acess.trade.gov,* and it is available to all parties in the Central Records Unit of the main Commerce Building, room B8024. In addition, a complete version of the Issues and Decision Memorandum is also accessible on the internet at *http://enforcement.trade.gov/frn/index.html.* The signed Issues and Decision Memorandum and the electronic versions of the Issues and Decision Memorandum are identical in content.

Period of Review

The period of review (POR) is February 1, 2013, through January 31, 2014.

Scope of the Order

The product covered by the order is all low-enriched uranium. Low-enriched uranium is enriched uranium hexafluoride (UF_6) with a U^{235} product assay of less than 20 percent that has not been converted into another chemical form, such as UO_2, or fabricated into nuclear fuel assemblies, regardless of the means by which the LEU is produced (including low-enriched uranium produced through the down-blending of highly enriched uranium).[3]

Analysis of Comments Received

All issues raised by the parties in the case and rebuttal briefs are addressed in the Issues and Decision Memorandum. A list of the issues addressed in the Issues and Decision Memorandum is appended to this notice.

Changes Since the Preliminary Results

In the *Preliminary Results* the Department determined that AREVA did have shipments of merchandise subject to the antidumping order on LEU from France during the POR. Upon review of the comments received from parties, the Department finds that AREVA had no shipments subject to the antidumping duty order. We have also determined to allow revised the re-export certifications required under the scope of the order to allow replenishment of LEU that has been re-exported and to address the issue of samples in future entries.[4]

Determination of No Shipments

We determine that AREVA had no shipments of merchandise subject to the antidumping duty order on LEU from France during the POR.

Determination of Revised Certifications

The Department will issue customs instructions with revised certifications to U.S. Customs and Border Protection (CBP). These instructions will be posted on CBP's Antidumping and Countervailing Duty Online Search System, available at *http://adcvd.cbp.dhs.gov/adcvdweb/,* and the Department will release the customs instructions with revised certifications via ACCESS. The revised certifications are effective when posted on the CBP's Antidumping and Countervailing Duty Online Search System.

Assessment Rates

Since the Department found that AREVA had no shipments subject to the order during the POR, we did not calculate importer-specific assessment rates for these final results.

The Department clarified its "automatic assessment" regulation on May 6, 2003. This clarification will apply to entries of subject merchandise during the POR produced by companies included in the final results of review for which these companies did not know that the merchandise was destined for the United States. In such instances, we will instruct CBP to liquidate un-reviewed entries at the all-others rate if there is no rate for the intermediate company(ies) involved in the transaction.[5]

We intend to issue instructions to CBP 15 days after publication of the final results of this review.

Cash Deposit Requirements

The following deposit requirements will be effective for all shipments of LEU from France entered, or withdrawn from warehouse, for consumption on or after the date of publication of the final results of this administrative review, as provided for by section 751(a)(2)(C) of the Act: (1) The cash deposit rate for AREVA will remain unchanged from the

[1] *See Low Enriched Uranium from France; Preliminary Results of Antidumping Duty Administrative Review; 2013–2014,* 80 FR 12434 (March 9, 2015) (*Preliminary Results*).

[2] *See* "Decision Memorandum for the Final Results of Antidumping Duty Administrative Review: Low-Enriched Uranium From France: 2013–2014" from Gary Taverman, Associate Deputy Assistant Secretary for Antidumping and Countervailing Duty Operations to Paul Piquado, Assistant Secretary for Enforcement and Compliance (Issues and Decision Memorandum), dated concurrently with these results and herby adopted by this notice.

[3] For a full description of the scope of the order, *see* the Issues and Decision Memorandum.

[4] *See* Issue 2: Re-export Certifications section of the Issues and Decision Memorandum.

[5] *See Antidumping and Countervailing Duty Proceedings: Assessment of Antidumping Duties,* 68 FR 23954 (May 6, 2003).

rate assigned to the company in the most recently completed review of that company, except for entries for which the importer claims to be excluded from the order under the re-export provision of the scope, which will require a cash deposit rate of zero percent; (2) for previously reviewed or investigated companies not listed above, the cash deposit rate will continue to be the company-specific rate published for the most recent period with a completed segment of this proceeding; (3) if the exporter is not a firm covered in this review, a prior review, or the less-than-fair-value investigation, but the manufacturer is, the cash deposit rate will be the rate established for the most recent period with a completed segment of this proceeding for the manufacturer of the merchandise; and (4) the cash deposit rate for all other manufacturers or exporters will continue to be 19.95 percent, the all-others rate established in the investigation.[6] Entries accompanied by certifications from the exporter, the importer, and the end user, indicating that the LEU will be re-exported within 18 months will be subject to a cash deposit requirement of zero percent *ad valorem*. These cash deposit requirements, when imposed, shall remain in effect until further notice.

Notification Regarding Administrative Protective Orders

This notice is the only reminder to parties subject to the administrative protective order (APO) of their responsibility concerning the return or destruction of proprietary information disclosed under the APO in accordance with 19 CFR 351.305(a)(3), which continues to govern business proprietary information in this segment of the proceeding. Timely written notification of the return or destruction of APO materials, or conversion to judicial protective order, is hereby requested. Failure to comply with the regulations and the terms of an APO is a sanctionable violation.

Notification to Importers

This notice serves as a final reminder to the importers of their responsibility under 19 CFR 351.402(f)(2) to file a certificate regarding the reimbursement of antidumping duties prior to liquidation of the relevant entries during this review period. Failure to comply with this requirement could result in the Secretary's presumption that reimbursement of antidumping duties occurred and the subsequent assessment of double antidumping duties.

Notification to Interested Parties

These final results of administrative review are issued and published in accordance with sections 751(a)(1) and 777(i)(1) of the Act.

Dated: September 4, 2015.

Paul Piquado,

Assistant Secretary for Enforcement and Compliance.

Appendix

Issues in the Issues and Decision Memorandum

I. Summary
II. Background
III. Scope of the Order
IV. Discussion of the Issues
Comment 1: Treatment of Samples
Comment 2: Re-export Certifications
V. Determination of No Shipments
VI. Revised Entry Certifications
VII. Recommendation

[FR Doc. 2015–23050 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

[6] *See Notice of Amended Final Determination of Sales at Less Than Fair Value and Antidumping Duty Order: Low Enriched Uranium From France*, 67 FR 6680 (February 13, 2002).

DEPARTMENT OF COMMERCE

International Trade Administration

[A–570–979]

Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, From the People's Republic of China: Rescission of Antidumping Duty New Shipper Review; 2013–2014

AGENCY: Enforcement and Compliance, International Trade Administration, Department of Commerce.

SUMMARY: The Department of Commerce ("Department") published its *Preliminary Rescission* for the new shipper review ("NSR") of the antidumping duty order on crystalline silicon photovoltaic cells, whether or not assembled into modules, from the People's Republic of China ("PRC") on April 21, 2015.[1] The period of review ("POR") is December 1, 2013, through May 31, 2014. As discussed below, we preliminarily found that the sale made by Hengdian Group DMEGC Magnetics Co., Ltd. ("DMEGC") was non-*bona fide*, and announced our preliminary intent to rescind its NSR. For the final results of this review, we continue to find DMEGC's sale to be non-*bona fide*. Therefore, we are rescinding this NSR.

DATES: *Effective Date:* September 14, 2015.

FOR FURTHER INFORMATION CONTACT: Jeffrey Pedersen, AD/CVD Operations, Office IV, Enforcement and Compliance, International Trade Administration, Department of Commerce, 1401 Constitution Avenue NW., Washington, DC 20230; telephone: (202) 482–2769.

SUPPLEMENTARY INFORMATION:

Background

For a complete description of the events that following the publication of the *Preliminary Results*, see the Issues and Decision Memorandum.[2] The Issues and Decision Memorandum is a public document and is on file electronically via Enforcement and Compliance's AD and Countervailing Duty (CVD) Centralized Electronic Service System (ACCESS). ACCESS is available to registered users at *http://access.trade.gov* and in the Central Records Unit, Room B8024 of the main Department of Commerce building. In addition, a complete version of the Issues and Decision Memorandum can be accessed directly at *http://enforcement.trade.gov/frn/index.html*. The signed Issues and Decision Memorandum and the electronic version of the Issues and Decision Memorandum are identical in content.

Scope of the Order

The merchandise covered by the order is crystalline silicon photovoltaic cells, and modules, laminates, and panels, consisting of crystalline silicon photovoltaic cells, whether or not partially or fully assembled into other products, including, but not limited to, modules, laminates, panels and building integrated materials.[3] Merchandise covered by the order is classifiable under subheadings 8501.61.0000, 8507.20.80, 8541.40.6020, 8541.40.6030,

[1] *See Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, From the People's Republic of China: Preliminary Rescission of 2013–2014 Antidumping Duty New Shipper Review*, 80 FR 22164 (April 21, 2015) ("*Preliminary Rescission*"); *see also* Memorandum to Howard Smith, Acting Director, Office 4, AD/CVD Operations, from Jeffrey Pedersen, International Trade Analyst, titled "2013–2014 Antidumping Duty New Shipper Review of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, From the People's Republic of China: Preliminary Bona Fide Sales Analysis for Hengdian Group DMEGC Magnetics Co., Ltd.," dated April 7, 2015.

[2] *See* Memorandum from Edward Yang, Senior Director, Office VII, Antidumping and Countervailing Operations, to Paul Piquado, Assistant Secretary for Enforcement and Compliance, entitled "Issues and Decision Memorandum for the Final Results of the Antidumping Duty New Shipper Review: Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, From the People's Republic of China" issued concurrently with and hereby adopted by this notice ("Issues and Decision Memorandum").

[3] For a complete description of the scope of the order, *see* the Issues and Decision Memorandum.

and 8501.31.8000 of the Harmonized Tariff Schedule of the United States ("HTSUS"). Although the HTSUS subheadings are provided for convenience and customs purposes, our written description of the scope of the order is dispositive.

Analysis of Comments Received

All issues raised in the case and rebuttal briefs by parties are addressed in the Issues and Decision Memorandum.[4] A list of the issues which parties raised is attached to this notice as an Appendix.

Bona Fide Analysis

For the *Preliminary Rescission*, the Department analyzed the *bona fides* of DMEGC's single sale and preliminarily found it to be a non-*bona fide* sale.[5] Based on the Department's complete analysis of all of the information and comments on the record of this review, the Department continues to find DMEGC's sale to be a non-*bona fide* sale. The Department reached this conclusion based on the totality of circumstances, namely: (a) The atypical nature of the price and sale quantity; (b) DMEGC's failure to demonstrate that its first unaffiliated customer resold the merchandise at a profit; (c) the timing of the sale; and (d) issues concerning payment.[6] For a complete discussion, *see* the Issues and Decision Memorandum.[7]

Rescission of New Shipper Review

For the foregoing reasons, the Department finds that DMEGC's sale is a non-*bona fide* sale and that this sale does not provide a reasonable or reliable basis for calculating a dumping margin. Because this non-*bona fide* sale was DMEGC's only sale of subject merchandise during the POR, the Department is rescinding this NSR.

Assessment

As the Department is rescinding this NSR, we have not calculated a company-specific dumping margin for DMEGC. DMEGC remains part of the PRC-wide entity and, accordingly, its entries will be assessed at the PRC-wide rate.

Cash Deposit Requirements

Effective upon publication of this notice of final rescission of the NSR of DMEGC, the Department will instruct U.S. Customs and Border Protection to discontinue the option of posting a bond or security in lieu of a cash deposit for entries of subject merchandise from DMEGC. Because we did not calculate a dumping margin for DMEGC or grant DMEGC a separate rate in this review, DMEGC continues to be part of the PRC-wide entity. The cash deposit rate for the PRC-wide entity is 238.95 percent. These cash deposit requirements shall remain in effect until further notice.

Administrative Protective Order

This notice also serves as a reminder to parties subject to Administrative Protective Order ("APO") of their responsibility concerning the return or destruction of proprietary information disclosed under APO in accordance with 19 CFR 351.305, which continues to govern business proprietary information in these segments of the proceeding. Timely written notification of the return or destruction of APO materials, or conversion to judicial protective order, is hereby requested. Failure to comply with the regulations and terms of an APO is a violation which is subject to sanction.

We are issuing and publishing this notice in accordance with sections 751(a)(2)(B) and 777(i) of the Tariff Act of 1930, as amended, and 19 CFR 351.214.

Dated: September 4, 2015.

Paul Piquado,

Assistant Secretary for Enforcement and Compliance.

Appendix—Issues and Decision Memorandum

Summary
Background
Scope of the Order
Discussion of the Issues
Comment 1: Commerce's *Bona Fide* Analysis for DMEGC
Comment 2: Surrogate Country and Value Selection
Recommendation

[FR Doc. 2015–23049 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

[4] *Id.*

[5] *See* "Decision Memorandum for the Preliminary Rescission of the 2013–2014 Antidumping Duty New Shipper Review: Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, from the People's Republic of China" from Christian Marsh, Deputy Assistant Secretary for Antidumping and Countervailing Operations, to Ronald K. Lorentzen, Acting Assistant Secretary for Enforcement and Compliance, dated April 7, 2015.

[6] *See* Issues and Decision Memorandum.

[7] *Id.* Further, because a significant amount of the information discussed may not be publicly disclosed, the Department addressed the issue in a separate business proprietary memorandum. *See* Memorandum to Edward Yang Senior Director, Office VII, Antidumping and Countervailing Duty Operations, from Abdelali Elouaradia, Director, Office IV, Antidumping and Countervailing Duty Operations: "2013–2014 Antidumping Duty New Shipper Review of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules, from the People's Republic of China: Comments in the Issues and Decision Memorandum Containing Business Proprietary Information," dated concurrently with this notice.

DEPARTMENT OF COMMERCE

International Trade Administration

[A–580–868]

Large Residential Washers From the Republic of Korea: Partial Rescission of Antidumping Duty Administrative Review; 2014–2015

AGENCY: Enforcement and Compliance, International Trade Administration, Department of Commerce.

SUMMARY: The Department of Commerce (the Department) is partially rescinding its administrative review of the antidumping duty order on large residential washers (LRW) from the Republic of Korea (Korea) for the period of review February 1, 2014, through January 31, 2015 (POR).

DATES: *Effective Date:* September 14, 2015.

FOR FURTHER INFORMATION CONTACT: David Goldberger or Reza Karamloo, Enforcement and Compliance, International Trade Administration, U.S. Department of Commerce, 14th Street and Constitution Avenue NW., Washington, DC 20230; telephone: (202) 482–4136 or (202) 482–4470, respectively.

SUPPLEMENTARY INFORMATION:

Background

On February 2, 2015, the Department published in the **Federal Register** a notice of "Opportunity to Request Administrative Review" of the antidumping duty order on LRW from Korea for the POR.[1]

On February 11, 2015, in accordance with section 751(a) of the Tariff Act of 1930, as amended (the Act), and 19 CFR 351.213(b), the Department received a timely request from LG Electronics, Inc. and its affiliate LG Electronics USA, Inc. (collectively, LG) to conduct a review of LG's sales and shipments to the United States during the POR. On February 26, 2015, Whirlpool Corporation, the petitioner, requested that the Department conduct an administrative review of the sales of LG, Samsung Electronics Co., Ltd. (Samsung), and Daewoo Electronics Corporation (Daewoo).[2]

On April 3, 2015, the Department published in the **Federal Register** a notice of initiation of an administrative review of the antidumping duty order

[1] *See Antidumping or Countervailing Duty Order, Finding, or Suspended Investigation; Opportunity to Request Administrative Review,* 80 FR 5509 (February 2, 2015).

[2] *See* February 11 and 26, 2015, letters from LG and the petitioner, respectively, regarding request for administrative review.

on LRW from Korea with respect to the above-named companies.[3]

On May 29, 2015, the petitioner timely withdrew its request for a review of Samsung and Daewoo.[4]

Partial Rescission of Review

Pursuant to 19 CFR 351.213(d)(1), the Department will rescind an administrative review, in whole or in part, if the parties that requested a review withdraw the request within 90 days of the date of publication of notice of initiation of the requested review. The petitioner's withdrawal request was filed before the 90-day deadline. Therefore, in response to the withdrawal of request for review of Samsung and Daewoo, and pursuant to 19 CFR 351.213(d)(1), we are rescinding this review with regard to these companies. The instant review will continue with respect to LG.

Assessment

The Department will instruct U.S. Customs and Border Protection (CBP) to assess antidumping duties on all appropriate entries. For the companies for which this review is rescinded, antidumping duties shall be assessed at rates equal to the cash deposit of estimated antidumping duties required at the time of entry, or withdrawal from warehouse, for consumption, in accordance with 19 CFR 351.212(c)(1)(i). The Department intends to issue appropriate assessment instructions directly to CBP 15 days after the date of publication of this notice in the **Federal Register**.

Notification to Importers

This notice serves as the only reminder to importers of their responsibility, under 19 CFR 351.402(f)(2), to file a certificate regarding the reimbursement of antidumping and/or countervailing duties prior to liquidation of the relevant entries during this review period. Failure to comply with this requirement may result in the presumption that reimbursement of antidumping and/or countervailing duties occurred and the subsequent assessment of double antidumping duties.

Notification Regarding Administrative Protective Order

This notice serves as the only reminder to parties subject to administrative protective order (APO) of their responsibility concerning the disposition of proprietary information disclosed under APO in accordance with 19 CFR 351.305(a)(3). Timely written notification of return/destruction of APO materials or conversion to judicial protective order is hereby requested. Failure to comply with the regulations and the terms of an APO is a sanctionable violation.

This notice is published in accordance with section 751 of the Act and 19 CFR 351.213(d)(4).

Dated: September 8, 2015.

Christian Marsh,

Deputy Assistant Secretary for Antidumping and Countervailing Duty Operations.

[FR Doc. 2015–23051 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

[3] *See Initiation of Antidumping and Countervailing Duty Administrative Reviews,* 80 FR 18202 (April 3, 2015).

[4] *See* May 29, 2015, letter from the petitioner regarding withdrawal of request for review.

DEPARTMENT OF COMMERCE

International Trade Administration

[A–552–801]

Certain Frozen Fish Fillets From the Socialist Republic of Vietnam: Preliminary Results and Partial Rescission of the Antidumping Duty Administrative Review; 2013–2014

AGENCY: Enforcement and Compliance, International Trade Administration, Department of Commerce.

SUMMARY: The Department of Commerce ("the Department") is conducting the 11th administrative review of the antidumping duty order on certain frozen fish fillets ("fish fillets") from the Socialist Republic of Vietnam ("Vietnam").[1] The Department preliminarily determines that the Hung Vuong Group ("HVG")[2] and Thuan An Production Trading and Service Co., Ltd. ("TAFISHCO") sold subject merchandise in the United States at prices below normal value ("NV") during the period of review ("POR") August 1, 2013, through July 31, 2014. If these preliminary results are adopted in the final results, the Department will instruct U.S. Customs and Border Protection ("CBP") to assess antidumping duties on all appropriate entries of subject merchandise during the POR. Interested parties are invited to comment on these preliminary results.

DATES: *Effective date:* September 14, 2015.

FOR FURTHER INFORMATION CONTACT: Javier Barrientos or Jerry Huang, AD/CVD Operations, Office V, Enforcement and Compliance, International Trade Administration, U.S. Department of Commerce, 14th Street and Constitution Avenue NW., Washington, DC 20230; telephone 202–482–2243 or 202–482–4047, respectively.

SUPPLEMENTARY INFORMATION:

Background

On September 30, 2014, the Department initiated the 11th administrative review of the antidumping duty order on fish fillets from Vietnam for the period August 1, 2013, through July 31, 2014.[3] On April 8, 2015, the Department partially extended the deadline for issuing the preliminary results by 106 days.[4] On August 11, 2015, the Department further extended the deadline for issuing the preliminary results by 14 days.[5] The revised deadline for the preliminary results of this administrative is now August 31, 2015.

Scope of the Order

The product covered by the order is frozen fish fillets, including regular, shank, and strip fillets and portions thereof, whether or not breaded or marinated, of the species *Pangasius Bocourti, Pangasius Hypophthalmus* (also known as *Pangasius Pangasius*) and *Pangasius Micronemus.* These products are classifiable under tariff article codes 0304.29.6033, 0304.62.0020, 0305.59.0000, 0305.59.4000, 1604.19.2000, 1604.19.2100, 1604.19.3000, 1604.19.3100, 1604.19.4000, 1604.19.4100, 1604.19.5000,

[1] *See Notice of Antidumping Duty Order: Certain Frozen Fish Fillets from the Socialist Republic of Vietnam,* 68 FR 47909 (August 12, 2003) ("*Order*").

[2] The Department previously found that An Giang Fisheries Import & Export Joint Stock Company ("Agifish") is a member of the Hung Vuong Group, which also includes Asia Pangasius Company Limited, Europe Joint Stock Company, Hung Vuong Joint Stock Company, Hung Vuong Mascato Company Limited, Hung Vuong—Vinh Long Co., Ltd. and Hung Vuong—Sa Dec Co., Ltd. *See Certain Frozen Fish Fillets From the Socialist Republic of Vietnam: Final Results of the Antidumping Duty Administrative Review and New Shipper Review; 2011–2012,* 79 FR 19053 (April 7, 2014).

[3] *See Initiation of Antidumping and Countervailing Duty Administrative Reviews,* 79 FR 58729 (September 30, 2014) ("*Initiation Notice*").

[4] *See* Memorandum to James P. Maeder, Senior Director, Office I, Antidumping and Countervailing Duty Operations, through James C. Doyle, Director, Office V, Antidumping and Countervailing Duty Operations regarding "Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Extension of Deadline for Preliminary Results of 2013–2014 Antidumping Duty Administrative Review," dated April 8, 2015.

[5] *See* Memorandum to Gary Taverman, Associate Deputy Assistant Secretary for Antidumping and Countervailing Duty Operations, through James C. Doyle, Director, Office V, Antidumping and Countervailing Duty Operations regarding "Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Second Extension of Deadline for Preliminary Results of 2013–2014 Antidumping Duty Administrative Review," dated August 11, 2015.

1604.19.5100, 1604.19.6100 and 1604.19.8100 (Frozen Fish Fillets of the species *Pangasius* including basa and tra) of the Harmonized Tariff Schedule of the United States ("HTSUS").[6] Although the HTSUS subheading is provided for convenience and Customs purposes, our written description of the scope of the order is dispositive.[7]

Partial Rescission of Administrative Review

Pursuant to 19 CFR 351.213(d)(1), the Department will rescind an administrative review, in whole or in part, if the parties that requested a review withdraw the request within 90 days of the date of publication of the notice of initiation. On November 25, 2014, Vinh Hoan Corporation ("Vinh Hoan") withdrew its review request.[8] On November 25, 2014, Petitioner[9] withdrew its review request with respect to Vinh Hoan.[10] On December 23, 2014, Bien Dong Seafood Co., Ltd ("Bien Dong") withdrew its review request,[11] and Petitioner withdrew its review request with respect to Bien Dong Seafood on the same date.[12] On December 29, 2014, Petitioner withdrew its review request with respect to Hung Vuong Seafood Joint Stock Company ("Hung Vuong Seafood"), Thanh Hung Co., Ltd. (also known as Thanh Hung Frozen Seafood Processing Import Export Co., Ltd. or Thanh Hung) ("Thanh Hung"), Vinh Long Import-Export Company (also known as Vinh Long or Imex Cuu Long) ("Vinh Long").[13] No other party requested an administrative review of Vinh Hoan, Bien Dong, Hung Vuong Seafood, Thanh Hung, and Vinh Long. Therefore, in accordance with 19 CFR 351.213(d)(1), the Department is rescinding this review of the antidumping duty order on certain frozen fish fillets from the Socialist Republic of Vietnam with respect to Vinh Hoan, Bien Dong, Hung Vuong Seafood, Thanh Hung, and Vinh Long. The review will continue with respect to the other firms for which a review was requested and initiated.

Preliminary Determination of No Shipments

The following companies filed no-shipment certifications indicating that they did not export subject merchandise to the United States during the POR: An Giang Agriculture and Food Import-Export Joint Stock Company, Anvifish Joint Stock Company, Asia Commerce Fisheries Joint Stock Company, Binh An Seafood Joint Stock Company, Dai Thanh Seafoods Company Limited, Fatifish Company Limited, Golden Quality Seafood Corporation, Hiep Thanh Seafood Joint Stock Company, Hoa Phat Seafood Import-Export and Processing JSC, Ngoc Ha Co., Ltd. Food Processing and Trading, Quang Minh Seafood Company, Limited, QVD Food Company, Ltd., Saigon-Mekong Fishery Co., Ltd., Southern Fisheries Industries Company, Ltd., TG Fishery Holdings Corporation, and To Chau Joint Stock Company (collectively "No Shipment Companies"). Based on the certifications submitted by the above companies, and our analysis of the CBP information, we preliminarily determine that the No Shipment Companies did not have any reviewable transactions during the POR. The Department finds that consistent with its practice in non-market economy ("NME") cases, it is appropriate not to rescind the review in part in this circumstance but, rather, to complete the review with respect to the No Shipment Companies and issue appropriate instructions to CBP based on the final results of the review.[14]

Vietnam-Wide Entity

A review was requested, but not rescinded, for Asia Pangasius Company Limited, Nam Phuong Seafood Co., Ltd., NTACO Corporation, Thien Ma Seafood Co., Ltd., Thuan Hung Co., Ltd. (collectively, "No Response Companies").[15] The No Response Companies are not eligible for separate rate status because they did not submit completed separate rate applications or certifications.[16] Accordingly, the Department finds that these No Response Companies are a part of the Vietnam-wide entity.

The Department's change in policy regarding conditional review of the NME-wide entity applies to this administrative review.[17] Under this policy, the Vietnam-wide entity will not be under review unless a party specifically requests, or the Department self-initiates, a review of the entity. Because no party requested a review of the Vietnam-wide entity in this review, the entity is not under review and the entity's rate is not subject to change.

Methodology

The Department conducted this review in accordance with sections 751(a)(1)(B) and 751(a)(2)(A) of the Tariff Act of 1930, as amended ("the Act"). Constructed export prices and export prices have been calculated in accordance with section 772 of the Act. Because Vietnam is an NME within the meaning of section 771(18) of the Act, NV has been calculated in accordance with section 773(c) of the Act.

For a full description of the methodology underlying our conclusions, *see* the Preliminary Decision Memorandum. The Preliminary Decision Memorandum is a public document and is on file electronically via Enforcement and Compliance's Antidumping and Countervailing Duty Centralized Electronic Service System ("ACCESS"). ACCESS is available to registered users at *http://access.trade.gov,* and is

[6] Until July 1, 2004, these products were classifiable under HTSUS 0304.20.6030 (Frozen Catfish Fillets), 0304.20.6096 (Frozen Fish Fillets, NESOI), 0304.20.6043 (Frozen Freshwater Fish Fillets) and 0304.20.6057 (Frozen Sole Fillets). Until February 1, 2007, these products were classifiable under HTSUS 0304.20.6033 (Frozen Fish Fillets of the species *Pangasius,* including basa and tra). On March 2, 2011, the Department added two HTSUS numbers at the request of U.S. Customs and Border Protection ("CBP"): 1604.19.2000 and 1604 19.3000. On January 30, 2012, the Department added eight HTSUS numbers at the request of CBP: 0304.62.0020, 0305.59.0000, 1604.19.2100, 1604.19.3100, 1604.19.4100, 1604.19.5100, 1604.19.6100 and 1604.19.8100.

[7] *See* "Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Decision Memorandum for the Preliminary Results of the 2012–2013 Antidumping Duty Administrative Review," dated concurrently with and hereby adopted by this notice ("Preliminary Decision Memorandum"), for a complete description of the Scope of the Order.

[8] *See* Letter from Vinh Hoan regarding Frozen Fish Fillets from the Socialist Republic of Vietnam: Withdraw of Request for Administrative Review—Vinh Hoan Corporation, dated November 25, 2014.

[9] Catfish Farmers of America and individual U.S. catfish processors America's Catch, Alabama Catfish Inc. dba Harvest Select Catfish, Inc., Heartland Catfish Company, Magnolia Processing, Inc. dba Pride of the Pond, and Simmons Farm Raised Catfish, Inc. (hereinafter, "Petitioner").

[10] *See* Letter from Petitioner regarding Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Partial Withdrawal of Request for Antidumping Duty Administrative Review, dated November 25, 2014.

[11] *See* Letter from Bien Dong Seafood regarding Frozen Fish Fillets from the Socialist Republic of Vietnam: Withdrawal of Request for Administrative Review—Bien Dong Seafood Co., Ltd., dated December 23, 2014.

[12] *See* Letter from Petitioner regarding Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Partial Withdrawal of Request for Antidumping Duty Administrative Review, dated December 23, 2014.

[13] *See* Letter from Petitioner regarding Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Partial Withdrawal of Request for Antidumping Duty Administrative Review, dated December 29, 2014. We note that Petitioners also withdrew their request for Anvifish Co., Ltd. ("Anvifish"), and Vinh Quang Fisheries Corporation ("Vinh Quang"). However, there are still outstanding review requests for these companies at this time.

[14] *See Non-Market Economy Antidumping Proceedings: Assessment of Antidumping Duties,* 76 FR 65694, 65694–65695 (October 24, 2011).

[15] *See Initiation Notice,* 79 FR at 58732.

[16] *Id.,* 79 FR at 58730.

[17] *See Antidumping Proceedings: Announcement of Change in Department Practice for Respondent Selection in Antidumping Duty Proceedings and Conditional Review of the Nonmarket Economy Entity in NME Antidumping Duty Proceedings,* 78 FR 65963 (November 4, 2013).

available to all parties in the Central Records Unit, room B8024 of the main Department of Commerce building. In addition, a complete version of the Preliminary Decision Memorandum can be accessed directly on the internet at *http://enforcement.trade.gov/frn/*. The signed Preliminary Decision Memorandum and the electronic versions of the Preliminary Decision Memorandum are identical in content.

Preliminary Results of Review

The Department preliminarily determines that the following weighted-average dumping margins exist for the period August 1, 2013, through July 31, 2014:

Exporter	Weighted-average margin (dollars/kilogram) [18]
Hung Vuong Group [19]	0.36
Thuan An Production Trading and Services Co., Ltd	0.84
Basa Joint Stock Company	0.60
Cadovimex II Seafood Import-Export and Processing Joint Stock Company	0.60
Cafatex Corporation	0.60
Can Tho Import-Export Joint Stock Company	0.60
C.P. Vietnam Corporation	0.60
Cuu Long Fish Joint Stock Company	0.60
East Sea Seafoods LLC	0.60
GODACO Seafood Joint Stock Company	0.60
Green Farms Seafood Joint Stock Company	0.60
Hoang Long Seafood Processing Company Limited	0.60
International Development and Investment Corporation	0.60
Nam Viet Corporation	0.60
NTSF Seafoods Joint Stock Company	0.60
Seafood Joint Stock Company No. 4—Branch Dong Tam Fisheries Processing Company	0.60
Viet Phu Foods and Fish Corporation	0.60
Vinh Quang Fisheries Joint-Stock Company	0.60

Disclosure, Public Comment and Opportunity To Request a Hearing

The Department will disclose the calculations used in our analysis to parties in this review within five days of the date of publication of this notice in accordance with 19 CFR 351.224(b).

Interested parties may submit case briefs within 30 days after the date of publication of these preliminary results of review in the **Federal Register**.[20] Rebuttals to case briefs, which must be limited to issues raised in the case briefs, must be filed within five days after the time limit for filing case briefs.[21] Parties who submit arguments are requested to submit with the argument (a) a statement of the issue, (b) a brief summary of the argument, and (c) a table of authorities.[22] Parties submitting briefs should do so pursuant to the Department's electronic filing system, ACCESS.

Pursuant to 19 CFR 351.310(c), interested parties who wish to request a hearing must submit a written request to the Assistant Secretary for Enforcement and Compliance within 30 days of the date of publication of this notice. Requests should contain: (1) The party's name, address and telephone number; (2) the number of participants; and (3) a list of issues parties intend to discuss. Issues raised in the hearing will be limited to those raised in the respective case and rebuttal briefs. If a request for a hearing is made, the Department intends to hold the hearing at the U.S. Department of Commerce, 14th Street and Constitution Avenue NW., Washington, DC 20230, at a date and time to be determined. *See* 19 CFR 351.310(d). Parties should confirm by telephone the date, time, and location of the hearing two days before the scheduled date.

The Department intends to issue the final results of this administrative review, which will include the results of our analysis of all issues raised in the case briefs, within 120 days of publication of these preliminary results in the **Federal Register**, pursuant to section 751(a)(3)(A) of the Act.

Assessment Rates

Upon issuance of the final results, the Department will determine, and CBP shall assess, antidumping duties on all appropriate entries covered by this review.[23] The Department intends to issue assessment instructions to CBP 15 days after the publication date of the final results of this review.

For any individually examined respondent whose weighted average dumping margin is above *de minimis* (*i.e.*, 0.50 percent) in the final results of this review, the Department will calculate importer-specific assessment rates on the basis of the ratio of the total amount of dumping calculated for the importer's examined sales to the total entered value of sales, in accordance with 19 CFR 351.212(b)(1). Where an importer- (or customer-) specific *ad valorem* rate is greater than *de minimis*, the Department will instruct CBP to collect the appropriate duties at the time of liquidation.[24] Where either a respondent's weighted average dumping margin is zero or *de minimis*, or an importer- (or customer-) specific *ad valorem* is zero or *de minimis*, the Department will instruct CBP to liquidate appropriate entries without regard to antidumping duties.[25]

Cash Deposit Requirements

The following cash deposit requirements will be effective upon publication of the final results of this review for shipments of the subject

[18] In the third administrative review of this order, the Department determined that it would calculate per-unit assessment and cash deposit rates for all future reviews. *See Certain Frozen Fish Fillets from the Socialist Republic of Vietnam: Final Results of Antidumping Duty Administrative Review and Partial Rescission*, 73 FR 15479 (March 24, 2008).

[19] This rate is applicable to the Hung Vuong Group, which includes: An Giang Fisheries Import and Export Joint Stock Company, Asia Pangasius Company Limited, Europe Joint Stock Company, Hung Vuong Joint Stock Company, Hung Vuong Mascato Company Limited, Hung Vuong—Vinh Long Co., Ltd., and Hung Vuong—Sa Dec Co., Ltd.

[20] *See* 19 CFR 351.309(c)(1)(ii).

[21] *See* 19 CFR 351.309(d)(1)–(2).

[22] *See* 19 CFR 351.309(c)(2), (d)(2).

[23] *See* 19 CFR 351.212(b).

[24] *See* 19 CFR 351.212(b)(1).

[25] *See* 19 CFR 351.106(c)(2).

merchandise from Vietnam entered, or withdrawn from warehouse, for consumption on or after the publication date, as provided by sections 751(a)(2)(C) of the Act: (1) For the companies listed above that have a separate rate, the cash deposit rate will be that established in the final results of this review (except, if the rate is zero or *de minimis,* then zero cash deposit will be required); (2) for previously investigated or reviewed Vietnam and non-Vietnam exporters not listed above that received a separate rate in a prior segment of this proceeding, the cash deposit rate will continue to be the existing exporter-specific rate; (3) for all Vietnam exporters of subject merchandise that have not been found to be entitled to a separate rate, the cash deposit rate will be that for the Vietnam -wide entity; and (4) for all non-Vietnam exporters of subject merchandise which have not received their own rate, the cash deposit rate will be the rate applicable to the Vietnam exporter that supplied that non-Vietnam exporter. These deposit requirements, when imposed, shall remain in effect until further notice.

Notification to Importers

This notice also serves as a preliminary reminder to importers of their responsibility under 19 CFR 351.402(f)(2) to file a certificate regarding the reimbursement of antidumping duties prior to liquidation of the relevant entries during the POR. Failure to comply with this requirement could result in the Department's presumption that reimbursement of antidumping duties occurred and the subsequent assessment of double antidumping duties.

This preliminary determination is issued and published in accordance with sections 751(a)(1) and 777(i)(1) of the Act.

Dated: August 21, 2015.

Paul Piquado,

Assistant Secretary for Enforcement and Compliance.

Appendix

List of Topics Discussed in the Preliminary Decision Memorandum

1. Summary
2. Case History
3. Scope of the Order
4. Discussion of the Methodology
   a. Selection of Respondents
   b. Preliminary Determination of No Shipments
   c. Non-Market Economy Country Status
   d. Separate Rates
   e. Vietnam-Wide Entity
   f. Surrogate Country
   g. Determination of Comparison Method
   h. Results of Differential Pricing Analysis
   i. Comparisons to Normal Value
   j. U.S. Price
   k. Use of Facts Available
   l. Normal Value
   m. Factor Valuations
   n. Currency Conversion
5. Recommendation

[FR Doc. 2015–22858 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–DS–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XE154

Endangered Species; File No. 18926

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; receipt of application.

SUMMARY: Notice is hereby given that Jane Provancha, Mail Code: IHA–005 OHF, Room 1104, Kennedy Space Center, FL 32815 has applied in due form for a permit to take green sea (*Chelonia mydas*), loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), and hawksbill (*Eretmochelys imbricata*) sea turtles for purposes of scientific research.

DATES: Written, telefaxed, or email comments must be received on or before October 14, 2015.

ADDRESSES: The application and related documents are available for review by selecting "Records Open for Public Comment" from the "Features" box on the Applications and Permits for Protected Species (APPS) home page, *https://apps.nmfs.noaa.gov,* and then selecting File No. 18926 from the list of available applications.

These documents are also available upon written request or by appointment in the Permits and Conservation Division, Office of Protected Resources, NMFS, 1315 East-West Highway, Room 13705, Silver Spring, MD 20910; phone (301) 427–8401; fax (301) 713–0376.

Written comments on this application should be submitted to the Chief, Permits and Conservation Division, at the address listed above. Comments may also be submitted by facsimile to (301) 713–0376, or by email to *NMFS.Pr1Comments@noaa.gov.* Please include the File No. in the subject line of the email comment.

Those individuals requesting a public hearing should submit a written request to the Chief, Permits and Conservation Division at the address listed above. The request should set forth the specific reasons why a hearing on this application would be appropriate.

FOR FURTHER INFORMATION CONTACT: Brendan Hurley or Amy Hapeman, (301) 427–8401.

SUPPLEMENTARY INFORMATION: The subject permit is requested under the authority of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq.*) and the regulations governing the taking, importing, and exporting of endangered and threatened species (50 CFR parts 222–226).

The applicant requests a five-year permit to continue monitoring the abundance and distribution of sea turtles inhabiting the waters of the northern Indian River Lagoon and Mosquito Lagoon system (in Volusia and Brevard Counties), Florida. The purpose of this project is to provide NASA-Kennedy Space Center with updates on the status of marine turtles within its boundaries and nearby waters. This area also will continue to be used as an index site to document distribution and movement of individuals in these waters. The applicant requests to capture by hand, tangle, or dip net up to 50 green, one Kemp's ridley, 1 hawksbill, and 50 loggerhead turtles, each year. Turtles will be placed onboard a research vessel for morphometric measures, tagging, photographs, tissue and blood sampling, and/or possible lavage, before release. A subset of captured turtles may also be released with sonic transmitters glued to the carapace.

Dated: September 8, 2015.

Julia Harrison,

Chief, Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service.

[FR Doc. 2015–23007 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XE172

Endangered Species; File No. 19528

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; receipt of application.

SUMMARY: Notice is hereby given that Michael Bresette, Inwater Research Group Inc., 4160 NE Hyline Dr., Jensen Beach, FL 34957, has applied in due form for a permit to take green (*Chelonia mydas*), hawksbill (*Eretmochelys*

imbricata), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and loggerhead (*Caretta caretta*) sea turtles for purposes of scientific research.

DATES: Written, telefaxed, or email comments must be received on or before October 14, 2015.

ADDRESSES: The application and related documents are available for review by selecting "Records Open for Public Comment" from the "Features" box on the Applications and Permits for Protected Species (APPS) home page, *https://apps.nmfs.noaa.gov,* and then selecting File No. 19528 from the list of available applications.

These documents are also available upon written request or by appointment in the Permits and Conservation Division, Office of Protected Resources, NMFS, 1315 East-West Highway, Room 13705, Silver Spring, MD 20910; phone (301) 427–8401; fax (301) 713–0376.

Written comments on this application should be submitted to the Chief, Permits and Conservation Division, at the address listed above. Comments may also be submitted by facsimile to (301) 713–0376, or by email to *NMFS.Pr1Comments@noaa.gov.* Please include the File No. in the subject line of the email comment.

Those individuals requesting a public hearing should submit a written request to the Chief, Permits and Conservation Division at the address listed above. The request should set forth the specific reasons why a hearing on this application would be appropriate.

FOR FURTHER INFORMATION CONTACT: Amy Hapeman, (301) 427–8401.

SUPPLEMENTARY INFORMATION: The subject permit is requested under the authority of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq.*) and the regulations governing the taking, importing, and exporting of endangered and threatened species (50 CFR parts 222–226).

The applicant requests a five-year permit to investigate habitat preference, species abundance, size frequencies, diet composition, genetic origin, disease occurrence and sex ratios of sea turtles in waters of the Indian River and Miami-Dade Counties in southeastern Florida. During vessel surveys, up to 250 greens, 100 loggerheads, 50 hawksbills, 10 Kemp's ridleys, and one leatherback sea turtle would be sighted and pursued for capture by hand, dip net or tangle net annually. Once captured, the following procedures may be performed on sea turtles: Measurements, flipper and passive integrated transponder tagging, temporary marking, photography/video, lavage, blood and tissue sampling, and/or attachment of a transmitter. In addition, up to 1,400 green, 100 loggerhead, 280 hawksbill, and 10 Kemp's ridley sea turtles could be harassed during vessel approaches.

Dated: September 8, 2015.

Julia Harrison,

Chief, Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service.

[FR Doc. 2015–23008 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Proposed Information Collection; Comment Request; A Creel Survey of the Recreational (Non-Commercial), Boat Ramp Based Fisheries in the United States Virgin Islands

AGENCY: National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice.

SUMMARY: The Department of Commerce, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995.

DATES: Written comments must be submitted on or before November 13, 2015.

ADDRESSES: Direct all written comments to Jennifer Jessup, Departmental Paperwork Clearance Officer, Department of Commerce, Room 6616, 14th and Constitution Avenue NW., Washington, DC 20230 (or via the Internet at *JJessup@doc.gov*).

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the information collection instrument and instructions should be directed to Dr. Brent Stoffle, Fishery Anthropologist, SEFSC, NMFS, 75 Virginia Beach Drive, Miami FL 33149, (305) 361–4276 or *Brent.Stoffle@noaa.gov.*

SUPPLEMENTARY INFORMATION:

I. Abstract

This request is for a new information collection.

The National Marine Fisheries Service (NMFS) proposes to collect landings and socioeconomic data from recreational anglers in the U.S. Virgin Islands. This data collection will assist in creating and utilizing an appropriate methodology for future sampling of this segment of these fisheries and to assist in the development of management proposals. In addition, the information will be used to satisfy legal mandates under Executive Order 12898, the Magnuson-Stevens Fishery Conservation and Management Act (U.S.C. 1801 *et seq.*), the Regulatory Flexibility Act, the Endangered Species Act, and the National Environmental Policy Act, and other pertinent statues.

II. Method of Collection

The information will be collected on paper using face to face interviews.

III. Data

OMB Control Number: 0648–xxxx.

Form Number(s): None.

Type of Review: Regular (request for a new information collection).

Affected Public: Business or other for-profit organizations; individuals or households.

Estimated Number of Respondents: 250.

Estimated Time per Response: 15 minutes.

Estimated Total Annual Burden Hours: 63.

Estimated Total Annual Cost to Public: $0 in recordkeeping/reporting costs.

IV. Request for Comments

Comments are invited on: (a) Whether the proposed collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden (including hours and cost) of the proposed collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology.

Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval of this information collection; they also will become a matter of public record.

Dated: September 9, 2015.

Sarah Brabson,

NOAA PRA Clearance Officer.

[FR Doc. 2015–23028 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XE153

Advisory Committee to the U.S. Section of the International Commission for the Conservation of Atlantic Tunas; Fall Meeting

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of public meeting.

SUMMARY: In preparation for the 2015 International Commission for the Conservation of Atlantic Tunas (ICCAT) meeting, the Advisory Committee to the U.S. Section to ICCAT is announcing the convening of its fall meeting.

DATES: The meeting will be held October 8–9, 2015. There will be an open session on Thursday, October 8, 2015, from 9 a.m. through approximately 12:30 p.m. The remainder of the meeting will be closed to the public and is expected to end by 1 p.m. on October 9. Interested members of the public may present their views during the public comment session on October 8, 2015.

ADDRESSES: The meeting will be held at the Sheraton Hotel, 8777 Georgia Ave., Silver Spring, MD 20910. Written comments should be sent via email (*Rachel.O'Malley@noaa.gov*). Comments may also be sent via mail to Rachel O'Malley at NMFS, Office of International Affairs and Seafood Inspection, Room 10653, 1315 East-West Highway, Silver Spring, MD 20910.

FOR FURTHER INFORMATION CONTACT: Rachel O'Malley, Office of International Affairs and Seafood Inspection, 301–427–8373.

SUPPLEMENTARY INFORMATION: The Advisory Committee to the U.S. Section to ICCAT will meet October 8–9, 2015, first in an open session to consider management-and research-related information on stock status of Atlantic highly migratory species and then in a closed session to discuss sensitive matters. The open session will be from 9 a.m. through 12:30 p.m. on October 8, 2015, including an opportunity for public comment beginning at approximately 12 p.m. Comments may also be submitted in writing for the Advisory Committee's consideration. Interested members of the public can submit comments by mail or email; use of email is encouraged. All written comments must be received by October 6, 2015 (see **ADDRESSES**).

NMFS expects members of the public to conduct themselves appropriately at the open session of the Advisory Committee meeting. At the beginning of the public comment session, an explanation of the ground rules will be provided (*e.g.*, alcohol in the meeting room is prohibited, speakers will be called to give their comments in the order in which they registered to speak, each speaker will have an equal amount of time to speak and speakers should not interrupt one another). The session will be structured so that all attending members of the public are able to comment, if they so choose, regardless of the degree of controversy of the subject(s). Those not respecting the ground rules will be asked to leave the meeting.

After the open session, the Advisory Committee will meet in closed session to discuss sensitive information relating to upcoming international negotiations regarding the conservation and management of Atlantic highly migratory species.

Special Accommodations

The meeting location is physically accessible to people with disabilities. Requests for sign language interpretation or other auxiliary aids should be directed to Rachel O'Malley at (301) 427–8373 or *Rachel.O'Malley@noaa.gov* at least 5 days prior to the meeting date.

Dated: September 9, 2015.

John Henderschedt,

Director, Office of International Affairs and Seafood Inspection, National Marine Fisheries Service.

[FR Doc. 2015–23066 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Proposed Information Collection; Comment Request; International Billfish Angler Survey

AGENCY: National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice.

SUMMARY: The Department of Commerce, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995.

DATES: Written comments must be submitted on or before November 13, 2015.

ADDRESSES: Direct all written comments to Jennifer Jessup, Departmental Paperwork Clearance Officer, Department of Commerce, Room 6616, 14th and Constitution Avenue NW., Washington, DC 20230 (or via the Internet at *JJessup@doc.gov*).

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the information collection instrument and instructions should be directed to James Wraith, Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA 92037, (858) 546 7087 or *james.wraith@noaa.gov.*

SUPPLEMENTARY INFORMATION:

I. Abstract

The International Billfish Angler Survey began in 1969 and is an integral part of the Billfish Research Program at the National Oceanic and Atmospheric Administration's (NOAA) Southwest Fisheries Science Center (SWFSC). The survey tracks recreational angler fishing catch and effort for billfish in the Pacific and Indian Oceans in support of the Pacific and Western Pacific Fishery Management Councils, authorized under the Magnuson-Stevens Fishery Conservation and Management and Act (MSA). The data are used by scientists and fishery managers to assist with assessing the status of billfish stocks. The survey is intended for anglers cooperating in the Billfish Program and is entirely voluntary. This survey is specific to recreational anglers fishing for Istiophorid and Xiphiid billfish in the Pacific and Indian Oceans; as such it provides the only estimates of catch per unit of effort for recreational billfish fishing in those areas.

II. Method of Collection

The paper form is sent to anglers with recent participation in the SWFSC Billfish Research Program and is also available for downloading on the SWFSC Billfish Program Web site. Completed forms are submitted by mail.

III. Data

OMB Number: 0648–0020.

Form Number: NOAA Form 88–10.

Type of Review: Regular (extension of a current information collection).

Affected public: Individuals or households.

Estimated Number of Respondents: 600.

Estimated Time per Response: 5 minutes.

Estimated Total Annual Burden Hours: 50.

Estimated Total Annual Cost to Public: $0 in recordkeeping/reporting costs.

IV. Request for Comments

Comments are invited on: (a) Whether the proposed collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden (including hours and cost) of the proposed collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology.

Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval of this information collection; they also will become a matter of public record.

Dated: September 8, 2015.

Sarah Brabson,

NOAA PRA Clearance Officer.

[FR Doc. 2015–22991 Filed 9–11–15; 8:45 am]

BILLING CODE 3510–22–P

COMMODITY FUTURES TRADING COMMISSION

Public Alert—Registration Deficient List

AGENCY: Commodity Futures Trading Commission.

ACTION: Notice; request for comment.

SUMMARY: The Commodity Futures Trading Commission ("CFTC" or "Commission") is announcing a new program, the Registration Deficient List ("RED List"), that will post on the Commission's Web site and distribute to the public certain factual information about foreign entities that are soliciting or accepting funds from U.S. residents and are acting in a manner that requires registration but are not appropriately registered with the CFTC.

DATES: Comments must be received on or before October 14, 2015.

ADDRESSES: You may submit comments, identified by "Registration Deficient List," by any of the following methods:

- *The agency's Web site, at http://comments.cftc.gov.* Follow the instructions for submitting comments through the Web site.
- *Mail:* Christopher Kirkpatrick, Secretary of the Commission, Commodity Futures Trading Commission, Three Lafayette Centre, 1155 21st Street NW., Washington, DC 20581.
- *Hand Delivery/Courier:* Same as Mail above.
- *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the instructions for submitting comments.

Please submit your comments using only one method.

All comments must be submitted in English, or if not, accompanied by an English translation. Comments will be posted as received to *www.cftc.gov.* You should submit only information that you wish to make available publicly. If you wish the Commission to consider information that you believe is exempt from disclosure under the Freedom of Information Act, a petition for confidential treatment of the exempt information may be submitted according to the procedures established in § 145.9 of the Commission's regulations.[1]

The Commission reserves the right, but shall have no obligation, to review, pre-screen, filter, redact, refuse or remove any or all of your submission from *www.cftc.gov* that it may deem to be inappropriate for publication, such as obscene language. All submissions that have been redacted or removed that contain comments on the merits of the rulemaking will be retained in the public comment file and will be considered as required under the Administrative Procedure Act and other applicable laws, and may be accessible under the Freedom of Information Act.

FOR FURTHER INFORMATION CONTACT: Rick Glaser, Deputy Director, Division of Enforcement, Commodity Futures Trading Commission, Three Lafayette Centre, 1151 21st Street NW., Washington, DC 20581, phone: (202) 418–5358, email: *rglaser@cftc.gov.*

SUPPLEMENTARY INFORMATION: The CFTC today is announcing a new program, effective immediately, for informing the public about unregistered foreign entities engaged in the solicitation or acceptance of funds from U.S. residents at a retail level. These entities solicit and/or accept funds for investments in, among other things, foreign currency ("forex") and binary options. Through this new program, the Registration Deficient List ("RED List"), the Commission will publish on its Web site the names of unregistered foreign entities that the Commission has reason to believe may be required to register with the CFTC but are not, in fact, registered. Publication does not represent final Commission disposition or a final Commission order. By making this information publicly available, the Commission expects investors to make more informed decisions whether to trade with or through such an entity. The more U.S. investors trade with and through registered entities, the more likely that their funds have a better chance of being protected.

I. Background

The Commission often receives investigative leads relating to foreign entities that solicit and/or accept funds from U.S. residents at a retail level. For example, the CFTC's Division of Enforcement ("Enforcement") has investigated approximately 60 such cases in the past twenty-four months. These cases involve unregistered foreign entities that engage in, among other things, forex in a capacity similar to Retail Foreign Exchange Dealers, Introducing Brokers, Commodity Trading Advisors or Commodity Pool Operators and binary options.[2] Almost all, if not all, of these foreign entities are acting in a capacity that requires them to be registered with the Commission.

In many cases, there are obstacles to bringing an effective enforcement action against these types of entities. For example, the Commission spends considerable resources investigating these matters. Even if Enforcement is able to develop a legal case against one of these entities, international service of process is cumbersome, often takes a very long time to effectuate and is not always successful. Even if service of process is successful, many of these entities are judgment proof.

The Commission believes that a consumer protection approach has a better chance of success than continuing to spend resources on Enforcement investigations and litigations that have a limited chance of success. The proposed RED List would disseminate information about certain foreign entities into the marketplace so that U.S. residents would be able to make more informed choices about how they trade their money. This approach is used by other regulators, including the Securities and Exchange Commission.[3]

[1] 17 CFR 145.9 (2014).

[2] The Commission uses forex and binary options merely as illustrative examples. Any entity that meets the criteria set forth below is a candidate for inclusion on the RED list.

[3] There are approximately 47 countries that issue, or have issued, lists, warning letters, or public statements, including Belgium, Brazil, British Virgin Islands, Canada (Ontario, British Columbia and the Quebec provincial regulators), Croatia, Denmark, Hong Kong, Ireland, Malaysia, Panama, Poland, Cyprus, Singapore, Spain, Sweden, Switzerland, Thailand, The Netherlands, the United Kingdom and the U.S.

The International Organization of Securities Commissions ("IOSCO") has established an

II. The RED List

In light of the challenges associated with taking enforcement action against such entities, the Commission believes it useful to educate and empower prospective investors. The goal of the RED List is to provide prospective investors with information regarding unregistered soliciting entities before they invest. For a foreign entity to be listed on the CFTC's RED List, reasonable grounds must exist to believe that the entity meets the following six criteria:

1. The entity is foreign;
2. The foreign entity has no or limited presence in the United States;[4]
3. The foreign entity is soliciting and/or accepting funds from U.S. residents;
4. The foreign entity is offering a product within the Commission's jurisdiction (*e.g.* "forex");
5. The foreign entity is required to be registered; and
6. The foreign entity is not registered.[5]

If the foreign entity meets these criteria, Enforcement will propose that it be included on a publicly disclosed list stating that the foreign entity is acting in a capacity that appears to require registration but is not registered with the Commission. This list will then be publicized by the Commission's Office of Consumer Outreach by a variety of different methods and media.

The RED List process contains three separate levels of review before a recommendation is made to the Commission for inclusion on the RED List. First the Intake Officer reviews the complaint and makes an initial determination of whether a foreign entity should potentially be included in the RED List. This initial determination is passed to a Triage Officer who will conduct a limited investigation and then make a recommendation to an Enforcement Deputy Director. The Deputy Director will, based on the information before him/her, make a decision as to whether to recommend to the Commission that it include a foreign entity on the RED List. These levels of review are to ensure that only those foreign entities that should be included on the RED List are included on the RED List.

The CFTC is committed to providing accurate information to investors using the RED List. Before listing an entity on the RED List, Commission staff will notify the entity by Notice Letter of the Commission's intent to list the entity. The entity will have the opportunity to respond to the Commission and provide relevant documentation. If the foreign entity does not respond to the notice letter or provides an unsatisfactory response, Enforcement will recommend to the Commission that a foreign entity should be included on the RED List.

To implement the RED List, the Commission will post on its public Web sites, *http://www.SmartCheck.gov/REDList,* the names, and only the names, of unregistered soliciting foreign entities that have been subject of complaints received by the CFTC. The RED list will contain the following information:

RED (Registration Deficient) LIST

List of Foreign Entities That Have Been Identified as Acting in a Capacity That Appears To Require Registration but Are Not Appropriately Registered With the Commission

The Commodity Futures Trading Commission ("CFTC") frequently receives investigative leads and questions from the public about foreign entities that solicit and/or accept funds from U.S. residents at a retail level. For example these leads and questions can relate to, among things, foreign entities that engage in foreign currency ("Forex") in a capacity similar to Retail Foreign Exchange Dealers ("RFEDs"), Introducing Brokers, Commodity Trading Advisors or Commodity Pool Operators *http://www.cftc.gov/ConsumerProtection/FraudAwarenessPrevention/ForeignCurrencyTrading/index.htm;* and binary options *http://www.cftc.gov/PressRoom/PressReleases/fraudadv_binaryoptions.* Many of these foreign entities are acting in a capacity that requires them to be registered with the CFTC.

If a foreign entity is registered with the CFTC, then it is subject to CFTC regulations and oversight that apply to registrants. Generally, foreign entities that solicit you to trade are required to register with the CFTC. For this reason, it is important for you to consider whether the foreign entity that solicits you is, in fact, registered with the CFTC.

In certain cases, a preliminary review by the CFTC reveals that foreign entities that solicit and/or accept funds from U.S. residents at a retail level have no or limited U.S. presence, and act in a capacity that requires registration, but are not in fact registered. In an effort to warn the public about these entities, the CFTC is publishing the names of those foreign entities.

The goal of this list is to provide information to U.S. consumers about foreign entities that are acting in an unregistered capacity and to help them make more informed decisions about whether to trade with or through such an entity. The more that U.S. consumers trade with and through registered entities, the more likely that their funds will have a greater chance of being protected.

The named foreign entities currently appear to be acting in a capacity that requires registration with the CFTC but are NOT registered with the CFTC.

[Inserted will be a list of all of the foreign entities that have met the criteria, as approved by the Commission.]

The inclusion of an entity's name on the RED list does not mean that the CFTC or a Court has concluded that a violation of any provision of the Commodity Exchange Act or the Commission's Regulations has occurred.

III. Review of RED List

Twice annually, on or about June 30 and December 31, the Triage Officer will review the RED List and, if it appears that a minimum of 12 months have elapsed during which no complaints have been received regarding the a foreign entity and the foreign entity's Web site is either inactive or taken down, Enforcement will submit a recommendation for Commission consideration to move the foreign entity from the active portion of the RED List homepage to the archival portion of such page.

Issued in Washington, DC, on September 9, 2015, by the Commission.

Robert N. Sidman,

Deputy Secretary of the Commission.

[FR Doc. 2015–23040 Filed 9–11–15; 8:45 am]

BILLING CODE 6351–01–P

investor Alert Portal on its Web site to receive and publish alerts and warnings from its members about firms which are not authorized to provide investment services in the jurisdiction that issued the alert or warning.

[4] Merely registering a Web site with a U.S. based domain name registrar does not constitute physical presence.

[5] If the foreign entity offers binary options there is one additional criterion: Whether the entity is a foreign board of trade. If it is a foreign board of trade, then the entity would not be eligible for the RED list.

BUREAU OF CONSUMER FINANCIAL PROTECTION

[Docket No: CFPB–2015–0038]

Agency Information Collection Activities: Submission for OMB Review; Comment Request

AGENCY: Bureau of Consumer Financial Protection.

ACTION: Notice and request for comment.

SUMMARY: In accordance with the Paperwork Reduction Act of 1995 (PRA), the Consumer Financial Protection Bureau (Bureau) is proposing a new information collection titled, "Regulation F: Fair Debt Collection Practices Act, State Application for Exemption (12 CFR 1006.2)".

DATES: Written comments are encouraged and must be received on or before October 14, 2015 to be assured of consideration.

ADDRESSES: You may submit comments, identified by the title of the information collection, OMB Control Number (see

below), and docket number (see above), by any of the following methods:

• *Electronic: http://www.regulations.gov.* Follow the instructions for submitting comments.

• *OMB:* Office of Management and Budget, New Executive Office Building, Room 10235, Washington, DC 20503 or fax to (202) 395–5806. Mailed or faxed comments to OMB should be to the attention of the OMB Desk Officer for the Bureau of Consumer Financial Protection.

Please note that comments submitted after the comment period will not be accepted. In general, all comments received will become public records, including any personal information provided. Sensitive personal information, such as account numbers or social security numbers, should not be included.

FOR FURTHER INFORMATION CONTACT: Documentation prepared in support of this information collection request is available at *www.reginfo.gov* (this link active on the day following publication of this notice). Select "Information Collection Review," under "Currently under review, use the dropdown menu "Select Agency" and select "Consumer Financial Protection Bureau" (recent submissions to OMB will be at the top of the list). The same documentation is also available at *http://www.regulations.gov.* Requests for additional information should be directed to the Consumer Financial Protection Bureau, (Attention: PRA Office), 1700 G Street NW., Washington, DC 20552, (202) 435–9575, or email: *PRA@cfpb.gov. Please do not submit comments to this email box.*

SUPPLEMENTARY INFORMATION:

Title of Collection: Regulation F: Fair Debt Collection Practices Act, State Application for Exemption (12 CFR 1006.2).

OMB Control Number: 3170–XXXX.

Type of Review: Request for a new OMB Control Number.

Affected Public: State and Tribal governments and the five (5) inhabited U.S. Territories.

Estimated Number of Respondents: 1.

Estimated Total Annual Burden Hours: 2.

Abstract: This Rule establishes procedures and criteria whereby states may apply to the Bureau for exemption of a class of debt collection practices within the applying state from the provisions of the Fair Debt Collection Practices Act (FDCPA) as provided in section 817 of the Act, 15 U.S.C. 1692. The information collection request seeks OMB approval for the state application for exemption from the provisions of FDCPA as contained in 12 CFR 1006.2.

Request for Comments: The Bureau issued a 60-day **Federal Register** notice on June 15, 2015, (80 FR 34148). Comments were solicited and continue to be invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the Bureau, including whether the information will have practical utility; (b) The accuracy of the Bureau's estimate of the burden of the collection of information, including the validity of the methods and the assumptions used; (c) Ways to enhance the quality, utility, and clarity of the information to be collected; and (d) Ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology. Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record.

Dated: September 9, 2015.

Linda F. Powell,

Chief Data Officer, Bureau of Consumer Financial Protection.

[FR Doc. 2015–23070 Filed 9–11–15; 8:45 am]

BILLING CODE 4810–AM–P

BUREAU OF CONSUMER FINANCIAL PROTECTION

[Docket No: CFPB–2015–0039]

Agency Information Collection Activities: Comment Request

AGENCY: Bureau of Consumer Financial Protection.

ACTION: Notice and request for comment.

SUMMARY: In accordance with the Paperwork Reduction Act of 1995 (PRA), the Consumer Financial Protection Bureau (Bureau) is requesting to renew the Office of Management and Budget (OMB) approval for an existing information collection, titled, "High-Cost Mortgage and Homeownership Counseling Amendments to the Truth in Lending Act (Regulation Z)."

DATES: Written comments are encouraged and must be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: You may submit comments, identified by the title of the information collection, OMB Control Number (see below), and docket number (see above), by any of the following methods:

• *Electronic: http://www.regulations.gov.* Follow the instructions for submitting comments.

• *Mail:* Consumer Financial Protection Bureau (Attention: PRA Office), 1700 G Street NW., Washington, DC 20552.

• *Hand Delivery/Courier:* Consumer Financial Protection Bureau (Attention: PRA Office), 1275 First Street NE., Washington, DC 20002.

Please note that comments submitted after the comment period will not be accepted. In general, all comments received will become public records, including any personal information provided. Sensitive personal information, such as account numbers or social security numbers, should not be included.

FOR FURTHER INFORMATION CONTACT: Documentation prepared in support of this information collection request is available at *www.regulations.gov.* Requests for additional information should be directed to the Consumer Financial Protection Bureau, (Attention: PRA Office), 1700 G Street NW., Washington, DC 20552, (202) 435–9575, or email: *PRA@cfpb.gov. Please do not submit comments to this mailbox.*

SUPPLEMENTARY INFORMATION:

Title of Collection: High-Cost Mortgage and Homeownership Counseling Amendments to the Truth in Lending Act (Regulation Z).

OMB Control Number: 3170–0023.

Type of Review: Extension without change of a currently approved collection.

Affected Public: Businesses and other for- and non-profit institutions.

Estimated Number of Respondents: 49.

Estimated Total Annual Burden Hours: 317.

Abstract: The Truth in Lending Act (TILA), 15 U.S.C. 1601 *et seq.,* was enacted to foster comparison credit shopping and informed credit decision making by requiring accurate disclosure of the costs and terms of credit to consumers. Creditors are subject to disclosure and other requirements that apply to open-end credit (*e.g.,* revolving credit or credit lines) and closed-end credit (*e.g.,* installment financing). TILA imposes disclosure requirements on all types of creditors in connection with consumer credit, including mortgage companies, finance companies, retailers, and credit card issuers, to ensure that consumers are fully apprised of the terms of financing prior to consummation of the transaction and, in some instances, during the loan term. It also imposes advertising disclosure requirements on advertisers of consumer credit. TILA also establishes billing error resolution procedures for open-end credit and limits consumer

liability for the unauthorized use of credit cards. An amendment to TILA, the Home Ownership and Equity Protection Act (HOEPA), imposes, among other things, various disclosure and other requirements on certain creditors offering high-cost mortgages to consumers. The CFPB promulgated its Regulation Z to implement TILA, as required by the statute. The CFPB enforces TILA as to certain creditors and advertisers. TILA also contains a private right of action for consumers and provides enhanced remedies to consumers in high-cost mortgages for violations of HOEPA.

Request for Comments: Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the Bureau, including whether the information will have practical utility; (b) The accuracy of the CFPB's estimate of the burden of the collection of information, including the validity of the methods and the assumptions used; (c) Ways to enhance the quality, utility, and clarity of the information to be collected; and (d) Ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology. Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record.

Dated: September 9, 2015.

Linda F. Powell,

Chief Data Officer, Bureau of Consumer Financial Protection.

[FR Doc. 2015–23068 Filed 9–11–15; 8:45 am]

BILLING CODE 4810–AM–P

DEPARTMENT OF DEFENSE

Office of the Secretary

National Commission on the Future of the Army; Notice of Federal Advisory Committee Meeting

AGENCY: Deputy Chief Management Officer, Department of Defense (DoD).

ACTION: Notice of Federal advisory committee meeting.

SUMMARY: The DoD is publishing this notice to announce an open meeting of the National Commission on the Future of the Army ("the Commission").

DATES: Date of the open meeting: Thursday, September 24, 2015, from 3 p.m. to 5 p.m.

ADDRESSES: Address of open meeting, September 24, 2015: Red Lion Hotel Conference Room, Red Lion Hotel—Tacoma, 8402 S. Hosmer Street, Tacoma, WA 98444.

FOR FURTHER INFORMATION CONTACT: Mr. Don Tison, Designated Federal Officer, National Commission on the Future of the Army, 700 Army Pentagon, Room 3E406, Washington, DC 20310–0700, Email: *dfo.public@ncfa.ncr.gov.* Desk (703) 692–9099. Facsimile (703) 697–8242.

SUPPLEMENTARY INFORMATION:

Due to circumstances beyond the control of the Designated Federal Officer and the Department of Defense, the National Commission on the Future of the Army was unable to provide public notification of its meeting of September 24, 2015, as required by 41 CFR 102–3.150(a). Accordingly, the Advisory Committee Management Officer for the Department of Defense, pursuant to 41 CFR 102–3.150(b), waives the 15-calendar day notification requirement. This meeting will be held under the provisions of the Federal Advisory Committee Act (FACA) of 1972 (5 U.S.C., Appendix, as amended), the Government in the Sunshine Act of 1976 (5 U.S.C. 552b, as amended), and 41 CFR 102–3.150.

Purpose of Meetings: During the open meeting on Thursday, September 24, 2015, the Commission will hear verbal comments from the public.

Agenda: September 24, 2015, 3 p.m. to 5 p.m.—Open Hearing: The public will have the opportunity to make verbal comments.

Meeting Accessibility: Pursuant to 41 CFR 102–3.140 through 102–3.165 and the availability of space, the meeting scheduled for September 24, 2015 from 3 p.m. to 5 p.m. at the Red Lion Hotel Conference Room is open to the public. Seating is limited and pre-registration is strongly encouraged. Media representatives are also encouraged to register. Members of the media must comply with the rules of photography and video filming published by the Red Lion Hotel. The closest public parking facility is located on the property. Visitors should keep their belongings with them at all times.

Written Comments: Pursuant to section 10(a)(3) of the FACA and 41 CFR 102–3.105(j) and 102–3.140, the public or interested organizations may submit written comments to the Commission in response to the stated agenda of the open and/or closed meeting or the Commission's mission. The Designated Federal Officer (DFO) will review all submitted written statements. Written comments should be submitted to Mr. Donald Tison, DFO, via facsimile or electronic mail, the preferred modes of submission. Each page of the comment must include the author's name, title or affiliation, address, and daytime phone number. All comments received before Wednesday, September 23, 2015, will be provided to the Commission before the September 24, 2015, meeting. Comments received after Wednesday, September 23, 2015, will be provided to the Commission before its next meeting. All contact information may be found in the **FOR FURTHER INFORMATION CONTACT** section.

Oral Comments: In addition to written statements, one hour and forty minutes will be reserved for individuals or interest groups to address the Commission on September 24, 2015. Those interested in presenting oral comments to the Commission must summarize their oral statement in writing and submit with their registration. The Commission's staff will assign time to oral commenters at the meeting; no more than five minutes each for individuals. While requests to make an oral presentation to the Commission will be honored on a first come, first served basis, other opportunities for oral comments will be provided at future meetings.

Registration: Individuals and entities who wish to attend the public hearing and meeting on Thursday, September 24, 2015 are encouraged to register for the event with the DFO using the electronic mail and facsimile contact information found in the **FOR FURTHER INFORMATION CONTACT** section. The communication should include the registrant's full name, title, affiliation or employer, email address, day time phone number. This information will assist the Commission in contacting individuals should it decide to do so at a later date. If applicable, include written comments and a request to speak during the oral comment session. (Oral comment requests must be accompanied by a summary of your presentation.) Registrations and written comments should be typed.

Additional Information

The DoD sponsor for the Commission is the Deputy Chief Management Officer. The Commission is tasked to submit a report, containing a comprehensive study and recommendations, by February 1, 2016 to the President of the United States and the Congressional defense committees. The report will contain a detailed statement of the findings and conclusions of the Commission, together with its recommendations for such legislation and administrative actions it may consider appropriate in light of the results of the study. The comprehensive

study of the structure of the Army will determine whether, and how, the structure should be modified to best fulfill current and anticipated mission requirements for the Army in a manner consistent with available resources.

Dated: September 8, 2015.

Aaron Siegel,

Alternate OSD Federal Register Liaison Officer, Department of Defense.

[FR Doc. 2015–22983 Filed 9–11–15; 8:45 am]

BILLING CODE 5001–06–P

DEPARTMENT OF DEFENSE

Office of the Secretary

Charter Establishment of Department of Defense Federal Advisory Committees

AGENCY: Department of Defense.

ACTION: Establishment of Federal advisory committee.

SUMMARY: The Department of Defense is publishing this notice to announce that it is establishing the charter for the Lake Eufaula Advisory Committee ("the Committee").

FOR FURTHER INFORMATION CONTACT: Jim Freeman, Advisory Committee Management Officer for the Department of Defense, 703–692–5952.

SUPPLEMENTARY INFORMATION: This committee's charter is being established in accordance with the Federal Advisory Committee Act (FACA) of 1972 (5 U.S.C., Appendix, as amended) and 41 CFR 102–3.50(a).

The Committee is a statutory Federal advisory committee that provides information and recommendations to the Secretary of Defense through the Secretary of the Army, the Assistant Secretary of the Army for Civil Works, and the U.S. Army Corps of Engineers ("the Corps"), regarding the operations of Lake Eufaula for the project purposes for Lake Eufaula.

According to section 3133(a) of the 2007 WRDA, the Lake Eufaula project goal is to maximize the use of available storage in a balanced approach that incorporates advice from representatives from all the project purposes to ensure that the full value of the reservoir is realized by the United States. To achieve this goal, recreation is recognized as a project purpose at Lake Eufaula, pursuant to section 4 of the Flood Control Act of December 22, 1944 (58 Stat. 889). The recommendations of the Committee shall be considered by the Secretary of the Army and the Corp in performing a reallocation study and developing an interim management plan as required by sections 3133(c) and (d) of the 2007 WRDA. The Department of Defense (DoD), through the Department of the Army and the Corps, shall provide support for the Committee and shall ensure compliance with the requirements of the FACA, the Government in the Sunshine Act of 1976 ("the Sunshine Act") (5 U.S.C. 552b, as amended), governing Federal statutes and regulations, and established DoD policies and procedures.

Pursuant to section 3133(b) of the 2007 WRDA, the Committee shall be composed of members that equally represent the project purposes for Lake Eufaula, identified as flood control, water supply, hydroelectric power, navigation, fish and wildlife, and recreation. The Committee shall consist of no more than 12 members. Committee members will serve a two-year term of service, with annual renewals, on the Committee. Members may be appointed to no more than two terms of service (four years total) without prior approval of the Secretary of Defense or Deputy Secretary of Defense. Members may subsequently be reappointed to the Committee but only after being off the Committee for at least two years.

The Committee will be comprised of a mix of regular government employee (RGE) members, special government employee (SGE) members, and representative members. Those individuals who are full-time or permanent part-time Federal officers or employees will be appointed pursuant to 41 CFR 102–3.130(a) to serve as RGE members. Those individuals who are not full-time or permanent part-time Federal officers or employees and provide their own best independent judgment based on their individual expertise will be appointed as experts or consultants pursuant to 5 U.S.C. 3109 to serve as SGE members. Those individuals who are not full-time or permanent part-time Federal officers or employees and are selected for the purpose of obtaining the point of view or perspective of an outside interest group or stakeholder interest will be appointed pursuant to 41 CFR 102–3.130(a) to serve as representative members.

The Secretary of the Army will appoint the Chair and the Vice Chair of the Committee and the leadership for any approved subcommittees from the respective Committee and subcommittee membership previously approved by the Secretary of Defense or Deputy Secretary of Defense.

With the exception of reimbursement for official travel and per diem, Committee members shall serve without compensation.

The DoD, when necessary and consistent with the Committee's mission and DoD policies and procedures, may establish subcommittees, task groups, or working groups to support the Committee. Establishment of subcommittees will be based upon a written determination, to include terms of reference, by the Secretary of Defense, the Deputy Secretary of Defense, or the Secretary of the Army. Currently, the Committee does not use subcommittees. If the DoD determines that the establishment of subcommittees is warranted, the Committee's charter and membership balance plan must be amended prior to such establishment.

The Designated Federal Officer (DFO) shall be a full-time or permanent part-time DoD officer or employee designated in accordance with governing DoD policies and procedures.

The Committee's DFO is required to be in attendance at all meetings of the Committee and any subcommittees for the entire duration of each and every meeting. However, in the absence of the Committee's DFO, a properly approved Alternate DFO, duly designated to the Committee according to DoD policies and procedures, shall attend the entire duration of the meetings of the Committee or any subcommittees.

The DFO, or the Alternate DFO, shall call all meetings of the Committees and any subcommittees; prepare and approve all meeting agendas; and adjourn any meeting when the DFO, or the Alternate DFO, determines adjournment to be in the public's interest or required by governing regulations or DoD policies and procedures.

Pursuant to 41 CFR 102–3.105(j) and 102–3.140, the public or interested organizations may submit written statements to Committee membership about the Committee's mission and functions. Written statements may be submitted at any time or in response to the stated agenda of planned meeting of the Committee.

All written statements shall be submitted to the DFO for the Committee, and this individual will ensure that the written statements are provided to the membership for their consideration. Contact information for the Committee's DFO can be obtained from the GSA's FACA Database—*http://www.facadatabase.gov/.*

The DFO, pursuant to 41 CFR 102–3.150, will announce planned meetings of the Committee. The DFO, at that time, may provide additional guidance on the submission of written statements that are in response to the stated agenda for the planned meeting in question.

Dated: September 8, 2015.

Aaron Siegel,

Alternate OSD Federal Register Liaison Officer, Department of Defense.

[FR Doc. 2015–22966 Filed 9–11–15; 8:45 am]

BILLING CODE 5001–06–P

DEPARTMENT OF DEFENSE

Department of the Army, Corps of Engineers

Intent To Prepare an Integrated Draft Feasibility Report and Environmental Impact Statement To Investigate Hydrologic and Hydraulic Problems Threatening Navigation, Aquatic Ecosystem Habitat, Recreation, Flood Damage Reduction and Existing Infrastructure at the Three Rivers Study Site in Arkansas and Desha Counties in Southeast Arkansas

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: The study is being conducted under the authority contained in the River and Harbor Act of 1946 (Pub. L. 79–525), as amended, which authorized the development of the Arkansas River and its tributaries for the purposes of navigation, flood control, hydropower, water supply, recreation, and fish and wildlife. Public Law 91–649 stated that the project would be known as the McClellan-Kerr Arkansas River navigation system. Additional authorization is included by the Flood Control Act of 1970, (Pub. L. 91–611), as amended, under Section 216 and under guidance provided in ER 1105–2–100. Pursuant to the National Environmental Policy Act (NEPA), the USACE, Little Rock District, will prepare a Draft Environmental Impact Statement (EIS) for the Three Rivers Study. The EIS will evaluate potential impacts (beneficial and adverse) to the natural, physical, and human environment as a result of implementing any of the proposed project alternatives developed during the process.

ADDRESSES: Submit written comments to Mr. Craig Hilburn, Biologist, U.S. Army Corps of Engineers, Planning and Environmental Division, Environmental Branch, Little Rock District, P.O. Box 867, Little Rock, AR 72203–0867. Comments will be accepted through October 15, 2015.

FOR FURTHER INFORMATION CONTACT: For questions or comments regarding the Three Rivers Draft Feasibility Report or EIS, please contact Mr. Craig Hilburn, (501) 324–5735 or email: *david.c.hilburn@usace.army.mil.*

SUPPLEMENTARY INFORMATION:

1. MKARNS: The McClellan-Kerr Arkansas River Navigation System consists of a series of 18 locks and dams that provide navigation from the Mississippi River to the Port of Catoosa near Tulsa, Oklahoma. River flow in the Arkansas River is modified primarily by 11 reservoirs in Oklahoma.

2. Study Location: The study is located at the confluence of the Mississippi, White, and Arkansas Rivers in Desha and Arkansas Counties, in southeast Arkansas. Prominent features include the McClellan-Kerr Arkansas River Navigation System (MKARNS) Post Canal and the 160,000-acre Dale Bumpers National Wildlife Refuge (U.S. Fish and Wildlife Service). The Arkansas Post Canal connects the Arkansas River to the White River for navigation onto the Mississippi River to complete the 445-mile navigation system. The study area is downstream of Lock No. 1 of the MKARNS and upstream of the Montgomery Point Lock & Dam and includes any adjacent landmasses that are presently being impacted or could be potentially impacted by the alternatives.

3. Study History: Studies in the area have occurred since the mid-1960's. Structures were placed along the White River and between the White and Arkansas River to regulate hydrologic flow between the two systems in the 1960's, 1970's and late 1980's.

4. Scoping/Public Involvement. The Public Scoping process provides information about the study to the public, serves as a mechanism to solicit agency and public input on alternatives and issues of concern, and ensures full and open participation in Scoping and review of the Draft EIS. Comments received as a result of this notice and news releases will be used to assist the preparers in identifying potential impacts to the quality of the human or natural environment. The Corps invites other Federal agencies, Native American Tribes, State and local agencies and officials, private organizations, and interested individuals to participate in the Scoping process by forwarding written comments to (see **ADDRESSES**). Interested parties may also request to be included on the mailing list for public distribution of announcements and documents.

5. Issues/Alternatives: The EIS will evaluate effects from a range of alternatives developed to address navigation and environmental concerns of the area. Anticipated significant issues to be addressed in the EIS include impacts on: (1) Navigation, (2) flooding, (3) recreation, (4) river hydraulics, (5) fish and wildlife resources and habitats, (6) wetlands, (7) timber and forestry management, and (8) other impacts identified by the Public, agencies or USACE studies.

The hydrology of the two rivers is strongly influenced by high water in the Mississippi River. Significant hydrologic and hydraulic problems currently threaten the Corps' mission areas of Navigation, Recreation, Flood Risk Management, as well as aquatic ecosystem habitat and existing infrastructure. Possible solutions may include increasing detention upstream, raising the height of the containment structure, removal of the control structure, or construction of a passive or active weir to restore a more natural hydrology between the two rivers. The study will evaluate opportunities for ecosystem restoration. Proposed improvements resulting from the study could impact (positively or negatively) navigation, agriculture, silviculture, hydropower, recreation, flood risk management, and fish and wildlife.

6. Availability of the Draft EIS: The Draft Environmental Impact Statement is anticipated to be available for public review in the spring of 2017, subject to the receipt of Federal funding.

Courtney W. Paul,

Colonel, U.S. Army, District Engineer.

[FR Doc. 2015–23032 Filed 9–11–15; 8:45 am]

BILLING CODE 3720–58–P

DEPARTMENT OF DEFENSE

Department of the Army, Corps of Engineers

National Wetland Plant List

AGENCY: U.S. Army Corps of Engineers, DoD.

ACTION: Notice.

SUMMARY: The National Wetland Plant List (NWPL) is used to delineate wetlands for purposes of the Clean Water Act and the Wetland Conservation Provisions of the Food Security Act. Other applications of the list include wetland restoration, establishment, and enhancement projects. To update the NWPL, the U.S. Army Corps of Engineers (Corps), as part of an interagency effort with the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS) and the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), is announcing the availability of the draft National Wetland Plant List (NWPL) 2015 and its Web address to solicit public comments. The public will now be provided the opportunity to

comment and vote on the proposed update of wetland indicator status ratings for 186 plants species in select Corps wetland regions.

DATES: Comments must be submitted on or before November 13, 2015.

ADDRESSES: U.S. Army Corps of Engineers, Attn: CECW–CO (Ms. Karen Mulligan), 441 G Street NW., Washington, DC 20314–1000.

FOR FURTHER INFORMATION CONTACT: Ms. Karen Mulligan, Headquarters, Operations and Regulatory Community of Practice, Washington, DC at 202–761–4664.

SUPPLEMENTARY INFORMATION: The U.S. Army Corps of Engineers (Corps) administers the National Wetland Plant List (NWPL) for the United States (U.S.) and its territories. Responsibility for the NWPL was transferred to the Corps from the U.S. Fish and Wildlife Service (FWS) in 2006. The Corps led interagency efforts to update the list in 2012, 2013, and 2014. The 2012 list contained 7,828 species, the 2013 update contained 7,937 species, and the 2014 update contained 8,061 species. Additions to these lists represent new records, range extensions, nomenclatural changes, and newly proposed species.

During the latest review process the ratings of two groups of plant species were reevaluated. The first consisted of a group of plants for which the public submitted rating changes on the NWPL Web site from November 10, 2014 to January 31, 2015. A total of 60 suggested rating changes for 42 species were submitted for eight Corps regions and two subregions. Twenty-two ratings and 14 species of these were not evaluated because (1) the proposed rating and the current rating were the same (nine species), (2) crops and epiphytic species were removed from the NWPL in the 2012 update (four species), and (3) insufficient information (one species). This leaves a total of 38 ratings for 28 species which were evaluated in seven Corps regions and two subregions. Of the 28 species evaluated, seven of these were suggested additions to the NWPL. The second group consisted of species with highly variable ratings, which were reexamined because they spanned more than three ratings categories, nationally (*i.e.,* rated FACW in the Arid West and UPL in the Caribbean). This group contained 885 ratings of 169 species. Three species were included in both groups. As a result of the process, 923 ratings of 194 species, in ten Corps regions were reviewed by the regional and national panels and a draft NWPL 2015, containing 8,056 species, has been compiled.

In group one, 71% percent of the public requests resulted in potential changes to the NWPL (resulting in 27 rating changes for 21 species). The ratings of the remaining species are unchanged, including one proposed addition that was determined to be an upland plant. Six new plants were recommended to be added to the NWPL. In group two, 30% percent of the highly variable ratings resulted in proposed changes to the NWPL (267 proposed rating changes for 168 species). One species was removed from the NWPL because it does not grow in soil. Removal of ten additional species is proposed because they were determined to be rated UPL in every region in which they occur. The overall net change between the 2014 list and the proposed 2015 list would be five species (6 proposed additions and 11 proposed removals).

Together, the proposed changes based on public requests and highly variable ratings total 1% of the ratings (294) and 2% (186) of the species on the 2014 NWPL. These proposed changes are nearly an equal split between species that received wetter ratings and those that received drier ratings. The specific break-down of proposed changes are: 51 percent (151 ratings for 116 species) rated wetter and 49 percent (143 ratings for 111 species) rated drier. The number of species above (227) exceeds the number of species included in the update (186) because 41 species were included in each category (*e.g.,* proposed to go drier in one region and wetter in another). Most of the rating changes are proposed in the Atlantic and Gulf Coastal Plain (55) and the Caribbean Islands (53) regions. The fewest changes are proposed in the Hawaii and Pacific Islands (12) and the Northcentral and Northeast (13) regions. Complete lists of changes by region, resources used to evaluate ratings and species, and newly submitted literature references are located at: *http://wetland_plants.usace.army.mil/nwpl2015_update/proposed_changes/.*

Indicator Status Ratings

On the NWPL, there are five categories of indicator status ratings, used to describe a plant's likelihood for occurrence in a wetland versus and upland: Obligate Wetland (OBL), Facultative Wetland (FACW), Facultative (FAC), Facultative Upland (FACU), and Obligate Upland (UPL). These rating categories are defined by the National Panel as follows: OBL—almost always is a hydrophyte, rarely in uplands; FACW—usually is a hydrophyte but occasionally found in uplands; FAC—commonly occurs as either a hydrophyte or non-hydrophyte; FACU—occasionally is a hydrophyte but usually occurs in uplands; UPL—rarely is a hydrophyte, almost always in uplands. These category definitions are qualitative descriptions that better reflect the qualitative supporting information, rather than numeric frequency ranges. The percentage frequency categories used in the older definitions are only used for testing problematic or contested species being recommended for indicator status changes. Plus and minus designations and wetland indicator designations such as No Indicator (NI), No Occurrence (NO), and No Agreement (NA) are no longer used on the NWPL. When assigning wetland indicator statuses, commenters should use the rating definitions described above and developed by the National Panel for updating the NWPL.

Wetlands are defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFR 328.3 and 40 CFR 230.3). Such wetlands are identified using the Corps 1987 Wetland Delineation Manual or relevant regional supplements, whichever is more recent. Wetlands are identified using the three factor approach. Because each species being evaluated occurs as part of a vegetation assemblage, examining the other species present may be useful in assessing hydrophytic vegetation.

Instructions for Providing Comments Online

Reviewers may consider the ecological information on the NWPL Web site, which includes prior information obtained by the FWS and others. Links to prior rating votes and maps of Corps wetland regions can be accessed from the NWPL *homepage.* To access regional voting records during the recent NWPL updates, click the *"Voting History (Rounds/Algos)"* link. To find ratings from the 1988 or 1996 Plant Lists, click *"National Wetland Plant List", "NWI 1988/1996 Lists"* and then either *"1996 National Summary"* or *"1988 National Summary (Reed 1988)."* The Corps wetland regions and subregions are based on Land Resource Regions (LRRs) and Major Land Resource Areas (MLRAs) (*http://soils.usda. gov/survey/geography/mlra/).* To display regional maps click the *"Wetland Regions and Rating Info"* link on the NWPL homepage. To view subregional maps, click the link under the "NWPL Viewer Tool" heading in the

upper left of the homepage. Once the viewer tool opens in a new window, click the "*Custom Plant List,*" "*Geographic Area,*" and "*USACE subregions*" links. The viewer tool is also used to access individual species pages. To find a species, type the scientific name into the search box in the upper right corner. Users are automatically redirected to the currently accepted name when a synonym is entered. Each species page includes scientific and common names, synonyms, and maps of distributions by county. Habitat descriptions from the literature can be displayed in the center of the page by clicking on "*Species Detail,*" "*Center Page View,*" and "*FWS or CRREL Literature.*"

The Corps is requesting assistance in the form of data, comments, literature references, or field experiences, to help clarify the status of the 186 species in the 2015 NWPL update. Comments may be made on one or more species in any of the wetland supplement regions or subregions where a rating change is proposed. A list of these species by region and the details of how their rating was evaluated by Regional and National Panel members can be viewed at the NWPL homepage, *http://wetland_plants. usace.army.mil/* by clicking on the "*Proposed FR NWPL2015 Update*" and "*Proposed Changes*" links. Recently submitted literature references are also shown here. Comments on these proposed changes to the NWPL are being accepted at the same Web site. To add input, commenters should click on the "*Federal Register Comments*" link underneath the "*Proposed Changes*" link. Commenters will be redirected to an online form for submitting comments. Literature citations, experiential references, monitoring data, and other relevant reports may be submitted through this form. In all cases, the most useful comments are from specific knowledge or studies related to individual species. Commenters should use their regional botanical and ecological expertise, field observations, reviews of the most recent indicator status information, appropriate botanical literature, floras, herbarium specimens with notation of habitat and associated species, habit data, relevant studies, and historic list information. Guessing ratings is inappropriate. The commenter can also submit general comments on the 2015 NWPL update that are not related to a specific species. General comments can be submitted by clicking on the email contact link titled "*Questions or Comments? Contact us!*" on the NWPL homepage. All votes and comments will be compiled and sent to the National Panel for their consideration.

Future Actions

Future updates to the NWPL will occur biennially according to the following proposed procedures. A change in indicator status may be requested at any time at *http://wetland_plants.usace.army.mil/* by clicking on the "Submit a NWPL *Change Request*" link and submitting the appropriate data. Data includes ecological data, literature reviews, testing descriptions, geographic data, and frequency and abundance data for the taxon in wetlands and uplands in the Corps wetland region or subregion for which the change is proposed. The regions and subregions are based on Land Resource Regions (LRRs) and Major Land Resource Areas (MLRAs) (*http://soils.usda.gov/survey/geography/mlra/*) and are shown for each wetland supplement region on the NWPL Web site. If the commenter believes that a wetland supplement region needs a subregion that has not yet been developed, the commenter should identify the MLRAs involved and provide a list of species from within that region that need their own wetland ratings.

Proposed rating changes will be compiled in January of odd years (*i.e.* 2017, 2019) and sent to the Regional Panels for input in February. The National Panel will assign wetland ratings to non-consensus species and will review all regional lists in April. The proposed changes will be compiled over the summer and published in the **Federal Register** for public comment in September. In October, public comments will be summarized and the National Panel will review and respond to comments. The final changes will be published in the **Federal Register** in December of odd years.

Dated: September 4, 2015.

Edward E. Belk, Jr.

Chief, Operations and Regulatory Division, Directorate of Civil Works.

[FR Doc. 2015–23031 Filed 9–11–15; 8:45 am]

BILLING CODE 3720–58–P

DEPARTMENT OF EDUCATION

[Docket No.: ED–2015–ICCD–0074]

Agency Information Collection Activities; Submission to the Office of Management and Budget for Review and approval; Comment Request; Mandatory Civil Rights Data Collection

AGENCY: Office of Civil Rights (OCR), Department of Education (ED).

ACTION: Notice.

SUMMARY: In accordance with the Paperwork Reduction Act of 1995 (44 U.S.C. chapter 3501 *et seq.*), ED is proposing a revision of an existing information collection.

DATES: Interested persons are invited to submit comments on or before October 14, 2015.

ADDRESSES: To access and review all the documents related to the information collection listed in this notice, please use *http://wwww.regulations.gov* by searching the Docket ID number ED–2015–ICCD–0074. Comments submitted in response to this notice should be submitted electronically through the Federal eRulemaking Portal at *http://www.regulations.gov* by selecting the Docket ID number or via postal mail, commercial delivery, or hand delivery. *Please note that comments submitted by fax or email and those submitted after the comment period will not be accepted.* Written requests for information or comments submitted by postal mail or delivery should be addressed to the Director of the Information Collection Clearance Division, U.S. Department of Education, 400 Maryland Avenue SW., LBJ, Room 2E105, Washington, DC 20202–4537.

FOR FURTHER INFORMATION CONTACT: For specific questions related to collection activities, please contact Rosa Olmeda, 202–453–5968.

SUPPLEMENTARY INFORMATION: The Department of Education (ED), in accordance with the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3506(c)(2)(A)), provides the general public and Federal agencies with an opportunity to comment on proposed, revised, and continuing collections of information. This helps the Department assess the impact of its information collection requirements and minimize the public's reporting burden. It also helps the public understand the Department's information collection requirements and provide the requested data in the desired format. ED is soliciting comments on the proposed information collection request (ICR) that is described below. The Department of Education is especially interested in public comment addressing the following issues: (1) Is this collection necessary to the proper functions of the Department; (2) will this information be processed and used in a timely manner; (3) is the estimate of burden accurate; (4) how might the Department enhance the quality, utility, and clarity of the information to be collected; and (5) how might the Department minimize the burden of this collection on the

respondents, including through the use of information technology. Please note that written comments received in response to this notice will be considered public records.

Title of Collection: Mandatory Civil Rights Data Collection

OMB Control Number: 1870–0504

Type of Review: A revision of an existing information collection.

Respondents/Affected Public: State, Local and Tribal Governments

Total Estimated Number of Annual Responses: 17, 620

Total Estimated Number of Annual Burden Hours: 1,520,260

Abstract: The collection, use and reporting of education data is an integral component of the mission of the U.S. Department of Education (ED). EDFacts, an ED initiative to put performance data at the center of ED's policy, management, and budget decision-making processes for all K–12 education programs, has transformed the way in which ED collects and uses data. For school years 2009–10 and 2011–12, the Civil Rights Data Collection (CRDC) was approved by OMB as part of the EDFacts information collection (1875–0240). For school years 2013–14 and 2015–16, the Office for Civil Rights (OCR) cleared the CRDC as a separate collection from EDFacts. OCR used the most current EDFacts information collection approved by OMB (1875–0240) as a model for the 2013–14 and 2015–16 CRDC information collection that was approved by OMB (1870–0504) in February 2014. Similarly, the currently proposed revised CRDC information collection for school year 2015–16 is modeled after the most recent OMB-approved EDFacts information collection. Except for a few data elements that were revised based on recommendations received from various school districts and advice received from experts across ED, the currently proposed CRDC information collection for school year 2015–16 is identical to the information collection for school year 2015–16 that was approved by OMB in February 2014. As with previous CRDC collections, the purpose of the 2015–16 CRDC is to obtain vital data related to the civil rights laws' requirement that public local educational agencies and elementary and secondary schools provide equal educational opportunity. ED seeks OMB approval under the Paperwork Reduction Act to collect from school districts, the elementary and secondary education data described in the sections of Attachment A.

Dated: September 9, 2015.

Stephanie Valentine,

Acting Director, Information Collection Clearance Division, Office of the Chief Privacy Officer, Office of Management.

[FR Doc. 2015–23002 Filed 9–11–15; 8:45 am]

BILLING CODE 4000–01–P

DEPARTMENT OF EDUCATION

National Advisory Council on Indian Education; Public Teleconference Meeting

AGENCY: National Advisory Council on Indian Education (NACIE or Council), U.S. Department of Education.

ACTION: Announcement of an open public teleconference meeting.

SUMMARY: This notice sets forth the schedule of an upcoming public meeting conducted by the National Advisory Council on Indian Education NACIE). Notice of the meeting is required by section 10(a)(2) of the Federal Advisory Committee Act and intended to notify the public of its opportunity to attend.

DATES: The NACIE teleconference meeting will be held via conference call on September 25, 2015—2:00 p.m.–2:30 p.m. Eastern Daylight Saving Time. Up to 20 dial-in, listen only phone lines will be made available to the public on a first come, first served basis. The conference call number is 1–800–857–9682 and the participant code is 5273162.

FOR FURTHER INFORMATION CONTACT: Tina Hunter, Designated Federal Official, Office of Elementary and Secondary Education, U.S. Department of Education, 400 Maryland Avenue SW., Washington, DC 20202. Telephone: 202–205–8527. Fax: 202–205–0310.

SUPPLEMENTARY INFORMATION: NACIE's Statutory Authority and Function: The National Advisory Council on Indian Education is authorized by § 7141 of the Elementary and Secondary Education Act. The Council is established within the Department of Education to advise the Secretary of Education on the funding and administration (including the development of regulations, and administrative policies and practices) of any program over which the Secretary has jurisdiction and includes Indian children or adults as participants or programs that may benefit Indian children or adults, including any program established under title VII, part A of the Elementary and Secondary Education Act. The Council submits to the Congress, not later than June 30 of each year, a report on the activities of the Council that includes recommendations the Council considers appropriate for the improvement of Federal education programs that include Indian children or adults as participants or that may benefit Indian children or adults, and recommendations concerning the funding of any such program.

One of the Council's responsibilities is to develop and provide recommendations to the Secretary of Education on the funding and administration (including the development of regulations, and administrative policies and practices) of any program over which the Secretary has jurisdiction that can benefit Indian children or adults participating in any program which could benefit Indian children.

Meeting Agenda: The purpose of the meeting is to convene the Council to conduct the following business: (1) Final discussion, review and approval of the annual report to Congress; and, (2) Discuss schedule to submit recommendations to the Secretary of Education on funding and administration of programs.

Access to Records of the Meeting: The Department will post the official report of the meeting on the Office of Elementary and Secondary Education (OESE) Web site at: *http://www2.ed.gov/about/offices/list/oese/index.html?src=oc* 21 days after the meeting. Pursuant to the FACA, the public may also inspect the materials at the Office of Indian Education, United States Department of Education, 400 Maryland Avenue SW., Washington, DC 20202, Monday-Friday, 8:30 a.m. to 5:00 p.m. Eastern Daylight Saving Time or by emailing *TribalConsultation@ed.gov* or by calling Terrie Nelson on (202) 401–0424 to schedule an appointment.

Reasonable Accommodations: The teleconference is accessible to individuals with disabilities. If you will need an auxiliary aid or service to participate in the meeting (*e.g.,* interpreting service, assistive listening device, or materials in an alternate format), notify Brandon Dent on (202) 453–6450 no later than September 18, 2015. Although we will attempt to meet a request received after request due date, we may not be able to make available the requested auxiliary aid or service because of insufficient time to make arrangements.

Electronic Access to this Document: The official version of this document is the document published in the **Federal Register.** Free Internet access to the official edition of the **Federal Register** and the Code of Federal Regulations is available via the Federal Digital System at: *www.gpo.gov/fdsys.* At this site you

can view this document, as well as all other documents of this Department published in the **Federal Register**, in text or Adobe Portable Document Format (PDF). To use PDF, you must have Adobe Acrobat Reader, which is available free at the site.

You may also access documents of the Department published in the **Federal Register** by using the article search feature at: *www.federalregister.gov.* Specifically, through the advanced search feature at this site, you can limit your search to documents published by the Department.

Authority: The National Advisory Council on Indian Education is authorized by section 7141 of the Elementary and Secondary Education Act.

Ann Whalen,

Senior Advisor to the Secretary Delegated the Duties of Assistant Secretary for Elementary and Secondary Education.

[FR Doc. 2015–22891 Filed 9–11–15; 8:45 am]

BILLING CODE P

DEPARTMENT OF EDUCATION

[Docket No.: ED–2015–ICCD–0110]

Agency Information Collection Activities; Comment Request; Pell for Students Who Are Incarcerated Experimental Site Initiative

AGENCY: Federal Student Aid (FSA), Department of Education (ED).

ACTION: Notice.

SUMMARY: In accordance with the Paperwork Reduction Act of 1995 (44 U.S.C. chapter 3501 *et seq.*), ED is proposing a new information collection.

DATES: Interested persons are invited to submit comments on or before November 13, 2015.

ADDRESSES: To access and review all the documents related to the information collection listed in this notice, please use *http://wwww.regulations.gov* by searching the Docket ID number ED–2015–ICCD–0110. Comments submitted in response to this notice should be submitted electronically through the Federal eRulemaking Portal at *http://www.regulations.gov* by selecting the Docket ID number or via postal mail, commercial delivery, or hand delivery. *Please note that comments submitted by fax or email and those submitted after the comment period will not be accepted.* Written requests for information or comments submitted by postal mail or delivery should be addressed to the Director of the Information Collection Clearance Division, U.S. Department of Education, 400 Maryland Avenue SW., LBJ, Room 2E103, Washington, DC 20202–4537.

FOR FURTHER INFORMATION CONTACT: For specific questions related to collection activities, please contact Beth Grebeldinger, 202–377–4018.

SUPPLEMENTARY INFORMATION: The Department of Education (ED), in accordance with the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3506(c)(2)(A)), provides the general public and Federal agencies with an opportunity to comment on proposed, revised, and continuing collections of information. This helps the Department assess the impact of its information collection requirements and minimize the public's reporting burden. It also helps the public understand the Department's information collection requirements and provide the requested data in the desired format. ED is soliciting comments on the proposed information collection request (ICR) that is described below. The Department of Education is especially interested in public comment addressing the following issues: (1) Is this collection necessary to the proper functions of the Department; (2) will this information be processed and used in a timely manner; (3) is the estimate of burden accurate; (4) how might the Department enhance the quality, utility, and clarity of the information to be collected; and (5) how might the Department minimize the burden of this collection on the respondents, including through the use of information technology. Please note that written comments received in response to this notice will be considered public records.

Title of Collection: Pell for Students who are Incarcerated Experimental Site Initiative.

OMB Control Number: 1845—NEW.

Type of Review: A new information collection.

Respondents/Affected Public: Private Sector, State, Local and Tribal Governments.

Total Estimated Number of Annual Responses: 100.

Total Estimated Number of Annual Burden Hours: 7,500.

Abstract: Through the Pell for Students who are Incarcerated experiment (also known as Second Chance Pell) the Department of Education will provide selected eligible postsecondary institutions with a waiver to the current statutory ban on incarcerated individuals, who are otherwise eligible, from receiving Federal Pell Grant funds to attend eligible postsecondary programs. The experiment aims to test whether participation in high-quality educational opportunities increases after access to financial aid for incarcerated adults is expanded and to examine how waiving the restriction influences individual academic and life outcomes.

Dated: September 8, 2015.

Kate Mullan,

Acting Director, Information Collection Clearance Division, Office of the Chief Privacy Officer, Office of Management.

[FR Doc. 2015–22970 Filed 9–11–15; 8:45 am]

BILLING CODE 4000–01–P

DEPARTMENT OF EDUCATION

National Committee on Foreign Medical Education and Accreditation

AGENCY: Office of Postsecondary Education, U.S. Department of Education, National Committee on Foreign Medical Education and Accreditation.

ACTION: Announcement of a Committee meeting.

SUMMARY: The purpose of this notice is to announce the upcoming meeting of the National Committee on Foreign Medical Education and Accreditation (NCFMEA). Parts of this meeting will be open to the public, and the public is invited to attend those portions.

Meeting Date and Place: The meeting will be held on October 28, 29, and 30, 2015, from 8:30 a.m. until approximately 5:00 p.m., at the U.S. Department of Education, Eighth Floor Conference Center, Office of Postsecondary Education, 1990 K Street NW., Washington, DC 20006. The Committee will meet in Executive Session on October 30, 2015. The entire October 30th session will be devoted to training sessions for the Committee; and, therefore, is closed to the public.

FOR FURTHER INFORMATION CONTACT: Jennifer Hong, Executive Director for the NCFMEA, U.S. Department of Education, 1990 K Street NW., Room 8073, Washington, DC 20006–8129; telephone: 202 502–7696; fax: 202 502–7874, or email: *Jennifer.Hong@ed.gov*

SUPPLEMENTARY INFORMATION: *Statutory Authority and Function:* The NCFMEA was established by the Secretary of Education under § 102 of the Higher Education Act of 1965, as amended. The NCFMEA's responsibilities are to:

- Evaluate the standards of accreditation applied to foreign medical schools and,
- Determine the comparability of those standards to standards for accreditation applied to United States medical schools.

A determination of comparability of accreditation standards by the NCFMEA is an eligibility requirement for foreign medical schools to participate in the William D. Ford Federal Direct Student Loan Program, 20 U.S.C. 1087a *et seq.*

Meeting Agenda: The NCFMEA will review the standards of accreditation applied to medical schools to determine whether those standards are comparable to the standards of accreditation applied to medical schools in the United States. The NCFMEA will also review previously requested reports from accrediting entities that accredit medical schools. Discussion of the standards of accreditation will be held in sessions open to the public. Discussions resulting in specific determinations of comparability are closed to the public until proper notification of the NCFMEA's decision is provided to the medical school by the Department.

The countries which are scheduled to be discussed are Antigua and Barbuda, Canada, Cayman Islands, Dominica, Dominican Republic, and Hungary. The meeting agenda, as well as the staff analyses pertaining to the meeting, will be posted on the Department of Education's Web site prior to the meeting at *http://www2.ed.gov/about/bdscomm/list/ncfmea.html.*

Reasonable Accommodations: The meeting site is accessible to individuals with disabilities. If you will need an auxiliary aid or service to participate in the meeting (*e.g.,* interpreting service, assistive listening device, or materials in an alternate format), notify the contact person listed in this notice by September 28, 2015, although we will attempt to meet a request received after that date.

Electronic Access To This Document: The official version of this document is the document published in the **Federal Register.** Free Internet access to the official edition of the **Federal Register** and the Code of Federal Regulations is available via the Federal Digital System at: *www.gpo.gov/fdsys.* At this site you can view this document, as well as all other documents of this Department published in the **Federal Register,** in text or Adobe Portable Document Format (PDF). To use PDF, you must have Adobe Acrobat Reader, which is available free at the site.

You may also access documents of the Department published in the **Federal Register** by using the article search feature at: *www.federalregister.gov.* Specifically, through the advanced search feature at this site, you can limit your search to documents published by the Department.

Delegation of Authority: The Secretary of Education has delegated authority to Jamienne S. Studley, Deputy Under Secretary, to perform the functions and duties of the Assistant Secretary for Postsecondary Education.

Authority: § 102 of the Higher Education Act of 1965, as amended.

Jamienne S. Studley,

Deputy Under Secretary.

[FR Doc. 2015–23018 Filed 9–11–15; 8:45 am]

BILLING CODE P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

Combined Notice of Filings #1

Take notice that the Commission received the following electric corporate filings:

Docket Numbers: EC15–202–000.

Applicants: Golden West Power Partners, LLC.

Description: Application for Authorization Under Section 203 of the Federal Power Act and Request for Expedited Action of Golden West Power Partners, LLC.

Filed Date: 9/4/15.

Accession Number: 20150904–5280.

Comments Due: 5 p.m. ET 9/25/15.

Take notice that the Commission received the following electric rate filings:

Docket Numbers: ER15–2101–001.

Applicants: Golden West Power Partners, LLC.

Description: Notice of Change in Status of Golden West Power Partners, LLC.

Filed Date: 9/3/15.

Accession Number: 20150903–5223.

Comments Due: 5 p.m. ET 9/24/15.

Docket Numbers: ER15–2241–000.

Applicants: MP2 Energy NJ LLC.

Description: Amendment and clarification to July 22, 2015 MP2 Energy NJ LLC tariff filing.

Filed Date: 9/4/15.

Accession Number: 20150904–5078.

Comments Due: 5 p.m. ET 9/18/15.

Docket Numbers: ER15–2242–000.

Applicants: MP2 Energy IL LLC.

Description: Amendment and clarification to July 22, 2015 MP2 Energy IL LLC tariff filing.

Filed Date: 9/4/15.

Accession Number: 20150904–5079.

Comments Due: 5 p.m. ET 9/18/15.

Docket Numbers: ER15–2550–000.

Applicants: Rancho Cucamonga Municipal Utility.

Description: Amendment to August 28, 2015 Petition of Rancho Cucamonga Municipal Utility for Limited Waiver of the California Independent System Operator Corporation's Tariff Provisions.

Filed Date: 9/2/15.

Accession Number: 20150902–5250.

Comments Due: 5 p.m. ET 9/23/15.

Docket Numbers: ER15–2615–000.

Applicants: Goodwell Wind Project, LLC.

Description: Baseline eTariff Filing: Goodwell Wind Project, LLC MBR Tariff to be effective 10/1/2015.

Filed Date: 9/3/15.

Accession Number: 20150903–5196.

Comments Due: 5 p.m. ET 9/24/15.

Docket Numbers: ER15–2616–000.

Applicants: Midcontinent Independent System Operator, Inc.

Description: § 205(d) Rate Filing: 2015–09–03_MISO–PJM JOA DA M2M FFE to be effective 9/30/2015.

Filed Date: 9/3/15.

Accession Number: 20150903–5212.

Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: ER15–2617–000.

Applicants: Midcontinent Independent System Operator, Inc.

Description: § 205(d) Rate Filing: 2015–09–04_SA 2836 NSP-City of Willmar TIA to be effective 9/5/2015.

Filed Date: 9/4/15.

Accession Number: 20150904–5168.

Comments Due: 5 p.m. ET 9/25/15.

Docket Numbers: ER15–2618–000.

Applicants: PJM Interconnection, L.L.C.

Description: § 205(d) Rate Filing: Service Agreement No. 4252; Queue W2–094 (WMPA) to be effective 8/10/2015.

Filed Date: 9/4/15.

Accession Number: 20150904–5177.

Comments Due: 5 p.m. ET 9/25/15.

Docket Numbers: ER15–2619–000.

Applicants: PJM Interconnection, L.L.C.

Description: § 205(d) Rate Filing: First Revised Service Agreement No. 4109; Queue No. Z1–073 to be effective 8/5/2015.

Filed Date: 9/4/15.

Accession Number: 20150904–5187.

Comments Due: 5 p.m. ET 9/25/15.

Take notice that the Commission received the following electric securities filings:

Docket Numbers: ES15–67–000.

Applicants: Louisville Gas & Electric Company.

Description: Application under Section 204 of the Federal Power Act of Louisville Gas and Electric Company.

Filed Date: 9/4/15.

Accession Number: 20150904–5269.

Comments Due: 5 p.m. ET 9/25/15.

Docket Numbers: ES15–68–000.

Applicants: Kentucky Utilities Company.

Description: Application under Section 204 of the Federal Power Act of Kentucky Utilities Company.

Filed Date: 9/4/15.

Accession Number: 20150904–5282.

Comments Due: 5 p.m. ET 9/25/15.

The filings are accessible in the Commission's eLibrary system by clicking on the links or querying the docket number.

Any person desiring to intervene or protest in any of the above proceedings must file in accordance with Rules 211 and 214 of the Commission's Regulations (18 CFR 385.211 and 385.214) on or before 5:00 p.m. Eastern time on the specified comment date. Protests may be considered, but intervention is necessary to become a party to the proceeding.

eFiling is encouraged. More detailed information relating to filing requirements, interventions, protests, service, and qualifying facilities filings can be found at: *http://www.ferc.gov/docs-filing/efiling/filing-req.pdf.* For other information, call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Dated: September 4, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23009 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

[Docket No. EL15–100–000]

Northwest Power Pool Members' Market, Assessment and Coordination Committee; Notice of Petition for Declaratory Order

Take notice that on September 4, 2015, pursuant to Rule 207(a)(2) of the Federal Energy Regulatory Commission's (Commission) Rules of Practice and Procedure, 18 CFR 385.207(a)(2), the Northwest Power Pool Members' Market Assessment and Coordination Committee (Petitioner), filed a petition for a declaratory order (petition) on limited threshold issues critical to the development of a subhourly energy market in the Northwest Power Pool footprint, all as more fully explained in the petition.

Any person desiring to intervene or to protest this filing must file in accordance with Rules 211 and 214 of the Commission's Rules of Practice and Procedure (18 CFR 385.211, 385.214). Protests will be considered by the Commission in determining the appropriate action to be taken, but will not serve to make protestants parties to the proceeding. Any person wishing to become a party must file a notice of intervention or motion to intervene, as appropriate. Such notices, motions, or protests must be filed on or before the comment date. Anyone filing a motion to intervene or protest must serve a copy of that document on the Petitioner.

The Commission encourages electronic submission of protests and interventions in lieu of paper using the "eFiling" link at *http://www.ferc.gov.* Persons unable to file electronically should submit an original and 5 copies of the protest or intervention to the Federal Energy Regulatory Commission, 888 First Street NE., Washington, DC 20426.

This filing is accessible on-line at *http://www.ferc.gov,* using the "eLibrary" link and is available for review in the Commission's Public Reference Room in Washington, DC. There is an "eSubscription" link on the Web site that enables subscribers to receive email notification when a document is added to a subscribed docket(s). For assistance with any FERC Online service, please email *FERCOnlineSupport@ferc.gov,* or call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Comment Date: 5:00 p.m. Eastern time on October 5, 2015.

Dated: September 8, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23012 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

[Project No. 13629–002]

Coleman Hydro LLC; Notice of Teleconference

a. Project Name and Number: Coleman Hydroelectric Project No. 13629.

b. Date and Time of Meeting: September 22, 2015; 10:00 a.m. Pacific Daylight Time (11:00 a.m. Mountain Daylight Time).

c. FERC Contact: Jim Hastreiter, *james.hastreiter@ferc.gov* or (503) 552–2760.

d. Purpose of Meeting: U.S. Fish and Wildlife Service has requested the teleconference to discuss the scope of the proposed Coleman Hydroelectric Project and its effects on federally-listed bull trout, as it relates to the Commission staff's request for formal consultation under section 7 of the Endangered Species Act.

e. All local, state, and federal agencies, Indian tribes, and other interested parties are invited to participate by phone. Please call Jim Hastreiter at (503) 552–2760 by September 15, 2015, to RSVP and to receive specific instructions on how to participate.

Dated: September 8, 2015.

Kimberly D. Bose,

Secretary.

[FR Doc. 2015–23054 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

[Docket No. RM98–1–000]

Records Governing Off-the-Record Communications; Public Notice

This constitutes notice, in accordance with 18 CFR 385.2201(b), of the receipt of prohibited and exempt off-the-record communications.

Order No. 607 (64 FR 51222, September 22, 1999) requires Commission decisional employees, who make or receive a prohibited or exempt off-the-record communication relevant to the merits of a contested proceeding, to deliver to the Secretary of the Commission, a copy of the communication, if written, or a summary of the substance of any oral communication.

Prohibited communications are included in a public, non-decisional file associated with, but not a part of, the decisional record of the proceeding. Unless the Commission determines that the prohibited communication and any responses thereto should become a part of the decisional record, the prohibited off-the-record communication will not be considered by the Commission in reaching its decision. Parties to a proceeding may seek the opportunity to respond to any facts or contentions made in a prohibited off-the-record communication, and may request that the Commission place the prohibited communication and responses thereto in the decisional record. The Commission will grant such a request only when it determines that fairness so requires. Any person identified below as having made a prohibited off-the-record communication shall serve the document on all parties listed on the official service list for the applicable

proceeding in accordance with Rule 2010, 18 CFR 385.2010.

Exempt off-the-record communications are included in the decisional record of the proceeding, unless the communication was with a cooperating agency as described by 40 CFR 1501.6, made under 18 CFR 385.2201(e)(1)(v).

The following is a list of off-the-record communications recently received by the Secretary of the Commission. The communications listed are grouped by docket numbers in ascending order. These filings are available for electronic review at the Commission in the Public Reference Room or may be viewed on the Commission's Web site at *http://www.ferc.gov* using the eLibrary link. Enter the docket number, excluding the last three digits, in the docket number field to access the document. For assistance, please contact FERC Online Support at *FERCOnlineSupport@ferc.gov* or toll free at (866)208–3676, or for TTY, contact (202)502–8659.

Docket No.	File date:	Presenter or requester
Prohibited:		
1. P–803–087	8–27–15	California Water Board.
Exempt:		
1. P–1494–000	8–17–15	Mayor Dewey F. Bartlett, Jr. City of Tulsa, OK.
2. CP14–96–000	8–17–15	Members of New York Assembly.[1]
3. CP14–96–000	8–17–15	New York State Senator George Latimer.
4. CP14–96–000	8–17–15	New York Assemblyman Steven Otis.
5. CP14–96–000	8–20–15	Westchester County Board of Legislators.[2]
6. CP14–96–000	8–21–15	Town of Cortlandt, NY.
7. CP13–483–000	8–24–15	FERC Staff.[3]
CP13–492–000		
8. CP13–483–000	8–24–15	FERC Staff.[4]
CP13–492–000		
9. CP14–96–000	8–24–15	New York State Senator Liz Krueger.
10. CP14–96–000	8–31–15	New York Assemblymember Shelley Mayer.
11. CP14–96–000	8–31–15	New York State Senator Andrea Stewart-Cousins.
12. CP14–503–000	9–1–15	FERC Staff.[5]
13. CP14–529–000	9–1–15	FERC Staff.[6]
14. CP14–529–000	9–1–15	FERC Staff.[7]

[1] Sandy Galef and David Buchwald.
[2] Alan Cole, Michael Kaplowitz, Benjamin Boykin, Catherine Parker, Alfreda Williams, Catherine Borgia, Mary Jane Shimsky, Lyndon Williams, Ken Jenkins.
[3] Notes from 8–20–15 telephone conference call with federal cooperating agencies regarding production of the final environmental impact statement.
[4] Letter dated 8–18–15 from the US Environmental Protection Agency.
[5] Record of 7–1–15 telephone call with Oklahoma Department of Environmental Quality.
[6] Record of 7–30–15 telephone call with USFWS New England Field Office.
[7] Record of 8–24–15 telephone call with USACE New England District.

Dated: September 8, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23013 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

[Docket No. ER15–2534–000]

Saddleback Ridge Wind, LLC; Supplemental Notice That Initial Market-Based Rate Filing Includes Request for Blanket Section 204 Authorization

This is a supplemental notice in the above-referenced proceeding of Saddleback Ridge Wind, LLC's application for market-based rate authority, with an accompanying rate tariff, noting that such application includes a request for blanket authorization, under 18 CFR part 34, of future issuances of securities and assumptions of liability.

Any person desiring to intervene or to protest should file with the Federal Energy Regulatory Commission, 888 First Street NE., Washington, DC 20426, in accordance with Rules 211 and 214 of the Commission's Rules of Practice and Procedure (18 CFR 385.211 and 385.214). Anyone filing a motion to intervene or protest must serve a copy of that document on the Applicant.

Notice is hereby given that the deadline for filing protests with regard to the applicant's request for blanket authorization, under 18 CFR part 34, of future issuances of securities and assumptions of liability, is September 28, 2015.

The Commission encourages electronic submission of protests and interventions in lieu of paper, using the FERC Online links at *http://www.ferc.gov.* To facilitate electronic service, persons with Internet access who will eFile a document and/or be listed as a contact for an intervenor must create and validate an eRegistration account using the eRegistration link. Select the eFiling link to log on and submit the intervention or protests.

Persons unable to file electronically should submit an original and 5 copies of the intervention or protest to the Federal Energy Regulatory Commission, 888 First Street NE., Washington, DC 20426.

The filings in the above-referenced proceeding are accessible in the Commission's eLibrary system by clicking on the appropriate link in the above list. They are also available for electronic review in the Commission's Public Reference Room in Washington, DC. There is an eSubscription link on the Web site that enables subscribers to receive email notification when a document is added to a subscribed docket(s). For assistance with any FERC Online service, please email *FERCOnlineSupport@ferc.gov.* or call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Dated: September 8, 2015.

Kimberly D. Bose,

Secretary.

[FR Doc. 2015–23055 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

Combined Notice of Filings #1

Take notice that the Commission received the following electric corporate filings:

Docket Numbers: EC15–203–000.
Applicants: Grant Wind, LLC.
Description: Application for Authorization under Section 203 of the Federal Power Act and Request for Expedited Consideration, Confidential Treatment and Waivers of Grant Wind, LLC.
Filed Date: 9/4/15.
Accession Number: 20150904–5426.
Comments Due: 5 p.m. ET 9/25/15.

Take notice that the Commission received the following exempt wholesale generator filings:

Docket Numbers: EG15–123–000.
Applicants: Moxie Freedom LLC.
Description: Notice of Self-Certification of EWG Status of Moxie Freedom LLC under EG15–123.
Filed Date: 9/8/15.
Accession Number: 20150908–5095.
Comments Due: 5 p.m. ET 9/29/15.

Take notice that the Commission received the following electric rate filings:

Docket Numbers: ER15–524–002.
Applicants: Tucson Electric Power Company.
Description: Compliance filing: Compliance Filing to be effective 5/15/2015.
Filed Date: 9/8/15.
Accession Number: 20150908–5137.
Comments Due: 5 p.m. ET 9/29/15.
Docket Numbers: ER15–584–001.
Applicants: ISO New England Inc., Connecticut Transmission Municipal Electric Energy Cooperative.
Description: Compliance filing: CT Transmission Municipal Electric Energy Cooperative—Compliance Filing to be effective 11/17/2014.
Filed Date: 9/8/15.
Accession Number: 20150908–5085.
Comments Due: 5 p.m. ET 9/29/15.
Docket Numbers: ER15–1407–002.
Applicants: Midcontinent Independent System Operator, Inc.
Description: Report Filing: 2015–09–08_SA 2767 Refund Report of ATC-Manitowoc CFA to be effective N/A.
Filed Date: 9/8/15.
Accession Number: 20150908–5086.
Comments Due: 5 p.m. ET 9/29/15.
Docket Numbers: ER15–2380–000.
Applicants: Willey Battery Utility, LLC.
Description: Amendment to August 5, 2015 Willey Battery Utility, LLC tariff filing.
Filed Date: 9/4/15.
Accession Number: 20150904–5166.
Comments Due: 5 p.m. ET 9/25/15.
Docket Numbers: ER15–2621–000.
Applicants: Pacific Gas and Electric Company.
Description: § 205(d) Rate Filing: Revisions to the Plumas-Sierra Operating Agreement to be effective 10/31/2015.
Filed Date: 9/8/15.
Accession Number: 20150908–5011.
Comments Due: 5 p.m. ET 9/29/15.
Docket Numbers: ER15–2622–000.
Applicants: California Independent System Operator Corporation.
Description: Transmission Access Charge Informational Filing, et al. of the California Independent System Operator Corporation.
Filed Date: 9/4/15.
Accession Number: 20150904–5405.
Comments Due: 5 p.m. ET 9/25/15.

Take notice that the Commission received the following electric reliability filings:

Docket Numbers: RR15–14–000.
Applicants: North American Electric Reliability Corporation.
Description: Errata (correction and clarification) to August 14, 2015 Petition of North American Electric Reliability Corporation for Approval of the Amendments, et. al.
Filed Date: 9/3/15.
Accession Number: 20150903–5222.
Comments Due: 5 p.m. ET 9/17/15.

The filings are accessible in the Commission's eLibrary system by clicking on the links or querying the docket number.

Any person desiring to intervene or protest in any of the above proceedings must file in accordance with Rules 211 and 214 of the Commission's Regulations (18 CFR 385.211 and 385.214) on or before 5:00 p.m. Eastern time on the specified comment date. Protests may be considered, but intervention is necessary to become a party to the proceeding.

eFiling is encouraged. More detailed information relating to filing requirements, interventions, protests, service, and qualifying facilities filings can be found at: *http://www.ferc.gov/docs-filing/efiling/filing-req.pdf.* For other information, call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Dated: September 8, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23011 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

Combined Notice of Filings

Take notice that the Commission has received the following Natural Gas Pipeline Rate and Refund Report filings:

Filings Instituting Proceedings

Docket Numbers: PR15–42–000.
Applicants: TPL SouthTex Transmission Company LP.
Description: Submits tariff filing per 284.123(e)/.224: Filing of Revised Operating Statement to be effective 9/1/2015 Filing Type: 770.
Filed Date: 8/27/15.
Accession Number: 20150827–5161.
Comments/Protests Due: 5 p.m. ET 9/17/15.

Docket Numbers: PR15–43–000.
Applicants: Enable Illinois Intrastate Transmission, LLC.
Description: Submits tariff filing per 284.123(e)/.224: 2015 Housekeeping to be effective 9/28/2015; Filing Type: 770.
Filed Date: 8/27/15.
Accession Number: 20150827–5288.
Comments/Protests Due: 5 p.m. ET 9/17/15.

Docket Numbers: RP15–1209–000.
Applicants: Enable Mississippi River Transmission, L.
Description: Section 4(d) Rate Filing: 2015 Housekeeping Filing to be effective 9/28/2015.
Filed Date: 8/26/15.
Accession Number: 20150826–5114.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1210–000.
Applicants: Northwest Pipeline LLC.
Description: Section 4(d) Rate Filing: 2015 Winter Fuel Filing to be effective 10/1/2015.
Filed Date: 8/26/15.
Accession Number: 20150826–5132.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1211–000.
Applicants: Northern Natural Gas Company.
Description: Section 4(d) Rate Filing: 20150826 Negotiated Rate to be effective 9/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5064.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1212–000.
Applicants: Transcontinental Gas Pipe Line Company.
Description: Section 4(d) Rate Filing: Cash Out Reference Spot Prices to be effective 10/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5084.
Comments Due: 5 p.m. ET 9/8/15.

Docket Numbers: RP15–1213–000.
Applicants: Alliance Pipeline L.P.
Description: Section 4(d) Rate Filing: September 1–30 2015 Auction to be effective 9/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5108.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1214–000.
Applicants: Florida Gas Transmission Company, LLC.
Description: Section 4(d) Rate Filing: Fuel Filing on 8–27–15 to be effective 10/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5123.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1215–000.
Applicants: El Paso Natural Gas Company, L.L.C.
Description: Section 4(d) Rate Filing: Negotiated Rate Agreement Update (APS Sept 2015) to be effective 9/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5210.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1216–000.
Applicants: El Paso Natural Gas Company, L.L.C.
Description: Section 4(d) Rate Filing: Park and Loan Locations Filing to be effective 10/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5215.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1217–000.
Applicants: Algonquin Gas Transmission, LLC.
Description: Section 4(d) Rate Filing: Exhibit A Filing to be effective 10/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5217.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1219–000.
Applicants: National Fuel Gas Supply Corporation.
Description: Section 4(d) Rate Filing: Non-Conforming (Range Resources) to be effective 9/1/2015.
Filed Date: 8/27/15.
Accession Number: 20150827–5277.
Comments Due: 5 p.m. ET 9/8/15.
Docket Numbers: RP15–1220–000.
Applicants: Transcontinental Gas Pipe Line Company.
Description: Section 4(d) Rate Filing: Negotiated Rates—Cherokee AGL—Replacement Shippers—Sep 2015 to be effective 9/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5000.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1221–000.
Applicants: Panhandle Eastern Pipe Line Company, LP.
Description: Section 4(d) Rate Filing: Negotiated Rates Filing on 8–28–15 to be effective 9/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5054.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1222–000.
Applicants: Algonquin Gas Transmission, LLC.
Description: Section 4(d) Rate Filing: BBPC 2015–09–01 Releases to EDF Trading to be effective 9/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5059.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1223–000.
Applicants: Ruby Pipeline, L.L.C.
Description: Section 4(d) Rate Filing: FL&U and EPC to be effective 10/1/15 to be effective 10/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5078.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1224–000.
Applicants: Dominion Transmission, Inc.
Description: Section 4(d) Rate Filing: DTI—August 28, 2015 Negotiated Rate Agreement to be effective 9/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5121.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1226–000.
Applicants: MarkWest Pioneer, L.L.C.
Description: Section 4(d) Rate Filing: Quarterly FRP Filing to be effective 10/1/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5165.
Comments Due: 5 p.m. ET 9/9/15.
Docket Numbers: RP15–1227–000.
Applicants: Dominion Carolina Gas Transmission, LLC.
Description: 2015 Penalty Revenue Sharing Report of Dominion Carolina Gas Transmission, LLC under RP15–1227.
Filed Date: 8/28/15.
Accession Number: 20150828–5235.
Comments Due: 5 p.m. ET 9/9/15.

Any person desiring to intervene or protest in any of the above proceedings must file in accordance with Rules 211 and 214 of the Commission's Regulations (18 CFR 385.211 and 385.214) on or before 5:00 p.m. Eastern time on the specified comment date. Protests may be considered, but intervention is necessary to become a party to the proceeding.

Filings in Existing Proceedings

Docket Numbers: RP15–1182–001.
Applicants: Enable Gas Transmission, LLC.
Description: Compliance filing RP15–1182 filing for Record 36 to be effective 9/14/2015.
Filed Date: 8/28/15.
Accession Number: 20150828–5257.
Comments Due: 5 p.m. ET 9/9/15.

Any person desiring to protest in any of the above proceedings must file in accordance with Rule 211 of the Commission's Regulations (18 CFR 385.211) on or before 5:00 p.m. Eastern time on the specified comment date.

The filings are accessible in the Commission's eLibrary system by clicking on the links or querying the docket number.

eFiling is encouraged. More detailed information relating to filing requirements, interventions, protests, service, and qualifying facilities filings can be found at: *http://www.ferc.gov/docs-filing/efiling/filing-req.pdf.* For other information, call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Dated: August 31, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23010 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission

Combined Notice of Filings

Take notice that the Commission has received the following Natural Gas Pipeline Rate and Refund Report filings:

Filings Instituting Proceedings

Docket Numbers: RP15–1248–000.
Applicants: Cimarron River Pipeline, LLC.
Description: 2015 Cash Out Report of Cimarron River Pipeline, LLC under RP15–1248.
Filed Date: 9/1/15.
Accession Number: 20150901–5272.
Comments Due: 5 p.m. ET 9/14/15.
Docket Numbers: RP15–1249–000.
Applicants: Dauphin Island Gathering Partners.
Description: 2015 Cash Out Report of Dauphin Island Gathering Partners under RP15–1249.
Filed Date: 9/1/15.
Accession Number: 20150901–5273.
Comments Due: 5 p.m. ET 9/14/15.
Docket Numbers: RP15–1259–000.
Applicants: Tennessee Gas Pipeline Company, L.L.C.
Description: § 4(d) Rate Filing: Volume No. 2—Neg. Rate Agrmts with Cargill, Inc. et al. to be effective 11/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5373.
Comments Due: 5 p.m. ET 9/16/15.

Any person desiring to intervene or protest in any of the above proceedings must file in accordance with Rules 211 and 214 of the Commission's Regulations (18 CFR 385.211 and § 385.214) on or before 5:00 p.m. Eastern time on the specified comment date. Protests may be considered, but intervention is necessary to become a party to the proceeding.

Filings in Existing Proceedings

Docket Numbers: RP15–755–001.
Applicants: Cheyenne Plains Gas Pipeline Company, L.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5345.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–756–001.
Applicants: Colorado Interstate Gas Company, L.L.C.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5343.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–757–001.
Applicants: Wyoming Interstate Company, L.L.C.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5334.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–758–001.
Applicants: Young Gas Storage Company, Ltd.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5328.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–760–001.
Applicants: Ruby Pipeline, L.L.C.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5340.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–761–001.
Applicants: El Paso Natural Gas Company, L.L.C.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5352.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–762–001.
Applicants: Mojave Pipeline Company, L.L.C.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5367.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–763–001.
Applicants: TransColorado Gas Transmission Company L.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5326.
Comments Due: 5 p.m. ET 9/14/15.

Docket Numbers: RP15–764–001.
Applicants: Sierrita Gas Pipeline LLC.
Description: Compliance filing Order No. 801 System Map Compliance Update Filing to be effective 5/1/2015.
Filed Date: 9/4/15.
Accession Number: 20150904–5332.
Comments Due: 5 p.m. ET 9/14/15.

Any person desiring to protest in any of the above proceedings must file in accordance with Rule 211 of the Commission's Regulations (18 CFR 385.211) on or before 5:00 p.m. Eastern time on the specified comment date.

The filings are accessible in the Commission's eLibrary system by clicking on the links or querying the docket number.

eFiling is encouraged. More detailed information relating to filing requirements, interventions, protests, service, and qualifying facilities filings can be found at: *http://www.ferc.gov/docs-filing/efiling/filing-req.pdf.* For other information, call (866) 208–3676 (toll free). For TTY, call (202) 502–8659.

Dated: September 8, 2015.

Nathaniel J. Davis, Sr.,

Deputy Secretary.

[FR Doc. 2015–23020 Filed 9–11–15; 8:45 am]

BILLING CODE 6717–01–P

ENVIRONMENTAL PROTECTION AGENCY

[EPA–HQ–OGC–2015–0612; FRL 9933–93–OGC]

Proposed Consent Decree, Clean Air Act Citizen Suit

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of proposed settlement agreement; request for public comment.

SUMMARY: In accordance with section 113(g) of the Clean Air Act, as amended ("CAA"), notice is hereby given of a proposed settlement agreement to settle lawsuits filed by Sinclair Wyoming Refining Company and Sinclair Casper Refining Company ("Petitioners"), in the United States Courts of Appeal for the Tenth and District of Columbia Circuits: *Sinclair Wyoming Refining Co. et al.* v. *EPA,* No. 14–9594 (10th Cir.) and *Sinclair Wyoming Refining Co. et al.* v. *EPA,* No. 14–1209 (D.C. Cir.). On October 24, 2014, Petitioners filed petitions for review challenging EPA's August 29, 2014 denials of Sinclair's requests for extensions of its small refinery temporary exemptions for its refineries in Evansville and Sinclair, Wyoming (collectively, the "Small Refinery Temporary Exemptions"). Under the terms of the proposed settlement agreement, Petitioners may submit a request for an extension of their Small Refinery Temporary Exemptions with respect to Petitioners' 2014 obligations under the Renewable Fuel Standards ("RFS") Program (the "2014 Exemption Request"). After EPA determines that the 2014 Exemption Request is complete, EPA will issue its decision to Petitioners on the 2014 Extension Request within 90 calendar days.

DATES: Written comments on the proposed settlement agreement must be received by October 14, 2015.

ADDRESSES: Submit your comments, identified by Docket ID number EPA–HQ–OGC–2015–0612, online at *www.regulations.gov* (EPA's preferred method); by email to *oei.docket@epa.gov;* mailed to EPA Docket Center, Environmental Protection Agency, Mailcode: 2822T, 1200 Pennsylvania Ave. NW., Washington, DC 20460–0001; or by hand delivery or courier to EPA Docket Center, EPA West, Room 3334, 1301 Constitution Ave. NW., Washington, DC, between 8:30 a.m. and 4:30 p.m. Monday through Friday, excluding legal holidays. Comments on a disk or CD–ROM should be formatted in Word or ASCII file, avoiding the use of special characters and any form of encryption, and may be mailed to the mailing address above.

FOR FURTHER INFORMATION CONTACT: Susan Stahle, Air and Radiation Law Office (2344A), Office of General Counsel, U.S. Environmental Protection Agency, 1200 Pennsylvania Ave. NW., Washington, DC 20460; telephone: (202) 564–1272; fax number (202) 564–5603; email address: *stahle.susan@epa.gov.*

SUPPLEMENTARY INFORMATION:

I. Additional Information About the Proposed Consent Decree

The proposed settlement agreement would settle Petitioners' petitions for review in the United States Courts of Appeal for the Tenth and District of Columbia Circuits challenging, under

section 307(b)(1) of the Clean Air Act, EPA's August 29, 2014 denials of Petitioners' requests for extensions of their Small Refinery Temporary Exemptions (*see Sinclair Wyoming Refining Co. et al.* v. *EPA,* No. 14–9594 (10th Cir.) and *Sinclair Wyoming Refining Co. et al.* v. *EPA,* No. 14–1209 (D.C. Cir.) (jointly, the "Pending Cases"). The proposed settlement agreement provides that after Petitioners submit their 2014 Exemption Request, EPA will, within 14 business days after receiving the 2014 Exemption Request, either make a determination that the Request is complete or advise Sinclair in writing of any additional information needed to make the Request complete (an Incompleteness Determination). After EPA determines that the 2014 Exemption Request is complete, EPA will issue its decision to Petitioners on the 2014 Exemption Request within 90 calendar days. Within five business days of EPA issuing its decision on the 2014 Exemption Request, Petitioners will (1) voluntarily dismiss the Pending Cases with prejudice and (2) send a letter to EPA withdrawing its January 13, 2015 "Request for Reconsideration of Petition for Partial Extension of Small Refinery RFS Exemptions" regarding EPA's August 29, 2014 denials of Petitioners' requests for extensions of the Small Refinery Temporary Exemptions.

For a period of 30 days following the date of publication of this notice, the Agency will receive written comments relating to the proposed settlement agreement from persons who were not named as parties or intervenors to the litigation in question. EPA or the Department of Justice may withdraw or withhold consent to the proposed settlement agreement if the comments disclose facts or considerations that indicate that such consent is inappropriate, improper, inadequate, or inconsistent with the requirements of the Act. Unless EPA or the Department of Justice determines that consent to the agreement should be withdrawn, the terms of the agreement will be affirmed.

II. Additional Information About Commenting on the Proposed Consent Decree

A. How can I get a copy of the consent decree?

Direct your comments to the official public docket for this action under Docket ID No. EPA–HQ–OGC–2015–0612 which contains a copy of the settlement agreement. The official public docket is available for public viewing at the Office of Environmental Information (OEI) Docket in the EPA Docket Center, EPA West, Room 3334, 1301 Constitution Ave. NW., Washington, DC. The EPA Docket Center Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the OEI Docket is (202) 566–1752.

An electronic version of the public docket is available through *www.regulations.gov.* You may use the *www.regulations.gov* to submit or view public comments, access the index listing of the contents of the official public docket, and to access those documents in the public docket that are available electronically. Once in the system, key in the appropriate docket identification number then select "search".

It is important to note that EPA's policy is that public comments, whether submitted electronically or in paper, will be made available for public viewing online at *www.regulations.gov* without change, unless the comment contains copyrighted material, CBI, or other information whose disclosure is restricted by statute. Information claimed as CBI and other information whose disclosure is restricted by statute is not included in the official public docket or in the electronic public docket. EPA's policy is that copyrighted material, including copyrighted material contained in a public comment, will not be placed in EPA's electronic public docket but will be available only in printed, paper form in the official public docket. Although not all docket materials may be available electronically, you may still access any of the publicly available docket materials through the EPA Docket Center.

B. How and to whom do I submit comments?

You may submit comments as provided in the **ADDRESSES** section. Please ensure that your comments are submitted within the specified comment period. Comments received after the close of the comment period will be marked "late." EPA is not required to consider these late comments.

If you submit an electronic comment, EPA recommends that you include your name, mailing address, and an email address or other contact information in the body of your comment and with any disk or CD ROM you submit. This ensures that you can be identified as the submitter of the comment and allows EPA to contact you in case EPA cannot read your comment due to technical difficulties or needs further information on the substance of your comment. Any identifying or contact information provided in the body of a comment will be included as part of the comment that is placed in the official public docket, and made available in EPA's electronic public docket. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment.

Use of the *www.regulations.gov* Web site to submit comments to EPA electronically is EPA's preferred method for receiving comments. The electronic public docket system is an "anonymous access" system, which means EPA will not know your identity, email address, or other contact information unless you provide it in the body of your comment. In contrast to EPA's electronic public docket, EPA's electronic mail (email) system is not an "anonymous access" system. If you send an email comment directly to the Docket without going through *www.regulations.gov,* your email address is automatically captured and included as part of the comment that is placed in the official public docket, and made available in EPA's electronic public docket.

Dated: September 3, 2015.

Gautam Srinivasan,

Acting Associate General Counsel.

[FR Doc. 2015–23061 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

[FRL–9933–83–Region 9]

Samoa Pulp Mill Removal Site, Samoa, CA; Notice of Proposed CERCLA Settlement Agreement for Recovery of Past Response Costs

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice; request for comment.

SUMMARY: In accordance with Section 122(i) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (CERCLA), 42 U.S.C. 9622(i), notice is hereby given of a proposed administrative settlement with Humboldt Bay Harbor, Conservation and Recreation District for recovery of response costs concerning the Samoa Pulp Mill Superfund Site in Samoa, California. The settlement is entered into pursuant to Section 122(h)(1) of CERCLA, 42 U.S.C. 9622(h)(1), and it requires the settling party to reimburse EPA based on any salvage of fixtures at the site, including the pulp mill boiler,

or on any sale of the real property that is the site. The settlement includes a covenant not to sue the settling party pursuant to Sections 106 or 107(a) of CERCLA, 42 U.S.C. 9606 or 9607(a). For thirty (30) days following the date of publication of this Notice in the **Federal Register**, the Agency will receive written comments relating to the settlement. The Agency will consider all comments received and may modify or withdraw its consent to the settlement if comments received disclose facts or considerations that indicate the proposed settlement is inappropriate, improper, or inadequate. The Agency's response to any comments received will be available for public inspection at 75 Hawthorne Street, San Francisco, CA 94105.

DATES: Pursuant to Section 122(i) of CERCLA, EPA will receive written comments relating to this proposed settlement until October 14, 2015.

ADDRESSES: The proposed settlement is available for public inspection at EPA Region IX, 75 Hawthorne Street, San Francisco, California. A copy of the proposed settlement may be obtained from J. Andrew Helmlinger, EPA Region IX, 75 Hawthorne Street, ORC–3, San Francisco, CA 94105, telephone number 415–972–3904. Comments should reference the Samoa Pulp Mill Superfund Site, Samoa, California and should be addressed to Mr. Helmlinger at the above address.

FOR FURTHER INFORMATION CONTACT: J. Andrew Helmlinger, Assistant Regional Counsel (ORC–3), Office of Regional Counsel, U.S. EPA Region IX, 75 Hawthorne Street, San Francisco, CA 94105; phone: (415) 972–3904; fax: (417) 947–3570; email: *helmlinger.andrew@epa.gov.*

SUPPLEMENTARY INFORMATION: *Parties to the Proposed Settlement:* Humboldt Bay Harbor, Conservation and Recreation District.

Dated: August 31, 2015.

Enrique Manzanilla,

Director, Superfund Division, U.S. EPA, Region IX.

[FR Doc. 2015–23062 Filed 9–11–15; 8:45 am]

BILLING CODE 6560–50–P

FEDERAL ELECTION COMMISSION

Sunshine Act Meetings

AGENCY: Federal Election Commission

DATE AND TIME: Thursday, September 17, 2015 at 10:00 a.m.

PLACE: 999 E Street NW., Washington, DC (Ninth Floor).

STATUS: This meeting will be open to the public.

ITEMS TO BE DISCUSSED:

Correction and Approval of Minutes for August 11, 2015
Draft Advisory Opinion 2015–03: Democracy Rules, Inc.
Draft Advisory Opinion 2015–06: Representative Maxine Waters
Audit Division Recommendation Memorandum on the Committee for Charlotte/Charlotte DNC Host Committee (CFC)
Commission Documents Public Disclosure Policies
Proposed Directive 74 on the Timely Resolution of Enforcement Matters
Management and Administrative Matters

Individuals who plan to attend and require special assistance, such as sign language interpretation or other reasonable accommodations, should contact Shawn Woodhead Werth, Secretary and Clerk, at (202) 694–1040, at least 72 hours prior to the meeting date.

PERSON TO CONTACT FOR INFORMATION: Judith Ingram, Press Officer, Telephone: (202) 694–1220.

Shelley E. Garr,

Deputy Secretary of the Commission.

[FR Doc. 2015–23145 Filed 9–10–15; 4:15 pm]

BILLING CODE 6715–01–P

FEDERAL RESERVE SYSTEM

Formations of, Acquisitions by, and Mergers of Bank Holding Companies

The companies listed in this notice have applied to the Board for approval, pursuant to the Bank Holding Company Act of 1956 (12 U.S.C. 1841 *et seq.*) (BHC Act), Regulation Y (12 CFR part 225), and all other applicable statutes and regulations to become a bank holding company and/or to acquire the assets or the ownership of, control of, or the power to vote shares of a bank or bank holding company and all of the banks and nonbanking companies owned by the bank holding company, including the companies listed below.

The applications listed below, as well as other related filings required by the Board, are available for immediate inspection at the Federal Reserve Bank indicated. The applications will also be available for inspection at the offices of the Board of Governors. Interested persons may express their views in writing on the standards enumerated in the BHC Act (12 U.S.C. 1842(c)). If the proposal also involves the acquisition of a nonbanking company, the review also includes whether the acquisition of the nonbanking company complies with the standards in section 4 of the BHC Act (12 U.S.C. 1843). Unless otherwise noted, nonbanking activities will be conducted throughout the United States.

Unless otherwise noted, comments regarding each of these applications must be received at the Reserve Bank indicated or the offices of the Board of Governors not later than October 9, 2015.

A. Federal Reserve Bank of Richmond (Adam M. Drimer, Assistant Vice President) 701 East Byrd Street, Richmond, Virginia 23261–4528:

1. *Old Line Bancshares, Inc.,* Bowie, Maryland; to acquire 100 percent of the voting shares of Regal Bancorp, Inc., and thereby indirectly acquire voting shares of Regal Bank & Trust, both in Owings Mill, Maryland.

Board of Governors of the Federal Reserve System, September 9, 2015.

Michael J. Lewandowski,

Associate Secretary of the Board.

[FR Doc. 2015–23004 Filed 9–11–15; 8:45 am]

BILLING CODE 6210–01–P

FEDERAL RESERVE SYSTEM

Change in Bank Control Notices; Acquisitions of Shares of a Bank or Bank Holding Company

The notificants listed below have applied under the Change in Bank Control Act (12 U.S.C. 1817(j)) and § 225.41 of the Board's Regulation Y (12 CFR 225.41) to acquire shares of a bank or bank holding company. The factors that are considered in acting on the notices are set forth in paragraph 7 of the Act (12 U.S.C. 1817(j)(7)).

The notices are available for immediate inspection at the Federal Reserve Bank indicated. The notices also will be available for inspection at the offices of the Board of Governors. Interested persons may express their views in writing to the Reserve Bank indicated for that notice or to the offices of the Board of Governors. Comments must be received not later than September 29, 2015.

A. Federal Reserve Bank of Chicago (Colette A. Fried, Assistant Vice President) 230 South LaSalle Street, Chicago, Illinois 60690–1414:

1. *Ronald G. Gerken and Karol S. Gerken,* both of Sterling, Illinois, as a group acting in concert, to retain voting shares of SV Financial, Inc., and thereby indirectly retain voting shares of Sauk Valley Bank & Trust Company, both in Sterling, Illinois.

Board of Governors of the Federal Reserve System, September 9, 2015.

Michael J. Lewandowski,

Associate Secretary of the Board.

[FR Doc. 2015–23005 Filed 9–11–15; 8:45 am]

BILLING CODE 6210–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Safety and Occupational Health Study Section, National Institute for Occupational Safety and Health

In accordance with section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463), the Centers for Disease Control and Prevention (CDC) announces the following committee meeting.

Times and Dates: 8 a.m.–5 p.m., October 14, 2015 (Closed), 8 a.m.–5 p.m., October 15, 2015 (Closed).

Place: Embassy Suites, 1900 Diagonal Road, Alexandria, Virginia 22314, Telephone: 703–684–5900, Fax: 703–684–0653.

Purpose: The Safety and Occupational Health Study Section (SOHSS) will review, discuss, and evaluate grant application(s) received in response to the National Institute for Occupational Safety and Health (NIOSH or Institute) standard grants review and funding cycles pertaining to research issues in occupational safety and health, and allied areas.

It is the intent of NIOSH to support broad-based research endeavors in keeping with the Institute's program goals. This will lead to improved understanding and appreciation for the magnitude of the aggregate health burden associated with occupational injuries and illnesses, as well as to support more focused research projects, which will lead to improvements in the delivery of occupational safety and health services, and the prevention of work-related injury and illness. It is anticipated that research funded will promote these program goals.

Matters for Dicussion: The meeting will convene to address matters related to the conduct of Study Section business and for the study section to consider safety and occupational health-related grant applications.

These portions of the meeting will be closed to the public in accordance with provisions set forth in Section 552b(c)(4) and (6), Title 5 U.S.C., and the Determination of the Director, Management Analysis and Services Office, Centers for Disease Control and Prevention, pursuant to Section 10(d) Pub. L. 92–463.

Agenda items are subject to change as priorities dictate.

Contact Person for More Information: Joanne Fairbanks, Committee Management Specialist, NIOSH, CDC, 1095 Willowdale Road, Morgantown, WV, 26506, Mailstop L1119, Telephone: (304) 285–6143.

The Director, Management Analysis and Services Office, has been delegated the authority to sign **Federal Register** notices pertaining to announcements of meetings and other committee management activities for both the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry.

Elaine L. Baker,

Director, Management Analysis and Services Office, Centers for Disease Control and Prevention.

[FR Doc. 2015–22996 Filed 9–11–15; 8:45 am]

BILLING CODE 4163–18–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Board of Scientific Counselors, Office of Public Health Preparedness and Response

In accordance with section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463), the Centers for Disease Control and Prevention (CDC), announces the following meeting of the aforementioned committee:

Times and Dates: 9:30 a.m.–5:15 p.m., EDT, October 7, 2015; 8:15 a.m.–3:45 p.m., EDT, October 8, 2015.

Place: Centers for Disease Control and Prevention (CDC), Global Communications Center, Building 19, Auditorium B3, 1600 Clifton Road NE., Atlanta, Georgia 30333.

Status: Open to the public limited only by the space available. The meeting room will accommodate up to 90 people. Members of the public that wish to attend this meeting should pre-register by submitting the following information by email, facsimile, or phone (see *Contact Person For More Information*) no later than 12 noon (EDT) on Tuesday, September 29, 2015:

- Full Name
- Organizational Affiliation
- Complete Mailing Address
- Citizenship
- Phone Number or Email Address

Purpose: The Board of Scientific Counselors (BSC), OPHPR is charged with providing advice and guidance to the Secretary, Department of Health and Human Services (HHS), the Assistant Secretary for Health (ASH), the Director, Centers for Disease Control and Prevention (CDC), and the Director, Office of Public Health Preparedness and Response (OPHPR), concerning strategies and goals for the programs and research within OPHPR, monitoring the overall strategic direction and focus of the OPHPR Divisions and Offices, and administration and oversight of peer review of OPHPR scientific programs. For additional information about the Board, please visit: *http://www.cdc.gov/phpr/science/counselors.htm.*

Matters for Discussion: Day one of the meeting will cover briefings and BSC deliberation on the following topics: interval updates from OPHPR Divisions and Offices; key issues associated with CDC's Incident Management Training and Development Program (IMTP); healthcare preparedness and public health interface during the Ebola response; and BSC liaison representative updates to the Board highlighting organizational activities relevant to the OPHPR mission.

Day two of the meeting will cover briefings and BSC deliberation on the following topics: OPHPR strategic priorities; OPHPR impact measurement; Public Health Emergency Preparedness (PHEP) review and impact; intramural portfolio initiative; select agent regulations; and mental and behavioral health and emergency preparedness and response.

Agenda items are subject to change as priorities dictate.

Contact Person for More Information: Sparklé Buissereth, Office of Science and Public Health Practice, Executive Assistant, Centers for Disease Control and Prevention, 1600 Clifton Road NE., Mailstop D–44, Atlanta, Georgia 30333, Telephone: (404) 639–7325; Facsimile: (404)639–7977; Email: *OPHPR.BSC.Questions@cdc.gov.*

The Director, Management Analysis and Services Office, has been delegated the authority to sign **Federal Register** notices pertaining to announcements of meetings and other committee management activities for both the Centers for Disease Control and Prevention, and Agency for Toxic Substances and Disease Registry.

Elaine L. Baker,

Director, Management Analysis and Services Office, Centers for Disease Control and Prevention.

[FR Doc. 2015–22995 Filed 9–11–15; 8:45 am]

BILLING CODE 4163–18–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Disease, Disability, and Injury Prevention and Control Special Emphasis Panel: Initial Review

In accordance with Section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463), the Centers for Disease Control and Prevention (CDC) announces a meeting for the initial review of applications in response to PAR 13–129, NIOSH Member Conflict Review.

Time and Date: 1 p.m.–4 p.m., EDT, October 27, 2015 (Closed).

Place: Teleconference.

Status: The meeting will be closed to the public in accordance with provisions set forth in Section 552b(c) (4) and (6), Title 5 U.S.C., and the Determination of the Director, Management Analysis and Services Office, CDC, pursuant to Public Law 92–463.

Matters For Discussion: The meeting will include the initial review, discussion, and

evaluation of applications received in response to "NIOSH Member Conflict PAR 13–129."

Contact Person For More Information: Nina Turner, Ph.D., Scientific Review Officer, NIOSH, 1095 Willowdale Road, Mailstop G800, Morgantown, West Virginia 26506, Telephone: (304) 285–5976.

The Director, Management Analysis and Services Office, has been delegated the authority to sign **Federal Register** notices pertaining to announcements of meetings and other committee management activities, for both the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry.

Elaine L. Baker,

Director, Management Analysis and Services Office, Centers for Disease Control and Prevention.

[FR Doc. 2015–22993 Filed 9–11–15; 8:45 am]

BILLING CODE 4163–18–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Advisory Committee to the Director, Centers for Disease Control and Prevention—Health Disparities Subcommittee

In accordance with section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463), the Centers for Disease Control and Prevention (CDC) announces the following meeting of the aforementioned subcommittee:

Time and Date: 10 a.m.–5:30 p.m., EDT, October 14, 2015.

Place: CDC, Building 19, Rooms 245/246, 1600 Clifton Road NE., Atlanta, Georgia 30333.

Status: Open to the public, limited only by the space available. The meeting room accommodates approximately 50 people. The public is welcome to participate during the public comment period, which is tentatively scheduled from 5 to 5:15 p.m. This meeting is also available by teleconference. Please dial (866) 763–0273 and enter code 6158968.

Purpose: The Subcommittee will provide advice to the CDC Director through the Advisory Committee to the Director (ACD) on health disparities and other strategic and health equity issues, and provide guidance on opportunities for CDC.

Matters for Discussion: The Health Disparities Subcommittee (HDS) members will discuss progress towards recommendations it made in 2014, as well as disparity issues related to HIV/AIDS, tuberculosis, sexually transmitted diseases, and viral hepatitis.

The agenda is subject to change as priorities dictate.

Web Links

Windows Media: http://wm.onlinevideoservice.com/CDC1.

Flash: http://www.onlinevideoservice.com/clients/CDC/?mount=CDC3.

Smart Phones and Mobile devices: http://wowza01.sea.onlinevideoservice.com/live/CDC3/playlist.m3u8.

Windows Media: http://wm.onlinevideoservice.com/CDC1.

If you are unable to connect using the link, copy and paste the link into your web browser.

Number for Technical Support: 404–639–3737.

Contact Person For More Information: Leandris Liburd, Ph.D., M.P.H., M.A., Designated Federal Officer, Health Disparities Subcommittee, Advisory Committee to the Director, CDC, 1600 Clifton Road NE., M/S K–77, Atlanta, Georgia 30333 Telephone (770) 488–8343, Email: *LEL1@cdc.gov.*

The Director, Management Analysis and Services Office, has been delegated the authority to sign **Federal Register** notices pertaining to announcements of meetings and other committee management activities, for both the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry.

Elaine L. Baker,

Director, Management Analysis and Services Office, Centers for Disease Control and Prevention.

[FR Doc. 2015–22994 Filed 9–11–15; 8:45 am]

BILLING CODE 4163–18–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Medicare & Medicaid Services

[Document Identifiers: CMS–10526]

Agency Information Collection Activities: Proposed Collection; Comment Request

AGENCY: Centers for Medicare & Medicaid Services, HHS.

ACTION: Notice.

SUMMARY: The Centers for Medicare & Medicaid Services (CMS) is announcing an opportunity for the public to comment on CMS' intention to collect information from the public. Under the Paperwork Reduction Act of 1995 (the PRA), federal agencies are required to publish notice in the **Federal Register** concerning each proposed collection of information (including each proposed extension or reinstatement of an existing collection of information) and to allow 60 days for public comment on the proposed action. Interested persons are invited to send comments regarding our burden estimates or any other aspect of this collection of information, including any of the following subjects: (1) The necessity and utility of the proposed information collection for the proper performance of the agency's functions; (2) the accuracy of the estimated burden; (3) ways to enhance the quality, utility, and clarity of the information to be collected; and (4) the use of automated collection techniques or other forms of information technology to minimize the information collection burden.

DATES: Comments must be received by November 13, 2015.

ADDRESSES: When commenting, please reference the document identifier or OMB control number. To be assured consideration, comments and recommendations must be submitted in any one of the following ways:

1. *Electronically.* You may send your comments electronically to *http://www.regulations.gov.* Follow the instructions for "Comment or Submission" or "More Search Options" to find the information collection document(s) that are accepting comments.

2. *By regular mail.* You may mail written comments to the following address: CMS, Office of Strategic Operations and Regulatory Affairs, Division of Regulations Development, Attention: Document Identifier/OMB Control Number _____, Room C4–26–05, 7500 Security Boulevard, Baltimore, Maryland 21244–1850.

To obtain copies of a supporting statement and any related forms for the proposed collection(s) summarized in this notice, you may make your request using one of following:

1. Access CMS' Web site address at *http://www.cms.hhs.gov/PaperworkReductionActof1995.*

2. Email your request, including your address, phone number, OMB number, and CMS document identifier, to *Paperwork@cms.hhs.gov.*

3. Call the Reports Clearance Office at (410) 786–1326.

FOR FURTHER INFORMATION CONTACT: Reports Clearance Office at (410) 786–1326.

SUPPLEMENTARY INFORMATION:

Contents

This notice sets out a summary of the use and burden associated with the following information collections. More detailed information can be found in each collection's supporting statement and associated materials (see **ADDRESSES**).

CMS–10526 Cost-Sharing Reduction Reconciliation

Under the PRA (44 U.S.C. 3501–3520), federal agencies must obtain approval from the Office of Management and Budget (OMB) for each collection of

information they conduct or sponsor. The term "collection of information" is defined in 44 U.S.C. 3502(3) and 5 CFR 1320.3(c) and includes agency requests or requirements that members of the public submit reports, keep records, or provide information to a third party. Section 3506(c)(2)(A) of the PRA requires federal agencies to publish a 60-day notice in the **Federal Register** concerning each proposed collection of information, including each proposed extension or reinstatement of an existing collection of information, before submitting the collection to OMB for approval. To comply with this requirement, CMS is publishing this notice.

Information Collection

1. *Type of Information Collection Request:* Revision of a currently approved collection; *Title of Information Collection:* Cost-Sharing Reduction Reconciliation; *Use:* Under established Department of Health and Human Services (HHS) regulations, qualified health plan (QHP) issuers will receive estimated advance payments of cost-sharing reductions throughout the year. Each issuer will then be subject to a reconciliation process at the end of the benefit year to ensure that HHS reimburses each issuer only for actual cost sharing. This revised collection eliminates some data elements and requires summary plan level reporting and reporting in the 2016 reconciliation cycle on the dollar amount of 2014 cost-sharing reductions used in calculations for medical loss ratio and risk corridors programs reporting. *Form Number:* CMS–10526 (OMB Control Number: 0938–1266); *Frequency:* Annually; *Affected Public:* Private Sector, Not-for-profit institutions; *Number of Respondents:* 295; *Total Annual Responses:* 4,000,000; *Total Annual Hours:* 6,939. (For policy questions regarding this collection contact Pat Meisol at 410–786–1917.)

Dated: September 8, 2015.

William N. Parham, III,

Director, Paperwork Reduction Staff, Office of Strategic Operations and Regulatory Affairs.

[FR Doc. 2015–22959 Filed 9–11–15; 8:45 am]

BILLING CODE 4120–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Medicare & Medicaid Services

[Document Identifier: CMS–10398 (#43)]

Agency Information Collection Activities: Submission for OMB Review; Comment Request

ACTION: Notice.

SUMMARY: The Centers for Medicare & Medicaid Services (CMS) is announcing an opportunity for the public to comment on CMS' intention to collect information from the public. Under the Paperwork Reduction Act of 1995 (PRA), federal agencies are required to publish notice in the **Federal Register** concerning each proposed collection of information, including each proposed extension or reinstatement of an existing collection of information, and to allow a second opportunity for public comment on the notice. Interested persons are invited to send comments regarding the burden estimate or any other aspect of this collection of information, including any of the following subjects: (1) The necessity and utility of the proposed information collection for the proper performance of the agency's functions; (2) the accuracy of the estimated burden; (3) ways to enhance the quality, utility, and clarity of the information to be collected; and (4) the use of automated collection techniques or other forms of information technology to minimize the information collection burden.

DATES: Comments on the collection(s) of information must be received by the OMB desk officer by October 14, 2015:

ADDRESSES: When commenting, please reference the document identifier or OMB control number. To be assured consideration, comments and recommendations must be submitted in any one of the following ways:

1. *Electronically.* You may send your comments electronically to *http://www.regulations.gov.* Follow the instructions for "Comment or Submission" or "More Search Options" to find the information collection document(s) that are accepting comments.

2. *By regular mail.* You may mail written comments to the following address: CMS, Office of Strategic Operations and Regulatory Affairs, Division of Regulations Development, Attention: Document Identifier/OMB Control Number _____, Room C4–26–05, 7500 Security Boulevard, Baltimore, Maryland 21244–1850.

To obtain copies of a supporting statement and any related forms for the proposed collection(s) summarized in this notice, you may make your request using one of following:

1. Access CMS' Web site address at *http://www.cms.hhs.gov/PaperworkReductionActof1995.*

2. Email your request, including your address, phone number, OMB number, and CMS document identifier, to *Paperwork@cms.hhs.gov.*

3. Call the Reports Clearance Office at (410) 786–1326.

FOR FURTHER INFORMATION CONTACT: Reports Clearance Office at (410) 786–1326.

SUPPLEMENTARY INFORMATION: Under the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501–3520), federal agencies must obtain approval from the Office of Management and Budget (OMB) for each collection of information they conduct or sponsor. The term "collection of information" is defined in 44 U.S.C. 3502(3) and 5 CFR 1320.3(c) and includes agency requests or requirements that members of the public submit reports, keep records, or provide information to a third party. Section 3506(c)(2)(A) of the PRA (44 U.S.C. 3506(c)(2)(A)) requires federal agencies to publish a 30-day notice in the **Federal Register** concerning each proposed collection of information, including each proposed extension or reinstatement of an existing collection of information, before submitting the collection to OMB for approval. To comply with this requirement, CMS is publishing this notice that summarizes the following proposed collection(s) of information for public comment:

1. *Type of Information Collection Request:* Revision of a currently approved collection; *Title of Information Collection:* Demonstration Programs to Improve Community Mental Health Services; *Use:* The Centers for Medicare and Medicaid Services (CMS), the Substance Abuse and Mental Health Services Administration (SAMHSA), and the Assistant Secretary of Planning and Evaluation (ASPE) intend to collect information from states selected to participate in the Section 223 Demonstration Programs to Improve Community Mental Health Services. To be completed annually by each certified community behavioral health clinic (CCBHC), the information collection's cost report would be used to determine each CCBHC's prospective payment system (PPS) rate, effective January 1, 2017, for the payment of demonstration services. The cost report would facilitate rate determinations for both PPS–1 and

PPS–2 (the two methodologies allowed by CMS and specified in CCBHC PPS guidance previously issued by CMS). The cost report would assist states in meeting the requirement for annual reporting of CCBHC cost to CMS in a manner that is consistent with the guidance's cost reporting and documentation requirements.

Information collections approved under this package's control number are reviewed/approved under OMB's generic process. As such, they are usually not subject to formal public review and comment. In this instance, however, CMS is interested in receiving public input and is posting the cost report, cost report instructions, and Supporting Statement on its Web site for public review (see **ADDRESSES** and **DATES**).

Form Number: CMS–10398 (#43) (OMB control number 0938–1148); *Frequency:* Yearly; *Affected Public:* Private sector (not-for-profits institutions) and State, Local, or Tribal Governments; *Number of Respondents:* 24; *Total Annual Responses:* 24; *Total Annual Hours:* 1,832. (For policy questions regarding this collection contact Mary Cieslicki at 410–786–4576).

Dated: September 9, 2015.

William N. Parham, III,

Director, Paperwork Reduction Staff, Office of Strategic Operations and Regulatory Affairs.

[FR Doc. 2015–23053 Filed 9–11–15; 8:45 am]

BILLING CODE 4120–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Administration for Children and Families

Submission for OMB Review; Comment Request

Title: Child Care Quarterly Case Record Report—ACF–801.

OMB No.: 0970–0167.

Description: Section 658K of the Child Care and Development Block Grant (CCDBG) Act (42 U.S.C. 9858, as amended by Pub. L. 113–186) requires that States and Territories submit monthly case-level data on the children and families receiving direct services under the Child Care and Development Fund (CCDF). The implementing regulations for the statutorily required reporting are at 45 CFR 98.70 and 98.71. Case-level reports, submitted quarterly or monthly (at grantee option), include monthly sample or full population case-level data. The data elements to be included in these reports are represented in the ACF–801. ACF uses disaggregate data to determine program and participant characteristics as well as costs and levels of child care services provided. This provides ACF with the information necessary to make reports to Congress, address national child care needs, offer technical assistance to grantees, meet performance measures, and conduct research.

Consistent with the recent reauthorization of the CCDBG statute, ACF requests extension of the ACF–801 including a number of changes and clarifications to the reporting requirements and instructions as set forth below.

- *Homeless Status:* Section 658K(a)(1)(B)(xi) of the CCDBG Act now requires States to report whether children receiving assistance under this subchapter are homeless children. Specifically, this data element will be required with the reporting period beginning October 2015.
- *Child Disability:* ACF proposes to add a new data element effective October 2016 indicating whether or not each child receiving services is a child with a disability, in part to track State implementation of priority for services requirements at section 658E(c)(3)(B) of the CCDBG Act (which includes children with special needs as defined by the State).
- *Military Status:* ACF proposes to add a new data element effective October 2016 to the ACF–801 to determine the family's status related to military service.
- *Family Zip Code and Provider Zip Code:* ACF proposes to add zip codes effective October 2016 to both the family and the provider records to identify the communities where CCDF families and providers are located, in part to support implementation of sections 658E(a)(2)(M) and 658E(a)(2)(Q) of the CCDBG Act that require States to address the supply and access to high-quality child care services for certain areas and populations.
- *Quality of Child Care Providers:* The existing ACF–801 allows States several ways of reporting information on the quality of each child's provider(s)—including: Quality Rating and Improvement System (QRIS) participation and rating, accreditation status, State pre-K standards, and other State-defined quality measure. To date, States have been required to report on at least one of the quality elements for a portion of the provider population. ACF is proposing that, effective with the October 2017 report, States must report quality information for every child care provider. States with a QRIS, at a minimum, would be required to report QRIS participation and rating for every provider. States without QRIS would be required to report quality information for every provider using one or more of the quality elements on the form. ACF is proposing to add a new option to indicate whether or not the provider is subject to Head Start or Early Head Start standards.
- *Inspection Date:* Section 658E(c)(2)(J) of the reauthorized CCDBG Act requires States to monitor both licensed and license-exempt CCDF providers. ACF proposes to add a data element effective October 2017 indicating, for each child care provider delivering services to a CCDF child, the date of the most recent inspection for compliance with health, safety, and fire standards (including licensing standards for licensed providers).
- *Personally Identifiable Information:* Section 658K(a)(1)(E) of the CCDBG Act now prohibits the ACF–801 report from containing personally identifiable information. As a result, ACF proposes to delete Social Security Numbers (SSNs) from the report. Specifically, this change will be required with the reporting period beginning October 2015. Note that the form will still require a unique identifying number, other than the SSN, that is assigned by the State for each family.
- *Language:* ACF proposes to add a data element effective October 2016 indicating, the primary language spoken in the home consistent with a Head Start Program Information Report question, *i.e.,* Primary Language of Family at Home.

Respondents: States, the District of Columbia, and Territories including Puerto Rico, Guam, the Virgin Islands, American Samoa, and the Northern Marianna Islands.

ANNUAL BURDEN ESTIMATES

Instrument	Number of respondents	Number of responses per respondent	Average burden hours per response	Total burden hours
ACF–801	56	4	25	5,600

Estimated Total Annual Burden Hours: 5,600.

Additional Information: Copies of the proposed collection may be obtained by writing to the Administration for Children and Families, Office of Planning, Research and Evaluation, 370 L'Enfant Promenade SW., Washington, DC 20447, Attn: ACF Reports Clearance Officer. All requests should be identified by the title of the information collection. Email address: *infocollection@acf.hhs.gov.*

OMB Comment: OMB is required to make a decision concerning the collection of information between 30 and 60 days after publication of this document in the **Federal Register.** Therefore, a comment is best assured of having its full effect if OMB receives it within 30 days of publication. Written comments and recommendations for the proposed information collection should be sent directly to the following: Office of Management and Budget, Paperwork Reduction Project, Email: *OIRA_SUBMISSION@OMB.EOP.GOV.* Attn: Desk Officer for the Administration for Children and Families.

Robert Sargis,

Reports Clearance Officer.

[FR Doc. 2015–23022 Filed 9–11–15; 8:45 am]

BILLING CODE 4184–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Administration for Children and Families

Submission for OMB Review; Comment Request

Title: Study of Early Head Start-Child Care Partnerships.

OMB No.: New Collection.

Description: The Administration for Children and Families (ACF) in the Department of Health and Human Services (HHS) has awarded 275 Early Head Start expansion and Early Head Start-child care partnership grants in 50 states; Washington, DC; Puerto Rico; and the Northern Mariana Islands. These grants will allow new or existing Early Head Start programs to partner with local child care centers and family child care providers to expand high-quality early learning opportunities for infants and toddlers from low-income families.

ACF is proposing to conduct a descriptive study of the new partnership grantees to document the characteristics and features of partnerships and the activities that aim to improve professional development and quality of services and better meet the needs of families. The study will focus on the grantees that have received funds for Early Head Start-child care partnership grants.

The proposed data collection for the descriptive Study of Early Head Start-Child Care Partnerships will include two components: (1) Surveys of 311 partnership grantee and delegate agency directors and a randomly selected sample of 933 child care partners, and (2) in-depth follow-up case studies of 12 purposively selected partnerships.

The goal of this work is to collect descriptive information about partnership grantees and delegate agencies, child care partners, and services and quality improvement activities implemented as part of the partnerships and explore how particular partnership models operate. These data will be used to describe the national landscape of partnerships, fill a knowledge gap about partnership models implemented in the field, lay the groundwork for future research, and provide information to inform technical assistance and actions aimed at informing the Early Head Start-child care partnerships grant initiative.

Respondents: Partnership grantee and delegate agency directors; child care partner managers/owners; partnership staff who focus on coordinating activities among partners, monitoring compliance with the Head Start Program Performance Standards, and providing technical assistance and training; frontline staff; parents; and other state and local stakeholders (such as staff from child care resource and referral agencies or child care subsidy administrators).

ANNUAL BURDEN ESTIMATES

Instrument	Total number of respondents	Annual number of respondents	Number of responses per respondent	Average burden hours per response	Annual burden hours
1. Partnership grantee and delegate agency director survey	311	156	1	1	156
2. Child care partner survey	933	467	1	0.50	234
3. Interview topic guide:					
Partnership grantee and delegate agency directors	12	6	1	1.5	9
Partnership staff	36	18	1	1	18
State and local stakeholders	48	24	1	1	24
4. Parent focus group guide	96	48	1	1.5	72
5. Child care center director focus group guide	96	48	1	1.5	72
6. Child care center teacher focus group guide	96	48	1	1.5	72
7. Family child care provider focus group guide	48	24	1	1.5	36
8. Partnership grantee and delegate agency director questionnaire	12	6	1	2	12
9. Child care partner questionnaire	180	90	1	0.33	30

Estimated Total Annual Burden Hours: 735.

Additional Information: Copies of the proposed collection may be obtained by writing to the Administration for Children and Families, Office of Planning, Research and Evaluation, 370 L'Enfant Promenade SW., Washington, DC 20447, Attn: OPRE Reports Clearance Officer. All requests should be identified by the title of the information collection. Email address: *OPREinfocollection@acf.hhs.gov.*

OMB Comment: OMB is required to make a decision concerning the collection of information between 30 and 60 days after publication of this document in the **Federal Register**. Therefore, a comment is best assured of having its full effect if OMB receives it within 30 days of publication. Written comments and recommendations for the proposed information collection should be sent directly to the following: Office of Management and Budget, Paperwork Reduction Project, *Email: OIRA_SUBMISSION@OMB.EOP.GOV, Attn:* Desk Officer for the Administration for Children and Families.

Robert Sargis,

ACF Reports Clearance Officer.

[FR Doc. 2015–23017 Filed 9–11–15; 8:45 am]

BILLING CODE 4184–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Administration for Children and Families

[CFDA Number: 93.612]

Announcement of the Award of a Single Source Emergency Grant to the Oglala Sioux Tribe in Pine Ridge, SD

AGENCY: Administration for Native Americans, ACF, HHS.

ACTION: Announcement of the award of a single source, emergency grant to the Oglala Sioux Tribe in Pine Ridge, SD to address the critically high levels of youth suicide on the reservation since December 2014.

SUMMARY: The Administration for Children and Families (ACF), Administration for Native Americans (ANA) announces the award of a single source emergency grant in the amount of $400,000 to the Oglala Sioux Tribe to provide empowerment activities for youth in order to address the critically high levels of youth suicide on the reservation since December 2014.

DATES: The timeframe for the initial award is July 31, 2015 to July 30, 2016.

FOR FURTHER INFORMATION CONTACT: Carmelia Strickland, Director, Division of Program Operations, Administration for Native Americans, 370 L'Enfant Promenade SW., Washington, DC 20047. Telephone: 877–922–9262; Email: *Carmelia.strickland@acf.hhs.gov.*

SUPPLEMENTARY INFORMATION: The Administration for Native Americans (ANA), Administration for Children and Families, has awarded an emergency single source grant to the Oglala Sioux Tribe (OST) for programs whose goal is to empower youth ages 8 to 24 to make changes in their communities, to be proud of their heritage, and to inspire them to celebrate life so that they may see that there is a positive future for them. It is intended that this program will have a 24-month project period so that another 12-month budget period will be funded noncompetitively for $400,000 in FY 2016. In testimony before the Senate Committee on Indian Affairs on June 24, 2015, Oglala Sioux Tribe President John Yellowbird Steele's testimony stated that 11 young people on the Pine Ridge Reservation have been lost to suicide since December. In addition, at least another 176 of the youth have attempted suicide in that period, according to the Indian Health Service, and 229 more were treated for suicidal ideation.

The awarded project is designed to increase positive youth empowerment activities in all nine districts on the Pine Ridge Indian Reservation through the development of Student Youth Councils, peer to peer mentoring, and Lakota cultural awareness activities. The award was made under ANA's program for Social and Economic Development Strategies (SEDS). The OST has been designated as a Federal government Promise Zone, because of the severe financial and economic status in the area in which they live. The Pine Ridge Reservation is also located in Shannon County, which is often referred to as the poorest county in the United States.

Statutory Authority: This program is authorized under § 803(a) of the Native American Programs Act of 1974 (NAPA), 42 U.S.C. 2991b.

Christopher Beach,

Senior Grants Policy Specialist, Division of Grants Policy, Office of Administration.

[FR Doc. 2015–22957 Filed 9–11–15; 8:45 am]

BILLING CODE 4184–34–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Administration for Community Living

Delegation of Authority

Notice is hereby given that I have delegated to the Administrator of the Administration for Community Living, or his or her successor, the following authorities vested in the Secretary:

- The authorities vested under 42 U.S.C. 300d–52 and 300d–53, as amended by Sections 3 and 4 of the Traumatic Brain Injury Reauthorization Act of 2014 (P.L. 113–196), titled "State Grants for Projects Regarding Traumatic Brain Injury" and "State Grants for Protection and Advocacy Services."

(Prior to the passage of the Traumatic Brain Injury Reauthorization Act of 2014, exercise of these authorities was vested by statute with the Administrator, Health Resources and Services Administration.)

These authorities may be redelegated.

This delegation excludes the authority to issue regulations, to establish advisory committees and councils, and appoint their members, and to submit reports to Congress, and shall be exercised in accordance with the Department's applicable policies, procedures, and guidelines.

This delegation will concurrently supersede all existing delegations of these authorities.

I hereby affirm and ratify any actions taken by agency officials which involved the exercise of the authorities delegated herein prior to the effective date of this delegation.

This delegation is effective October 1, 2015.

Dated: August 31, 2015.

Sylvia M. Burwell,

Secretary.

[FR Doc. 2015–23122 Filed 9–11–15; 8:45 am]

BILLING CODE 4154–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Food and Drug Administration

[Docket No. FDA–2015–N–0007]

Fee for Using a Tropical Disease Priority Review Voucher in Fiscal Year 2016

AGENCY: Food and Drug Administration, HHS.

ACTION: Notice.

SUMMARY: The Food and Drug Administration (FDA or the Agency) is announcing the fee rates for using a

tropical disease priority review voucher for fiscal year (FY) 2016. The Federal Food, Drug, and Cosmetic Act (the FD&C Act), as amended by the Food and Drug Administration Amendments Act of 2007 (FDAAA), authorizes FDA to determine and collect priority review user fees for certain applications for approval of drug or biological products when those applications use a tropical disease priority review voucher awarded by the Secretary of Health and Human Services. These vouchers are awarded to the sponsors of certain tropical disease product applications, submitted after September 27, 2007, upon FDA approval of such applications. The amount of the fee submitted to FDA with applications using a tropical disease priority review voucher is determined each fiscal year based on the difference between the average cost incurred by FDA in the review of a human drug application subject to priority review in the previous fiscal year, and the average cost incurred in the review of an application that is not subject to priority review in the previous fiscal year. This notice establishes the tropical disease priority review fee rate for FY 2016.

FOR FURTHER INFORMATION CONTACT: Robert J. Marcarelli, Office of Financial Management, Food and Drug Administration, 8455 Colesville Rd., COLE–14202F, Silver Spring, MD, 20993–0002, 301–796–7223.

SUPPLEMENTARY INFORMATION:

I. Background

Section 1102 of FDAAA (Pub. L. 110–85) added section 524 to the FD&C Act (21 U.S.C. 360n). In section 524, Congress encouraged development of new drug and biological products for prevention and treatment of certain tropical diseases by offering additional incentives for obtaining FDA approval of such products. Under section 524, the sponsor of an eligible human drug application submitted after September 27, 2007, for a qualified tropical disease (as defined in section 524(a)(3) of the FD&C Act), shall receive a priority review voucher upon approval of the tropical disease product application. The recipient of a tropical disease priority review voucher may either use the voucher with a future submission to FDA under section 505(b)(1) of the FD&C Act (21 U.S.C. 355(b)(1)) or section 351 of the Public Health Service Act (42 U.S.C. 262), or transfer (including by sale) the voucher to another party that may then use it. A priority review is a review conducted with a Prescription Drug User Fee Act (PDUFA) goal date of 6 months after the receipt or filing date, depending upon the type of application. Information regarding the PDUFA goals is available at: *http://www.fda.gov/downloads/forindustry/userfees/prescriptiondruguserfee/ucm270412.pdf.*

The applicant that uses a priority review voucher is entitled to a priority review but must pay FDA a priority review user fee in addition to any other fee required by PDUFA. FDA published a draft guidance on its Web site about how this tropical disease priority review voucher program operates (available at: *http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080599.pdf).*

This notice establishes the tropical disease priority review fee rate for FY 2016 as $2,727,000 and outlines FDA's process for implementing the collection of the priority review user fees. This rate is effective on October 1, 2015, and will remain in effect through September 30, 2016, for applications submitted with a tropical disease priority review voucher. The payment of this priority review user fee is required in addition to the payment of any other fee that would normally apply to such an application under PDUFA before FDA will consider the application complete and acceptable for filing.

II. Tropical Disease Priority Review User Fee for FY 2016

Under section 524(c)(2) of the FD&C Act, the amount of the tropical disease priority review user fee is determined each fiscal year based on the difference between the average cost incurred by FDA in the review of a human drug application subject to priority review in the previous fiscal year, and the average cost incurred by FDA in the review of a human drug application that is not subject to priority review in the previous fiscal year. The priority review voucher fee is intended to cover the incremental costs for FDA to do a priority review on a product that would otherwise get a standard review. The formula provides the Agency with the added resources to conduct a priority review while still ensuring a robust priority review voucher program that is consistent with the Agency's public health goal of encouraging the development of new drug and biological products.

A priority review is a review conducted with a PDUFA goal date of 6 months after the receipt or filing date, depending on the type of application. Under the PDUFA goals letter, FDA has committed to reviewing and acting on 90 percent of the applications granted priority review status within this expedited timeframe. Normally, an application for a human drug or biological product will qualify for priority review if the product is intended to treat a serious condition and, if approved, would provide a significant improvement in safety or effectiveness. An application that does not receive a priority designation will receive a standard review. Under the PDUFA goals letter, FDA committed to reviewing and acting on 90 percent of standard applications within 10 months of the receipt or filing date, depending on the type of application. A priority review involves a more intensive level of effort and a higher level of resources than a standard review.

Section 524 of the FD&C Act specifies that the fee amount should be based on the difference between the average cost incurred by the Agency in the review of a human drug application subject to a priority review in the previous fiscal year, and the average cost incurred by FDA in the review of a human drug application that is not subject to priority review in the previous fiscal year. FDA is setting fees for FY 2016, and the previous fiscal year is FY 2015. However, the FY 2015 submission cohort has not been closed out yet, and the cost data for FY 2015 are not complete. The latest year for which FDA has complete cost data is FY 2014. Furthermore, because FDA has never tracked the cost of reviewing applications that get priority review as a separate cost subset, FDA estimated this cost based on other data that the Agency has tracked. FDA uses data that the Agency estimates and publishes on its Web site each year—standard costs for review. FDA does not publish a standard cost for "the review of a human drug application subject to priority review in the previous fiscal year." However, we expect all such applications would contain clinical data. The standard cost application categories with clinical data that FDA does publish each year are: (1) New drug applications (NDAs) for a new molecular entity (NME) with clinical data and (2) biologics license applications (BLAs).

The worksheets for standard costs for FY 2014, show a standard cost (rounded to the nearest thousand dollars) of $5,646,000 for a NME NDA and $5,533,000 for a BLA. Based on these standard costs, the total cost to review the 48 applications in these two categories in FY 2014 (30 NME NDAs with clinical data and 18 BLAs) was $268,974,000. (Note: these numbers exclude the President's Emergency Plan for AIDS Relief NDAs; no

investigational new drug review costs are included in this amount.) Twenty-nine of these applications (20 NDAs and 9 BLAs) received priority review, which would mean that the remaining 19 received standard reviews. Because a priority review compresses a review that ordinarily takes 10 months into 6 months, FDA estimates that a multiplier of 1.67 (10 months divided by 6 months) should be applied to non-priority review costs in estimating the effort and cost of a priority review as compared to a standard review. This multiplier is consistent with published research on this subject. In the article "Developing Drugs for Developing Countries," published in "Health Affairs," Volume 25, Number 2, in 2006, the comparison of historical average review times by David B. Ridley, Henry G. Grabowski, and Jeffrey L. Moe, supports a priority review multiplier in the range of 1.48 to 2.35. The multiplier derived by FDA falls well below the midpoint of this range. Using FY 2014 figures, the costs of a priority and standard review are estimated using the following formula:

$(29\ \alpha \times 1.67) + (19\ \alpha) = \$268{,}974{,}000$

where "α" is the cost of a standard review and "$\alpha \times 1.67$" is the cost of a priority review. Using this formula, the cost of a standard review for NME NDAs and BLAs is calculated to be $3,989,000 (rounded to the nearest thousand dollars) and the cost of a priority review for NME NDAs and BLAs is 1.67 times that amount, or $6,662,000 (rounded to the nearest thousand dollars). The difference between these two cost estimates, or $2,673,000, represents the incremental cost of conducting a priority review rather than a standard review.

For the FY 2016 fee, FDA will need to adjust the FY 2014 incremental cost by the average amount by which FDA's average costs increased in the 3 years prior to FY 2015, to adjust the FY 2014 amount for cost increases in FY 2015. That adjustment, published in the **Federal Register** on August 3, 2015 (see 80 FR 46028 at 46029), setting FY 2016 PDUFA fees, is 2.0266 percent for the most recent year, not compounded. Increasing the FY 2014 incremental priority review cost of $2,673,000 by 2.0266 percent results in an estimated cost of $2,727,000 (rounded to the nearest thousand dollars). This is the priority review user fee amount for FY 2016 that must be submitted with a priority review voucher in FY 2016, in addition to any PDUFA fee that is required for such an application.

III. Fee Schedule for FY 2016

The fee rate for FY 2016 is set out in table 1:

TABLE 1—TROPICAL DISEASE PRIORITY REVIEW SCHEDULE FOR FY 2016

Fee category	Fee rate for FY 2016
Application submitted with a tropical disease priority review voucher in addition to the normal PDUFA fee	$2,727,000

IV. Implementation of Tropical Disease Priority Review User Fee

Under section 524(c)(4)(A) of the FD&C Act, the priority review user fee is due upon submission of a human drug application for which the priority review voucher is used. Section 524(c)(4)(B) of the FD&C Act specifies that the application will be considered incomplete if the priority review user fee and all other applicable user fees are not paid in accordance with FDA payment procedures. In addition, FDA may not grant a waiver, exemption, reduction, or refund of any fees due and payable under this section of the FD&C Act and FDA may not collect priority review voucher fees prior to a relevant appropriation for fees for that fiscal year. Beginning with FDA's appropriation for FY 2009, the annual appropriation language states specifically that "priority review user fees authorized by 21 U.S.C. 360n (section 524 of the FD&C Act) may be credited to this account, to remain available until expended." (Pub. L. 111–8, Section 5, Division A, Title VI).

The tropical disease priority review fee established in the new fee schedule must be paid for any application that is received on or after October 1, 2015, and submitted with a priority review voucher. This fee must be paid in addition to any other fee due under PDUFA. Payment must be made in U.S. currency by check, bank draft, or U.S. postal money order payable to the order of the Food and Drug Administration. The user fee identification (ID) number should be included on the check, followed by the words "Tropical Disease Priority Review." Payments can be mailed to: Food and Drug Administration, P.O. Box 979107, St. Louis, MO 63197–9000.

If checks are sent by a courier that requests a street address, the courier can deliver the checks to: U.S. Bank, Attention: Government Lockbox 979107, 1005 Convention Plaza, St. Louis, MO 63101. (Note: This U.S. Bank address is for courier delivery only.) The FDA post office box number (P.O. Box 979107) must be written on the check. The tax identification number of FDA is 53–0196965.

Wire transfer payments may also be used. Please reference your unique user fee ID number when completing your transfer. The originating financial institution may charge a wire transfer fee. Please ask your financial institution about the fee and include it with your payment to ensure that your fee is fully paid. The account information is as follows: New York Federal Reserve Bank, U.S. Dept. of Treasury, TREAS NYC, 33 Liberty St., New York, NY 10045, Account Number: 75060099, Routing Number: 021030004, SWIFT: FRNYUS33, Beneficiary: FDA, 8455 Colesville Rd., Silver Spring, MD 20993–0002.

Dated: September 8, 2015.

Leslie Kux,

Associate Commissioner for Policy.

[FR Doc. 2015–23006 Filed 9–11–15; 8:45 am]

BILLING CODE 4164–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Food and Drug Administration

[Docket No. FDA–2015–N–0001]

Anesthetic and Analgesic Drug Products Advisory Committee; Notice of Meeting

AGENCY: Food and Drug Administration, HHS.

ACTION: Notice.

This notice announces a forthcoming meeting of a public advisory committee of the Food and Drug Administration (FDA). The meeting will be open to the public.

Name of Committee: Anesthetic and Analgesic Drug Products Advisory Committee.

General Function of the Committee: To provide advice and recommendations to the Agency on FDA's regulatory issues.

Date and Time: The meeting will be held on November 6, 2015, from 8 a.m. to 5 p.m.

Location: FDA White Oak Campus, 10903 New Hampshire Ave., Bldg. 31 Conference Center, the Great Room (Rm. 1503), Silver Spring, MD 20993–0002. Answers to commonly asked questions including information regarding special accommodations due to a disability, visitor parking, and transportation may be accessed at: *http://www.fda.gov/AdvisoryCommittees/*

AboutAdvisoryCommittees/ucm408555.htm.

Contact Person: Stephanie L. Begansky, Center for Drug Evaluation and Research, Food and Drug Administration, 10903 New Hampshire Ave., Bldg. 31, Rm. 2417, Silver Spring, MD 20993–0002, 301–796–9001, FAX: 301–847–8533, *AADPAC@fda.hhs.gov,* or FDA Advisory Committee Information Line, 1–800–741–8138 (301–443–0572 in the Washington, DC area). A notice in the **Federal Register** about last minute modifications that impact a previously announced advisory committee meeting cannot always be published quickly enough to provide timely notice. Therefore, you should always check the Agency's Web site at *http://www.fda.gov/AdvisoryCommittees/default.htm* and scroll down to the appropriate advisory committee meeting link, or call the advisory committee information line to learn about possible modifications before coming to the meeting.

Agenda: The committee will discuss new drug application (NDA) 022225, sugammadex sodium injection, submitted by Organon USA Inc., a subsidiary of Merck & Co., Inc., for the proposed indication of reversal of moderate or deep neuromuscular blockade (NMB) induced by rocuronium or vecuronium.

FDA intends to make background material available to the public no later than 2 business days before the meeting. If FDA is unable to post the background material on its Web site prior to the meeting, the background material will be made publicly available at the location of the advisory committee meeting, and the background material will be posted on FDA's Web site after the meeting. Background material is available at *http://www.fda.gov/AdvisoryCommittees/Calendar/default.htm.* Scroll down to the appropriate advisory committee meeting link.

Procedure: Interested persons may present data, information, or views, orally or in writing, on issues pending before the committee. Written submissions may be made to the contact person on or before October 23, 2015. Oral presentations from the public will be scheduled between approximately 1 p.m. and 2 p.m. Those individuals interested in making formal oral presentations should notify the contact person and submit a brief statement of the general nature of the evidence or arguments they wish to present, the names and addresses of proposed participants, and an indication of the approximate time requested to make their presentation on or before October 15, 2015. Time allotted for each presentation may be limited. If the number of registrants requesting to speak is greater than can be reasonably accommodated during the scheduled open public hearing session, FDA may conduct a lottery to determine the speakers for the scheduled open public hearing session. The contact person will notify interested persons regarding their request to speak by October 16, 2015.

Persons attending FDA's advisory committee meetings are advised that the Agency is not responsible for providing access to electrical outlets.

FDA welcomes the attendance of the public at its advisory committee meetings and will make every effort to accommodate persons with disabilities. If you require accommodations due to a disability, please contact Stephanie L. Begansky at least 7 days in advance of the meeting.

FDA is committed to the orderly conduct of its advisory committee meetings. Please visit our Web site at *http://www.fda.gov/AdvisoryCommittees/AboutAdvisoryCommittees/ucm111462.htm* for procedures on public conduct during advisory committee meetings.

Notice of this meeting is given under the Federal Advisory Committee Act (5 U.S.C. app. 2).

Dated: September 8, 2015.

Jill Hartzler Warner,

Associate Commissioner for Special Medical Programs.

[FR Doc. 2015–22984 Filed 9–11–15; 8:45 am]

BILLING CODE 4164–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Food and Drug Administration

[Docket No. FDA–2013–D–1600]

Enforcement Policy for Certain (Provisional) Tobacco Products That the Food and Drug Administration Finds Not Substantially Equivalent; Guidance for Industry and Tobacco Retailers; Availability

AGENCY: Food and Drug Administration, HHS.

ACTION: Notice.

SUMMARY: The Food and Drug Administration (FDA) is announcing the availability of a guidance for industry entitled "Enforcement Policy for Certain (Provisional) Tobacco Products that FDA Finds Not Substantially Equivalent." This guidance provides information to tobacco retailers on FDA's enforcement policy regarding certain so-called provisional tobacco products that become subject to not substantially equivalent (NSE) orders issued under the Federal Food, Drug, and Cosmetic Act (the FD&C Act).

DATES: Submit either electronic or written comments on Agency guidances at any time.

ADDRESSES: Submit written requests for single copies of this guidance to the Center for Tobacco Products, Food and Drug Administration, Document Control Center, 10903 New Hampshire Ave., Bldg. 71, Rm. G335, Silver Spring, MD 20993–2000. Send one self-addressed adhesive label to assist that office in processing your request or include a fax number to which the guidance document may be sent. See the **SUPPLEMENTARY INFORMATION** section for information on electronic access to the guidance.

Submit electronic comments on the guidance to *http://www.regulations.gov.* Submit written comments to the Division of Dockets Management (HFA–305), Food and Drug Administration, 5630 Fishers Lane, Rm. 1061, Rockville, MD 20852. Identify comments with the docket number found in brackets in the heading of this document.

FOR FURTHER INFORMATION CONTACT: Annette Marthaler, Center for Tobacco Products, Food and Drug Administration, Document Control Center, 10903 New Hampshire Ave., Bldg. 71, Rm. G335, Silver Spring, MD 20993–2000, email: *CTPRegulations@fda.hhs.gov.*

SUPPLEMENTARY INFORMATION:

I. Background

FDA is announcing the availability of a guidance for industry entitled "Enforcement Policy for Certain (Provisional) Tobacco Products that FDA Finds Not Substantially Equivalent." This guidance provides information to tobacco retailers on FDA's enforcement policy regarding certain so-called provisional tobacco products that become subject to NSE orders issued under the FD&C Act. We received several comments to the draft guidance (79 FR 10534, February 25, 2014), and those comments were considered as the guidance was finalized.

II. Significance of Guidance

This guidance is being issued consistent with FDA's good guidance practices regulation (21 CFR 10.115). The guidance represents the current thinking of FDA on "Enforcement Policy for Certain (Provisional) Tobacco Products that FDA Finds Not Substantially Equivalent." It does not

establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations.

III. Comments

A. General Information About Submitting Comments

Interested persons may submit either electronic comments regarding this document to *http://www.regulations.gov* or written comments to the Division of Dockets Management (see **ADDRESSES**). It is only necessary to send one set of comments. Identify comments with the docket number found in brackets in the heading of this document.

B. Public Availability of Comments

Received comments may be seen in the Division of Dockets Management between 9 a.m. and 4 p.m., Monday through Friday, and will be posted to the docket at *http://www.regulations.gov*. As a matter of Agency practice, FDA generally does not post comments submitted by individuals in their individual capacity on *http://www.regulations.gov*. This is determined by information indicating that the submission is written by an individual, for example, the comment is identified with the category "Individual Consumer" under the field titled "Category (Required)," on the "Your Information" page on *www.regulations.gov*. For this docket, however, FDA will not be following this general practice. Instead, FDA will post on *http://www.regulations.gov* comments to this docket that have been submitted by individuals in their individual capacity. If you wish to submit any information under a claim of confidentiality, please refer to 21 CFR 10.20.

C. Information Identifying the Person Submitting the Comment

Please note that your name, contact information, and other information identifying you will be posted on *http://www.regulations.gov* if you include that information in the body of your comments. For electronic comments submitted to *http://www.regulations.gov*, FDA will post the body of your comment on *http://www.regulations.gov* along with your State/province and country (if provided), the name of your representative (if any), and the category identifying you (*e.g.*, individual, consumer, academic, industry). For written submissions submitted to the Division of Dockets Management, FDA will post the body of your comments on *http://www.regulations.gov*, but you can put your name and/or contact information on a separate cover sheet and not in the body of your comments.

IV. Electronic Access

Persons with access to the Internet may obtain an electronic version of the guidance at either *http://www.regulations.gov* or *http://www.fda.gov/TobaccoProducts/GuidanceComplianceRegulatoryInformation/default.htm*.

Dated: September 9, 2015.

Leslie Kux,

Associate Commissioner for Policy.

[FR Doc. 2015–23001 Filed 9–11–15; 8:45 am]

BILLING CODE 4164–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Food and Drug Administration

[Docket No. FDA–2014–N–1206]

Authorization of Emergency Use of an In Vitro Diagnostic Device for Detection of Ebola Zaire Virus; Availability

AGENCY: Food and Drug Administration, HHS.

ACTION: Notice.

SUMMARY: The Food and Drug Administration (FDA) is announcing the issuance of an Emergency Use Authorization (EUA) (the Authorization) for an in vitro diagnostic device for detection of the Ebola Zaire virus in response to the Ebola virus outbreak in West Africa. FDA issued this Authorization under the Federal Food, Drug, and Cosmetic Act (the FD&C Act), as requested by OraSure Technologies, Inc. The Authorization contains, among other things, conditions on the emergency use of the authorized in vitro diagnostic device. The Authorization follows the September 22, 2006, determination by then-Secretary of the Department of Homeland Security (DHS), Michael Chertoff, that the Ebola virus presents a material threat against the U.S. population sufficient to affect national security. On the basis of such determination, the Secretary of Health and Human Services (HHS) declared on August 5, 2014, that circumstances exist justifying the authorization of emergency use of in vitro diagnostic devices for detection of Ebola virus subject to the terms of any authorization issued under the FD&C Act. The Authorization, which includes an explanation of the reasons for issuance, is reprinted in this document.

DATES: The Authorization is effective as of July 31, 2015.

ADDRESSES: Submit written requests for single copies of the EUA to the Office of Counterterrorism and Emerging Threats, Food and Drug Administration, 10903 New Hampshire Ave., Bldg. 1, Rm. 4338, Silver Spring, MD 20993–0002. Send one self-addressed adhesive label to assist that office in processing your request or include a fax number to which the Authorization may be sent. See the **SUPPLEMENTARY INFORMATION** section for electronic access to the Authorization.

FOR FURTHER INFORMATION CONTACT: Carmen Maher, Acting Assistant Commissioner for Counterterrorism Policy and Acting Director, Office of Counterterrorism and Emerging Threats, Food and Drug Administration, 10903 New Hampshire Ave., Bldg. 1, Rm. 4347, Silver Spring, MD 20993–0002, 301–796–8510 (this is not a toll free number).

SUPPLEMENTARY INFORMATION:

I. Background

Section 564 of the FD&C Act (21 U.S.C. 360bbb–3) as amended by the Project BioShield Act of 2004 (Pub. L. 108–276) and the Pandemic and All-Hazards Preparedness Reauthorization Act of 2013 (Pub. L. 113–5) allows FDA to strengthen the public health protections against biological, chemical, nuclear, and radiological agents. Among other things, section 564 of the FD&C Act allows FDA to authorize the use of an unapproved medical product or an unapproved use of an approved medical product in certain situations. With this EUA authority, FDA can help assure that medical countermeasures may be used in emergencies to diagnose, treat, or prevent serious or life-threatening diseases or conditions caused by biological, chemical, nuclear, or radiological agents when there are no adequate, approved, and available alternatives.

Section 564(b)(1) of the FD&C Act provides that, before an EUA may be issued, the Secretary of HHS must declare that circumstances exist justifying the authorization based on one of the following grounds: (1) A determination by the Secretary of Homeland Security that there is a domestic emergency, or a significant potential for a domestic emergency, involving a heightened risk of attack with a biological, chemical, radiological, or nuclear agent or agents; (2) a determination by the Secretary of Defense that there is a military emergency, or a significant potential for a military emergency, involving a

heightened risk to U.S. military forces of attack with a biological, chemical, radiological, or nuclear agent or agents; (3) a determination by the Secretary of HHS that there is a public health emergency, or a significant potential for a public health emergency, that affects, or has a significant potential to affect, national security or the health and security of U.S. citizens living abroad, and that involves a biological, chemical, radiological, or nuclear agent or agents, or a disease or condition that may be attributable to such agent or agents; or (4) the identification of a material threat by the Secretary of Homeland Security under section 319F–2 of the Public Health Service (PHS) Act (42 U.S.C. 247d–6b) sufficient to affect national security or the health and security of U.S. citizens living abroad.

Once the Secretary of HHS has declared that circumstances exist justifying an authorization under section 564 of the FD&C Act, FDA may authorize the emergency use of a drug, device, or biological product if the Agency concludes that the statutory criteria are satisfied. Under section 564(h)(1) of the FD&C Act, FDA is required to publish in the **Federal Register** a notice of each authorization, and each termination or revocation of an authorization, and an explanation of the reasons for the action. Section 564 of the FD&C Act permits FDA to authorize the introduction into interstate commerce of a drug, device, or biological product intended for use when the Secretary of HHS has declared that circumstances exist justifying the authorization of emergency use. Products appropriate for emergency use may include products and uses that are not approved, cleared, or licensed under sections 505, 510(k), or 515 of the FD&C Act (21 U.S.C. 355, 360(k), and 360e) or section 351 of the PHS Act (42 U.S.C. 262). FDA may issue an EUA only if, after consultation with the HHS Assistant Secretary for Preparedness and Response, the Director of the National Institutes of Health, and the Director of the Centers for Disease Control and Prevention (to the extent feasible and appropriate given the applicable circumstances), FDA [1] concludes: (1) That an agent referred to in a declaration of emergency or threat can cause a serious or life-threatening disease or condition; (2) that, based on the totality of scientific evidence available to FDA, including data from adequate and well-controlled clinical trials, if available, it is reasonable to believe that: (A) The product may be effective in diagnosing, treating, or preventing (i) such disease or condition; or (ii) a serious or life-threatening disease or condition caused by a product authorized under section 564, approved or cleared under the FD&C Act, or licensed under section 351 of the PHS Act, for diagnosing, treating, or preventing such a disease or condition caused by such an agent; and (B) the known and potential benefits of the product, when used to diagnose, prevent, or treat such disease or condition, outweigh the known and potential risks of the product, taking into consideration the material threat posed by the agent or agents identified in a declaration under section 564(b)(1)(D) of the FD&C Act, if applicable; (3) that there is no adequate, approved, and available alternative to the product for diagnosing, preventing, or treating such disease or condition; and (4) that such other criteria as may be prescribed by regulation are satisfied.

No other criteria for issuance have been prescribed by regulation under section 564(c)(4) of the FD&C Act. Because the statute is self-executing, regulations or guidance are not required for FDA to implement the EUA authority.

II. EUA Request for an In Vitro Diagnostic Device for Detection of the Ebola Zaire Virus

On September 22, 2006, then-Secretary of DHS, Michael Chertoff, determined that the Ebola virus presents a material threat against the U.S. population sufficient to affect national security.[2] On August 5, 2014, under section 564(b)(1) of the FD&C Act, and on the basis of such determination, the Secretary of HHS declared that circumstances exist justifying the authorization of emergency use of in vitro diagnostics for detection of Ebola virus, subject to the terms of any authorization issued under section 564 of the FD&C Act. Notice of the declaration of the Secretary was published in the **Federal Register** on August 12, 2014 (79 FR 47141). On July 20, 2015, OraSure Technologies, Inc. requested, and on July 31, 2015, FDA issued, an EUA for the OraQuick® Ebola Rapid Antigen Test, subject to the terms of the Authorization.

III. Electronic Access

An electronic version of this document and the full text of the Authorization are available on the Internet at *http://www.regulations.gov.*

IV. The Authorization

Having concluded that the criteria for issuance of the Authorization under section 564(c) of the FD&C Act are met, FDA has authorized the emergency use of an in vitro diagnostic device for detection of the Ebola Zaire virus (detected in the West Africa outbreak in 2014) subject to the terms of the Authorization. The Authorization in its entirety (not including the authorized versions of the fact sheets and other written materials) follows and provides an explanation of the reasons for its issuance, as required by section 564(h)(1) of the FD&C Act:

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[1] The Secretary of HHS has delegated the authority to issue an EUA under section 564 of the FD&C Act to the Commissioner of Food and Drugs.

[2] Under section 564(b)(1) of the FD&C Act, the HHS Secretary's declaration that supports EUA issuance must be based on one of four determinations, including the identification by the DHS Secretary of a material threat under section 319F–2 of the PHS Act sufficient to affect national security or the health and security of U.S. citizens living abroad (section 564(b)(1)(D) of the FD&C Act).

DEPARTMENT OF HEALTH & HUMAN SERVICES

Food and Drug Administration
Silver Spring, MD 20993

July 31, 2015

Tiffany Miller
Director, Regulatory Affairs
OraSure Technologies, Inc.
220 East First Street
Bethlehem, PA 18015

Dear Ms. Miller:

This letter is in response to your request that the Food and Drug Administration (FDA) issue an Emergency Use Authorization (EUA) for emergency use of the OraQuick® Ebola Rapid Antigen Test[1] for the presumptive detection of Ebola Zaire virus (detected in the West Africa outbreak in 2014)[2] in venipuncture whole blood or fingerstick whole blood specimens from individuals with signs and symptoms of Ebola virus infection in conjunction with epidemiological risk factors (including geographic locations with high prevalence of Ebola infection), by laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics), pursuant to section 564 of the Federal Food, Drug, and Cosmetic Act (the Act) (21 U.S.C. § 360bbb-3). The OraQuick® Ebola Rapid Antigen Test is intended for circumstances when the use of a rapid Ebola virus test is determined to be more appropriate than the use of an authorized Ebola virus nucleic acid test, which has been demonstrated to be more sensitive in detecting the Ebola Zaire virus. The OraQuick® Ebola Rapid Antigen Test is not intended for use for general Ebola virus infection screening, such as airport screening or contact tracing of individuals without signs and symptoms of Ebola infection.

On September 22, 2006, then-Secretary of the Department of Homeland Security (DHS), Michael Chertoff, determined, pursuant to section 319F-2 of the Public Health Service (PHS) Act (42 U.S.C. § 247d-6b), that the Ebola virus presents a material threat against the United States population sufficient to affect national security.[3] Pursuant to section 564(b)(1) of the Act (21 U.S.C. § 360bbb-3(b)(1)), and on the basis of such determination, the Secretary of the

[1] For purposes of this authorization, the term "OraQuick® Ebola Rapid Antigen Test" includes, in addition to the OraQuick® Ebola Rapid Antigen Test Kit, the OraQuick® Ebola Rapid Antigen Test Kit Controls (quality control reagents intended for use only with the OraQuick® Ebola Rapid Antigen Test) and the OraQuick® Ebola Visual Reference Panel (intended to assist new operators in becoming proficient at reading specimens with antigen levels near the limit of detection of the device). While the OraQuick® Ebola Rapid Antigen Test Kit Controls and OraQuick® Ebola Visual Reference Panel are both sold separately, under this authorization they must be used in conjunction with the OraQuick® Ebola Rapid Antigen Test Kit.

[2] This assay is intended for the qualitative detection of antigens from Zaire Ebola virus (detected in the West Africa outbreak in 2014), but may also detect antigens from Sudan Ebola virus and Bundibugyo Ebola virus; however, it does not distinguish between these different Ebola virus species.

[3] Pursuant to section 564(b)(1) of the Act (21 U.S.C. § 360bbb-3(b)(1)), the HHS Secretary's declaration that supports EUA issuance must be based on one of four determinations, including the identification by the DHS Secretary of a material threat pursuant to section 319F-2 of the PHS Act sufficient to affect national security or the health and security of United States citizens living abroad (section 564(b)(1)(D) of the Act).

Department of Health and Human Services (HHS) declared on August 5, 2014, that circumstances exist justifying the authorization of emergency use of *in vitro* diagnostics for detection of Ebola virus, subject to the terms of any authorization issued under section 564(a) of the Act (21 U.S.C. § 360bbb-3(a)).[4]

Having concluded that the criteria for issuance of this authorization under section 564(c) of the Act (21 U.S.C. § 360bbb-3(c)) are met, I am authorizing the emergency use of the OraQuick® Ebola Rapid Antigen Test (as described in the Scope of Authorization section of this letter (section II)) in individuals with signs and symptoms of Ebola virus infection in conjunction with epidemiological risk factors (including geographic locations with high prevalence of Ebola infection) (as described in the Scope of Authorization section of this letter (section II)) for the presumptive detection of Ebola Zaire virus (detected in the West Africa outbreak in 2014).

I. Criteria for Issuance of Authorization

I have concluded that the emergency use of the OraQuick® Ebola Rapid Antigen Test for the presumptive detection of Ebola Zaire virus (detected in the West Africa outbreak in 2014) in the specified population meets the criteria for issuance of an authorization under section 564(c) of the Act, because I have concluded that:

1. The Ebola Zaire virus (detected in the West Africa outbreak in 2014) can cause Ebola virus disease, a serious or life-threatening disease or condition to humans infected with this virus;

2. Based on the totality of scientific evidence available to FDA, it is reasonable to believe that the OraQuick® Ebola Rapid Antigen Test may be effective in diagnosing Ebola Zaire virus (detected in the West Africa outbreak in 2014) infection, and that the known and potential benefits of the OraQuick® Ebola Rapid Antigen Test for diagnosing Ebola Zaire virus (detected in the West Africa outbreak in 2014) infection, outweigh the known and potential risks of such product; and

3. There is no adequate, approved, and available alternative to the emergency use of the OraQuick® Ebola Rapid Antigen Test for diagnosing Ebola Zaire virus (detected in the West Africa outbreak in 2014) infection.[5]

II. Scope of Authorization

I have concluded, pursuant to section 564(d)(1) of the Act, that the scope of this authorization is limited to the use of the authorized OraQuick® Ebola Rapid Antigen Test by laboratories and facilities adequately equipped, trained, and capable of such testing (including treatment centers and public health clinics) for the presumptive detection of Ebola Zaire virus (detected in the

[4] U.S. Department of Health and Human Services. *Declaration Regarding Emergency Use of In Vitro Diagnostics for Detection of Ebola Virus.* 79 Fed. Reg. 47141 (August 12, 2014).

[5] No other criteria of issuance have been prescribed by regulation under section 564(c)(4) of the Act.

West Africa outbreak in 2014) in individuals with signs and symptoms of Ebola virus infection in conjunction with epidemiological risk factors (including geographic locations with high prevalence of Ebola infection). The authorized OraQuick® Ebola Rapid Antigen Test is intended for circumstances when use of a rapid Ebola virus test is determined to be more appropriate than use of an authorized Ebola virus nucleic acid test, which has been demonstrated to be more sensitive in detecting the Ebola Zaire virus. The authorized OraQuick® Ebola Rapid Antigen Test is not intended for use for general Ebola infection screening, such as airport screening or contact tracing of individuals without signs and symptoms of Ebola infection.

The Authorized OraQuick® Ebola Rapid Antigen Test

The OraQuick® Ebola Rapid Antigen Test is a rapid single-use chromatographic lateral flow immunoassay contained within a rigid plastic device housing that is intended for the *in vitro* qualitative detection of antigens from the Ebola Zaire virus (detected in the West Africa outbreak 2014) in venipuncture whole blood, fingerstick whole blood, and other authorized specimen types from individuals with signs and symptoms of Ebola virus infection in conjunction with epidemiological risk factors (including geographic locations with high prevalence of Ebola infection). The OraQuick® Ebola Rapid Antigen Test is a point-of-care test.

The OraQuick® Ebola Rapid Antigen Test utilizes a sandwich capture lateral flow immunoassay method to detect Ebola virus antigens. This lateral flow test is composed of an assay strip with several components: the flat pad, the blocker pad, the conjugate pad, the nitrocellulose membrane (with a Test Line ("T") and a Control ("C") line), and the absorbent pad. The clinical specimen is applied to the device followed by insertion of the device into the developer solution. The execution of the assay occurs as reagents are hydrated and liquid is transported along with the specimen across the strip towards the test zone.

If Ebola viral antigens are present in the patient sample they will be bound by biotinylated anti-Ebola polyclonal antibodies eluting from the blocker pad. These complexed Ebola antigens will then form immunological sandwiches with signal generating colloidal gold labeled Ebola antibodies that are eluting from the conjugate pad. The immunological sandwich complex is subsequently captured through reaction of the biotinylated anti-Ebola antibody with the biotin binding protein streptavidin that is immobilized at the Test Line ("T") of the test strip.

The OraQuick® Ebola Rapid Antigen Test Kit is comprised of an OraQuick® Ebola Rapid Antigen Test device, a filled, capped and labeled Developer Vial, a device stand (used to hold the device during the running of the test following specimen collection), micropipettes, a quick reference guide and the package insert. The test kit has a built-in procedural control that demonstrates assay validity. A purple line in the Control ("C") area of the Result Window indicates that the fluid migrated appropriately through the Test Device. The Control line will appear on all valid tests, whether or not the sample is positive (i.e., reactive) or negative (i.e., non-reactive).

The OraQuick® Ebola Rapid Antigen Test Kit Controls must be used with the OraQuick® Ebola Rapid Antigen Test. The OraQuick® Ebola Rapid Antigen Test Kit Controls contain two vials,

one Ebola positive control vial (orange capped) and one Ebola negative control vial (white capped).

The OraQuick® Ebola Visual Reference Panel is intended to assist new operators in becoming proficient at reading specimens with antigen levels near the limit of detection of the device. It consists of three devices that have been specifically formulated and manufactured to represent positive results near the limit of detection, low positive, and negative test results. New operators must be able to correctly interpret all devices of the OraQuick® Ebola Visual Reference Panel prior to using the OraQuick® Ebola Rapid Antigen Test device with patient samples.

The above described OraQuick® Ebola Rapid Antigen Test, when labeled consistently with the labeling authorized by FDA entitled "OraQuick® Ebola Rapid Antigen Test Instructions for Use" (available at http://www.fda.gov/MedicalDevices/Safety/EmergencySituations/ucm161496.htm), which may be revised by OraSure Technologies, Inc. in consultation with FDA, is authorized to be distributed to laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics), despite the fact that it does not meet certain requirements otherwise required by federal law.

The above described OraQuick® Ebola Rapid Antigen Test is authorized to be accompanied by the following information pertaining to the emergency use, which is authorized to be made available to health care professionals and patients:

- Fact Sheet for Health Care Providers: Interpreting OraQuick® Ebola Rapid Antigen Test Results
- Fact Sheet for Patients: Understanding Results from the OraQuick® Ebola Rapid Antigen Test

As described in section IV below, OraSure Technologies, Inc. and any authorized distributor(s) are also authorized to make available additional information relating to the emergency use of the authorized OraQuick® Ebola Rapid Antigen Test that is consistent with, and does not exceed, the terms of this letter of authorization.

I have concluded, pursuant to section 564(d)(2) of the Act, that it is reasonable to believe that the known and potential benefits of the authorized OraQuick® Ebola Rapid Antigen Test in the specified population, when used for presumptive detection of Ebola Zaire virus (detected in the West Africa outbreak in 2014), outweigh the known and potential risks of such a product.

I have concluded, pursuant to section 564(d)(3) of the Act, based on the totality of scientific evidence available to FDA, that it is reasonable to believe that the authorized OraQuick® Ebola Rapid Antigen Test may be effective in the diagnosis of Ebola Zaire virus (detected in the West Africa outbreak in 2014) infection pursuant to section 564(c)(2)(A) of the Act. FDA has reviewed the scientific information available to FDA including the information supporting the conclusions described in section I above, and concludes that the authorized OraQuick® Ebola Rapid Antigen Test, when used to diagnose Ebola Zaire virus (detected in the West Africa

outbreak in 2014) infection in the specified population, meets the criteria set forth in section 564(c) of the Act concerning safety and potential effectiveness.

The emergency use of the authorized OraQuick® Ebola Rapid Antigen Test under this EUA must be consistent with, and may not exceed, the terms of this letter, including the Scope of Authorization (section II) and the Conditions of Authorization (section IV). Subject to the terms of this EUA and under the circumstances set forth in the Secretary of DHS's determination described above and the Secretary of HHS's corresponding declaration under section 564(b)(1), the OraQuick® Ebola Rapid Antigen Test described above is authorized to diagnose Ebola Zaire virus (detected in the West Africa outbreak in 2014) infection in individuals with signs and symptoms of Ebola virus infection in conjunction with epidemiological risk factors (including geographic locations with high prevalence of Ebola infection).

This EUA will cease to be effective when the HHS declaration that circumstances exist to justify the EUA is terminated under section 564(b)(2) of the Act or when the EUA is revoked under section 564(g) of the Act.

III. Waiver of Certain Requirements

I am waiving the following requirements for the OraQuick® Ebola Rapid Antigen Test during the duration of this EUA:

- Current good manufacturing practice requirements, including the quality system requirements under 21 CFR Part 820 with respect to the design, manufacture, packaging, labeling, storage, and distribution of the OraQuick® Ebola Rapid Antigen Test.

- Labeling requirements for cleared, approved, or investigational devices, including labeling requirements under 21 CFR 809.10 and 21 CFR 809.30, except for the intended use statement (21 CFR 809.10(a)(2), (b)(2)), adequate directions for use (21 U.S.C. 352(f)), (21 CFR 809.10(b)(5), (7), and (8)), any appropriate limitations on the use of the device including information required under 21 CFR 809.10(a)(4), and any available information regarding performance of the device, including requirements under 21 CFR 809.10(b)(12).

IV. Conditions of Authorization

Pursuant to section 564 of the Act, I am establishing the following conditions on this authorization:

OraSure Technologies, Inc. and Any Authorized Distributor(s)

A. OraSure Technologies, Inc. and any authorized distributor(s) will distribute the authorized OraQuick® Ebola Rapid Antigen Test with the authorized labeling, as may be revised by OraSure Technologies, Inc. in consultation with FDA, to laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics).

B. OraSure Technologies, Inc. and any authorized distributor(s) will provide to laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics), the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Health Care Providers and the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Patients.

C. OraSure Technologies, Inc. and any authorized distributor(s) will make available on their websites the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Health Care Providers and the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Patients.

D. OraSure Technologies, Inc. and any authorized distributor(s) will inform laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) and relevant public health authority(ies) of this EUA, including the terms and conditions herein.

E. OraSure Technologies, Inc. and any authorized distributor(s) will ensure that first time users of the OraQuick® Ebola Rapid Antigen Test Kit will be informed about the requirement for use of the control material and the visual reference panel.

F. OraSure Technologies, Inc. and any authorized distributor(s) will ensure that laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) using the authorized OraQuick® Ebola Rapid Antigen Test have a process in place for reporting test results to health care professionals and relevant public health authorities, as appropriate.

G. Through a process of inventory control, OraSure Technologies, Inc. and any authorized distributor(s) will maintain records of device usage.

H. OraSure Technologies, Inc. and any authorized distributor(s) will collect information on the performance of the assay, and report to FDA any suspected occurrence of false positive or false negative results of which OraSure Technologies, Inc. and any authorized distributor(s) become aware.

I. OraSure Technologies, Inc. and any authorized distributor(s) are authorized to make available additional information relating to the emergency use of the authorized OraQuick® Ebola Rapid Antigen Test that is consistent with, and does not exceed, the terms of this letter of authorization.

OraSure Technologies, Inc.

J. OraSure Technologies, Inc. will notify FDA of any authorized distributor(s) of the OraQuick® Ebola Rapid Antigen Test, including the name, address, and phone number of any authorized distributor(s).

K. OraSure Technologies, Inc. will provide any authorized distributor(s) with a copy of this EUA, and communicate to any authorized distributor(s) any subsequent amendments that might be made to this EUA and its authorized accompanying materials (e.g., fact sheets, instructions for use).

L. OraSure Technologies, Inc. only may request changes to the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Health Care Providers or the authorized OraQuick® Ebola Rapid Antigen Test Fact Sheet for Patients. Such requests will be made only by OraSure Technologies, Inc. in consultation with FDA.

M. OraSure Technologies, Inc. may request the addition of other specimen types for use with the authorized OraQuick® Ebola Rapid Antigen Test. Such requests will be made by OraSure Technologies, Inc. in consultation with, and require concurrence of, FDA.

N. OraSure Technologies, Inc. will track adverse events and report to FDA under 21 CFR Part 803.

Laboratories and Facilities Adequately Equipped, Trained, and Capable of Testing for Ebola Infection (Including Treatment Centers and Public Health Clinics)

O. Laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) will include with reports of the results of the OraQuick® Ebola Rapid Antigen Test the authorized Fact Sheet for Health Care Providers and the authorized Fact Sheet for Patients. Under exigent circumstances, other appropriate methods for disseminating these Fact Sheets may be used, which may include mass media.

P. Laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) will have a process in place for reporting test results to health care professionals and relevant public health authorities, as appropriate.

Q. Laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) will collect information on the performance of the assay, and report to OraSure Technologies, Inc. and any authorized distributor(s) any suspected occurrence of false positive or false negative results of which they become aware.

R. All personnel from laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) using the assay will be appropriately trained on the OraQuick® Ebola Rapid Antigen Test and use appropriate laboratory and personal protective equipment when handling this kit.

OraSure Technologies, Inc., Any Authorized Distributor(s), and Laboratories and Facilities Adequately Equipped, Trained, and Capable of Testing for Ebola Infection (Including Treatment Centers and Public Health Clinics)

S. OraSure Technologies, Inc., any authorized distributor(s), and laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics) will ensure that any records associated with this EUA are maintained until notified by FDA. Such records will be made available to FDA for inspection upon request.

Conditions Related to Advertising and Promotion

T. All advertising and promotional descriptive printed matter relating to the use of the authorized OraQuick® Ebola Rapid Antigen Test shall be consistent with the Fact Sheets and authorized labeling, as well as the terms set forth in this EUA and the applicable requirements set forth in the Act and FDA regulations.

U. All advertising and promotional descriptive printed matter relating to the use of the authorized OraQuick® Ebola Rapid Antigen Test shall clearly and conspicuously state that:

- This test has not been FDA cleared or approved;
- This test has been authorized by FDA under an EUA for use by laboratories and facilities adequately equipped, trained, and capable of testing for Ebola infection (including treatment centers and public health clinics);
- This test has been authorized only for the detection of Ebola Zaire virus (detected in the West Africa outbreak in 2014); and
- This test is authorized only for the duration of the declaration that circumstances exist justifying the authorization of the emergency use of *in vitro* diagnostics for detection of Ebola virus under section 564(b)(1) of the Act, 21 U.S.C. § 360bbb-3(b)(1), unless the authorization is terminated or revoked sooner.

No advertising or promotional descriptive printed matter relating to the use of the authorized OraQuick® Ebola Rapid Antigen Test may represent or suggest that this test is safe or effective for the diagnosis of Ebola Zaire virus (detected in the West Africa outbreak in 2014).

The emergency use of the authorized OraQuick® Ebola Rapid Antigen Test described in this letter of authorization must comply with the conditions and all other terms of this authorization.

V. Duration of Authorization

This EUA will be effective until the declaration that circumstances exist justifying the authorization of the emergency use of *in vitro* diagnostics for detection of Ebola virus is terminated under section 564(b)(2) of the Act or the EUA is revoked under section 564(g) of the Act.

Sincerely,

Stephen M. Ostroff, M.D.
Acting Commissioner of Food and Drugs

Enclosures

Dated: September 8, 2015.

Leslie Kux,

Associate Commissioner for Policy.

[FR Doc. 2015–23003 Filed 9–11–15; 8:45 am]

BILLING CODE 4164–01–C

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Health Resources and Services Administration

Administration for Children and Families

Agency Information Collection Activities: Submission to OMB for Review and Approval; Public Comment Request

AGENCY: Health Resources and Services Administration, HHS. Administration for Children and Families, HHS.

ACTION: Notice.

SUMMARY: In compliance with Section 3507(a)(1)(D) of the Paperwork Reduction Act of 1995, the Health Resources and Services Administration (HRSA) and the Administration for Children and Families (ACF) has submitted an Information Collection Request (ICR) to the Office of Management and Budget (OMB) for review and approval. Comments submitted during the first public review of this ICR will be provided to OMB. OMB will accept further comments from the public during the review and approval period.

DATES: Comments on this ICR should be received no later than October 14, 2015.

ADDRESSES: Submit your comments, including the Information Collection Request Title, to the desk officer for HRSA, either by email to *OIRA_submission@omb.eop.gov* or by fax to 202–395–5806.

FOR FURTHER INFORMATION CONTACT: To request a copy of the clearance requests submitted to OMB for review, email the HRSA Information Collection Clearance Officer at *paperwork@hrsa.gov* or call (301) 594–4306.

SUPPLEMENTARY INFORMATION:

Information Collection Request Title: The Maternal, Infant, and Early Childhood Home Visiting Program Quarterly Data Request.

OMB No. 0906–xxxx—NEW.

Abstract: The Maternal, Infant, and Early Childhood Home Visiting Program (MIECHV), administered by HRSA in close partnership with the Administration for Children and Families (ACF), supports voluntary, evidence-based home visiting services during pregnancy and to parents with young children up to kindergarten entry. States, Territories, nonprofit organizations (in some circumstances), and Tribal entities are eligible to receive funding from the MIECHV Program and have the flexibility to tailor the program to serve the specific needs of the communities that they serve.

Need and Proposed Use of the Information: In order to continuously monitor and provide oversight, quality improvement guidance, and technical assistance to MIECHV grantees, HHS is seeking to collect two categories of information: Service Utilization Data and Corrective Action Benchmark Data. This information will be used to monitor and provide continued oversight for grantee performance and to target technical assistance resources to grantees.

Service Utilization Data is made up of four data categories:

(1) *Program Capacity:* HHS is seeking to collect information related to the overall home visiting service capacity (*i.e.,* number of families) that grantees are able to provide to the communities they work in, the actual capacity being utilized at certain points in time, as well as updates of home visiting enrollment in number of families.

(2) *Place-Based Services:* HHS is seeking to collect information to identify the geographic areas where home visiting services are being provided. Specifically, data on zip code and locally defined communities are being requested from MIECHV grantees in order to allow grantees an opportunity to provide data that identifies geographic areas that are most salient to their respective programs. Currently, HHS collects information related to service area zip code on an annual basis (OMB–0915–0357, expiration 7/31/2017). HHS plans to allow the grantee to describe the service community at the neighborhood, town, or city level where services are provided based on their judgment of local salience, rather than solely at the county level, which is how geographic services are currently reported.

(3) *Family Engagement:* Currently HHS collects information related to family engagement (attrition) on an annual basis (OMB–0915–0357, expiration 7/31/2017). However, HHS has learned through grants monitoring and technical assistance efforts that family engagement is an ongoing and complex issue for home visiting service providers. In order to monitor grantee performance and target technical assistance efforts most effectively, HHS proposes that, in addition to annual reporting, MIECHV grantees will report quarterly on the existing family engagement metrics they are currently required to submit to HHS. These metrics are currently defined as the number of participants currently receiving services who have completed the program, who stopped services before completion, and other participants.

(4) *Staff Recruitment and Retention:* HHS is seeking to collect information related to the number of home visitors and other support staff who are currently employed directly or through sub-contracted grant funds. Staff recruitment and retention is a key component to the successful delivery of home visiting services and to maximizing the number of cases each local implementing agency can reach. MIEHCV grantees will report quarterly on the actual number of staff and current vacancies in three categories: home visitors, home visiting supervisors, and other staff.

Corrective Action Benchmark Data (Improvement Action Benchmark Data): *Corrective Action Constructs consist of one category of data.* MIECHV grantees that have not shown improvement in four of six Benchmark areas identified in the authorizing legislation after 3 years of grant funding are required to complete corrective action plans (Improvement Action Technical Assistance Plans), subject to approval by the Secretary, in order to show how they plan to achieve improvement in deficient areas. Currently HHS collects information related to selected Benchmark areas from all MIECHV grantees on an annual basis (OMB–0915–0357, expiration 7/31/2017). In order to monitor grantee improvement toward meeting these Benchmarks, HHS is seeking to collect information from grantees on implementation of their Improvement Action Plans on a more frequent basis. HHS proposes that state, territory, and nonprofit organization grantees with Improvement Action Plans report the Benchmark measures for which they were deemed as not showing improvement on a quarterly basis. It is estimated that approximately 9 grantees per year will require this more frequent reporting. Tribal grantees that did not demonstrate improvement after 3 years will continue to develop program improvement plans as currently required.

Likely Respondents: MIECHV grantees.

Burden Statement: Burden in this context means the time expended by persons to generate, maintain, retain, disclose or provide the information requested. This includes the time needed to review instructions; to develop, acquire, install and utilize technology and systems for the purpose of collecting, validating and verifying information, processing and maintaining information, and disclosing and providing information; to train personnel and to be able to respond to

a collection of information; to search data sources; to complete and review the collection of information; and to transmit or otherwise disclose the information. The total annual burden hours estimated for this ICR are summarized in the table below.

TOTAL ESTIMATED ANNUALIZED BURDEN—HOURS

Form name	Number of respondents	Number of responses per respondent	Total responses	Average burden per response (in hours)	Total burden hours
Service Utilization Form—State, Territory, and Tribal MIECHV Grantees	[1] 125	4	500	24	12,000
Improvement Action Benchmark Form—State and Territory MIECHV Grantees	[2] 9	4	36	40	1,440
Total	125		536		13,440

[1] This figures includes two responses for jurisdictions which received both formula and competitive funding in FY 2015.
[2] Only includes MIECHV state, territory, and non-profit grantees that did not demonstrate improvement in 4 of 6 Benchmark areas after 3 years of grant funding.

Dated: September 2, 2015.

Jackie Painter,

Director, Division of the Executive Secretariat, Health Resources and Services Administration.

Robert Sargis,

Reports Clearance Officer, Administration for Children and Families.

[FR Doc. 2015–23033 Filed 9–11–15; 8:45 am]

BILLING CODE 4165–15–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Health Resources and Services Administration

Agency Information Collection Activities: Submission to OMB for Review and Approval; Public Comment Request

AGENCY: Health Resources and Services Administration, HHS.

ACTION: Notice.

SUMMARY: In compliance with Section 3507(a)(1)(D) of the Paperwork Reduction Act of 1995, the Health Resources and Services Administration (HRSA) has submitted an Information Collection Request (ICR) to the Office of Management and Budget (OMB) for review and approval. Comments submitted during the first public review of this ICR will be provided to OMB. OMB will accept further comments from the public during the review and approval period.

DATES: Comments on this ICR should be received no later than October 14, 2015.

ADDRESSES: Submit your comments, including the Information Collection Request Title, to the desk officer for HRSA, either by email to *OIRA_submission@omb.eop.gov* or by fax to 202–395–5806.

FOR FURTHER INFORMATION CONTACT: To request a copy of the clearance requests submitted to OMB for review, email the HRSA Information Collection Clearance Officer at *paperwork@hrsa.gov* or call (301) 594–4306.

SUPPLEMENTARY INFORMATION: Information Collection Request Title: Maternal, Infant, and Childhood Home Visiting (Home Visiting) Program for Non-Competing Continuation Progress Report OMB No. 0915–0356—Extension

A 30-day notice was previously published on July 22, 2015 for this information collection request but it contained incorrect burden figures.

Abstract: The Maternal, Infant, and Early Childhood Home Visiting (MIECHV) Program, administered by the Health Resources and Services Administration (HRSA) in close partnership with the Administration for Children and Families (ACF), supports voluntary, evidence-based home visiting services during pregnancy and to parents with young children up to kindergarten entry. Competitive grants support the efforts of eligible entities that have already made significant progress towards establishing a high quality home visiting program or embedding their home visiting program into a comprehensive, high-quality early childhood system. All fifty states, the District of Columbia, five territories, and nonprofit organizations that would provide services in jurisdictions that have not directly applied for or been approved for a grant are eligible for competitive grants and if awarded, are required to submit non-competing continuation progress reports annually. There are currently 48 entities with competitive grant awards. Some eligible entities have been awarded more than one competitive grant.

Need and Proposed Use of the Information: This information collection is needed for eligible entities to report progress under the Home Visiting Program annually. On March 23, 2010, the President signed into law the Patient Protection and Affordable Care Act (ACA). Section 2951 of the ACA amended Title V of the Social Security Act by adding a new section, 511, which authorized the creation of the Home Visiting Program (*http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h3590enr.txt.pdf*, pages 216–2250). A portion of funding under this program is awarded to participating states and eligible jurisdictions competitively. The purpose of the competitive funding is to provide additional support to entities that have already made significant progress towards establishing a high-quality home visiting program and also want to implement innovative home visiting strategies in their states and jurisdictions.

The information collected will be used to review grantee progress on proposed project plans sufficient to permit project officers to assess whether the project is performing adequately to achieve the goals and objectives that were previously approved. This report will also provide implementation plans for the upcoming year, which project officers can assess to determine whether the plan is consistent with the grant as approved, and will result in implementation of a high-quality project that will complement the home visiting program as a whole. Progress Reports are submitted to project officers through the Electronic HandBooks (EHB). Failure to collect this information would result in the inability of the project officers to exercise due diligence in monitoring and overseeing the use of grant funds in keeping with legislative, policy, and programmatic requirements.

Grantees are required to provide a performance narrative with the following sections: Project identifier information, accomplishments and barriers, state home visiting program goals and objectives, an update on the state home visiting innovative approach and evaluations conducted under the competitive grant, implementation of the program in targeted at-risk communities, progress toward meeting legislatively-mandated reporting on benchmark areas, state home visiting quality improvement efforts, and updates on the administration of state home visiting innovation program.

Since federal fiscal year 2011, 48 eligible entities have received competitive grant awards. Grantees of the competitive grant program need to complete annual reports in order to comply with HRSA reporting requirements.

Likely Respondents: Grantees with Home Visiting Competitive Expansion Grants Awarded in Federal Fiscal Years 2011–2015

Burden Statement: Burden in this context means the time expended by persons to generate, maintain, retain, disclose or provide the information requested. This includes the time needed to review instructions; to develop, acquire, install and utilize technology and systems for the purpose of collecting, validating and verifying information, processing and maintaining information, and disclosing and providing information; to train personnel and to be able to respond to a collection of information; to search data sources; to complete and review the collection of information; and to transmit or otherwise disclose the information. The total annual burden hours estimated for this ICR are summarized in the table below.

TOTAL ESTIMATED ANNUALIZED BURDEN—HOURS

Summary progress on the following activities	Number of respondents	Number of responses per respondent	Total responses	Hours per response	Total burden hours
Home Visiting Competitive Grant Progress Report—FY 2012, FY 2013, FY 2014	37	1	37	25	925
Home Visiting Competitive Grant Progress Report—FY 2015	35	1	35	20	700
Home Visiting Competitive Grant Progress Report—FY 2016	56	1	56	20	1,120
Home Visiting Competitive Grant Progress Report—FY 2017	56	1	56	20	1,120
Total	184	4	184		3,865

Jackie Painter,

Director, Division of the Executive Secretariat.

[FR Doc. 2015–22999 Filed 9–11–15; 8:45 am]

BILLING CODE 4165–15–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Office of the Secretary

[Document Identifier: HHS–OS–0937–0166–30D]

Agency Information Collection Activities; Submission to OMB for Review and Approval; Public Comment Request

AGENCY: Office of the Secretary, HHS.

ACTION: Notice.

SUMMARY: In compliance with section 3507(a)(1)(D) of the Paperwork Reduction Act of 1995, the Office of the Secretary (OS), Department of Health and Human Services, has submitted an Information Collection Request (ICR), described below, to the Office of Management and Budget (OMB) for review and approval. The ICR is for renewal of the approved information collection assigned OMB control number 0937–0166, scheduled to expire on October 31, 2015. Comments submitted during the first public review of this ICR will be provided to OMB. OMB will accept further comments from the public on this ICR during the review and approval period.

DATES: Comments on the ICR must be received on or before October 14, 2015.

ADDRESSES: Submit your comments to *OIRA_submission@omb.eop.gov* or via facsimile to (202) 395–5806.

FOR FURTHER INFORMATION CONTACT: Information Collection Clearance staff, *Information.CollectionClearance@hhs.gov* or (202) 690–6162.

SUPPLEMENTARY INFORMATION: When submitting comments or requesting information, please include the OMB control number 0937–0166 and document identifier.

Information Collection Request Title: HHS 42 CFR part 50, subpart B; Sterilization of Persons in Federally Assisted Family Planning Projects—OMB No. 0937–0166–Extension–OASH, Office of Population Affairs—Office of Family Planning.

Abstract: This is a request for extension of a currently approved collection for the disclosure and record-keeping requirements codified at 42 CFR part 50, subpart B ("Sterilization of Persons in Federally Assisted Family Planning Projects"). The consent form solicits information to assure voluntary and informed consent to persons undergoing sterilization in programs of health services which are supported by federal financial assistance administered by the Public Health Service (PHS). Consent forms are signed by individuals undergoing a federally funded sterilization procedure and certified by necessary medical authorities. Forms are incorporated into the patient's medical records and the agency's records. Through periodic site audits and visits, PHS staff review completed consent forms to determine compliance with the regulation. Thus, the purpose of the consent form is twofold. First, it serves as a mechanism to ensure that a person receives information about sterilization and voluntarily consents to the procedure. Second, it facilitates compliance monitoring. The Sterilization Consent Form has been revised to reflect a new expiration date on the Required Consent Form. There are no other revisions to the form.

Likely Respondents: Interested persons who desire to send comments regarding this burden estimate or any other aspect of this collection of information that OS specifically requests comments.

TOTAL ESTIMATED ANNUALIZED BURDEN—HOURS

Type of respondent	Information collection	Number of respondents	Number of responses per respondent	Average burden per response	Total hours
Citizens Seeking Sterilization	Information Disclosure for *Sterilization Consent Form.*	100,000	1	1	100,000
Citizens Seeking Sterilization	Record-keeping for *Sterilization Consent Form.*	100,000	1	15/60	25,000
Total					125,000

Darius Taylor,

Information Collection Clearance Officer.

[FR Doc. 2015–23024 Filed 9–11–15; 8:45 am]

BILLING CODE 4150–34–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Center for Scientific Review Notice of Closed Meetings

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meetings.

The meetings will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), Title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable material, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: Center for Scientific Review Special Emphasis Panel; Psychosocial Risk and Disease Prevention.

Date: October 5, 2015.

Time: 2:00 p.m. to 2:30 p.m.

Agenda: To review and evaluate grant applications.

Place: Embassy Suites at the Chevy Chase Pavilion, 4300 Military Road NW., Washington, DC 20015.

Contact Person: John H. Newman, Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3222, MSC 7808, Bethesda, MD 20892, (301) 435–0628, *newmanjh@csr.nih.gov.*

Name of Committee: Interdisciplinary Molecular Sciences and Training Integrated Review Group; Enabling Bioanalytical and Imaging Technologies Study Section; Enabling Bioanalytical and Imaging Technologies.

Date: October 8–9, 2015.

Time: 8:00 a.m. to 8:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Bethesda North Marriott Hotel & Conference Center, 5701 Marinelli Road, Bethesda, MD 20852.

Contact Person: Kenneth Ryan, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3218, MSC 7717, Bethesda, MD 20892, 301–435–0229, *kenneth.ryan@nih.hhs.gov.*

Name of Committee: Oncology 1—Basic Translational Integrated Review Group; Cancer Etiology Study Section.

Date: October 8–9, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Marriott Courtyard Gaithersburg Washingtonian Ctr, 204 Boardwalk Place, Gaithersburg, MD 20878.

Contact Person: Svetlana Kotliarova, Ph.D., Scientific Review Officer, Center For Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6214, Bethesda, MD 20892, 301–594–7945, *kotliars@mail.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel; Musculoskeletal, Oral and Skin Sciences AREA review.

Date: October 14, 2015.

Time: 9:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, 6701 Rockledge Drive, Bethesda, MD 20892, (Virtual Meeting).

Contact Person: Yanming Bi, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 4214, MSC 7814, Bethesda, MD 20892, 301–451–0996, *ybi@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel; Risk, Prevention and Health Behavior AREA Review.

Date: October 14, 2015.

Time: 2:00 p.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, 6701 Rockledge Drive, Bethesda, MD 20892, (Virtual Meeting).

Contact Person: John H. Newman, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3222, MSC 7808, Bethesda, MD 20892, (301) 435–0628, *newmanjh@csr.nih.gov.*

Name of Committee: Oncology 2—Translational Clinical Integrated Review Group; Developmental Therapeutics Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Hotel Monaco Alexandria, 480 King Street, Alexandria, VA 22314.

Contact Person: Sharon K. Gubanich, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6214, MSC 7804, Bethesda, MD 20892, (301) 408–9512, *gubanics@csr.nih.gov.*

Name of Committee: Digestive, Kidney and Urological Systems Integrated Review Group; Hepatobiliary Pathophysiology Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Mayflower Park Hotel, 405 Olive Way, Seattle, WA 98101.

Contact Person: Jonathan K. Ivins, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 2190, MSC 7850, Bethesda, MD 20892, (301) 594–1245, *ivinsj@csr.nih.gov.*

Name of Committee: Brain Disorders and Clinical Neuroscience Integrated Review Group; Aging Systems and Geriatrics Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Embassy Suites at the Chevy Chase Pavilion, 4300 Military Road NW., Washington, DC 20015,

Contact Person: Inese Z. Beitins, MD, Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6152, MSC 7892, Bethesda, MD 20892, 301–435–1034, *beitinsi@csr.nih.gov.*

Name of Committee: Healthcare Delivery and Methodologies Integrated Review Group; Community-Level Health Promotion Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Embassy Row Hotel, 2015 Massachusetts Ave. NW., Washington, DC 20036.

Contact Person: Ping Wu, Ph.D., Scientific Review Officer, HDM IRG, Center for Scientific Review, National Institutes of

Health, 6701 Rockledge Drive, Room 3166, Bethesda, MD 20892, 301–451–8428, *wup4@csr.nih.gov.*

Name of Committee: Musculoskeletal, Oral and Skin Sciences Integrated Review Group; Musculoskeletal Rehabilitation Sciences Study Section.

Date: October 19, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Westin BWI (Baltimore), 1100 Old Elkridge Landing Road, Baltimore, MD 21090.

Contact Person: Maria Nurminskaya, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, Bethesda, MD 20892, (301) 435–1222,*nurminskayam@csr.nih.gov.*

Name of Committee: Healthcare Delivery and Methodologies Integrated Review Group; Community Influences on Health Behavior Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Embassy Suites at the Chevy Chase Pavilion, 4300 Military Road NW., Washington, DC 20015.

Contact Person: Wenchi Liang, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3150, MSC 7770, Bethesda, MD 20892, 301–435–0681, *liangw3@csr.nih.gov.*

Name of Committee: Biological Chemistry and Macromolecular Biophysics Integrated Review Group; Synthetic and Biological Chemistry B Study Section.

Date: October 19–20, 2015.

Time: 8:30 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Renaissance Washington DC, Dupont Circle, 1143 New Hampshire Avenue NW., Washington, DC 20037.

Contact Person: Kathryn M. Koeller, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 4166, MSC 7806, Bethesda, MD 20892, 301–435–2681, *koellerk@csr.nih.gov.*

Name of Committee: Genes, Genomes, and Genetics Integrated Review Group; Molecular Genetics A Study Section.

Date: October 19–20, 2015.

Time: 8:30 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Renaissance M Street Hotel, 1143 New Hampshire Avenue NW., Washington, DC 20037.

Contact Person: Michael M. Sveda, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 1114, MSC 7890, Bethesda, MD 20892, 301–435–3565, *svedam@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel; Shared Instrumentation: Flow Cytometry.

Date: October 19, 2015.

Time: 11:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, 6701 Rockledge Drive, Bethesda, MD 20892, (Virtual Meeting).

Contact Person: Savvas Makrides, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive Room 2200, Bethesda, MD 20892, 301–435–2514, *makridessc@mail.nih.gov.*

Name of Committee: Biological Chemistry and Macromolecular Biophysics Integrated Review Group; Macromolecular Structure and Function A Study Section.

Date: October 20–21, 2015.

Time: 8:00 a.m. to 7:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Marriott Wardman Park Washington DC Hotel, 2660 Woodley Road NW., Washington, DC 20008.

Contact Person: Nitsa Rosenzweig, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 4152, MSC 7760, Bethesda, MD 20892, (301) 404–7419, *rosenzweign@csr.nih.gov.*

Name of Committee: Bioengineering Sciences & Technologies Integrated Review Group; Gene and Drug Delivery Systems Study Section.

Date: October 21–22, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Serrano Hotel, 405 Taylor Street, San Francisco, CA 94102.

Contact Person: Amy L. Rubinstein, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 5152, MSC 7844, Bethesda, MD 20892, 301–408–9754, *rubinsteinal@csr.nih.gov.*

Name of Committee: Genes, Genomes, and Genetics Integrated Review Group; Genomics, Computational Biology and Technology Study Section.

Date: October 21–22, 2015.

Time: 8:30 a.m. to 3:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Doubletree Hotel Washington, 1515 Rhode Island Ave NW., Washington, DC 20005.

Contact Person: Barbara J. Thomas, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 2218, MSC 7890, Bethesda, MD 20892, 301–435–0603, *bthomas@csr.nih.gov.*

(Catalogue of Federal Domestic Assistance Program Nos. 93.306, Comparative Medicine; 93.333, Clinical Research, 93.306, 93.333, 93.337, 93.393–93.396, 93.837–93.844, 93.846–93.878, 93.892, 93.893, National Institutes of Health, HHS)

Dated: September 8, 2015.

Michelle Trout,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–22986 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

National Institute of Allergy and Infectious Diseases; Notice of Closed Meetings

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meetings.

The meetings will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable material, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: National Institute of Allergy and Infectious Diseases Special Emphasis Panel; NIAID Investigator Initiated Project Applications (P01).

Date: September 29, 2015.

Time: 10:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, Conference Room 4H100, 5601 Fishers Lane, Rockville, MD 20892, (Telephone Conference Call).

Contact Person: Jay R. Radke, Ph.D., Scientific Review Officer, Scientific Review Program, Division of Extramural Activities, Room #3G11B, National Institutes of Health, NIAID, 5601 Fishers Lane MSC–9823, Bethesda, MD 20892–9823, (240) 669–5046, *jay.radke@nih.gov.*

Name of Committee: National Institute of Allergy and Infectious Diseases Special Emphasis Panel; NIAID Investigator Initiated Program Project Applications (P01).

Date: October 8, 2015.

Time: 10:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, Conference Room 5F100, 5601 Fishers Lane, Rockville, MD 20892, (Telephone Conference Call).

Contact Person: Jay R. Radke, Ph.D., Scientific Review Officer, Scientific Review Program, Division of Extramural Activities, Room #3G11B, National Institutes of Health, NIAID, 5601 Fishers Lane MSC–9823, Bethesda, MD 20892–9823, (240) 669–5046, *jay.radke@nih.gov.*

(Catalogue of Federal Domestic Assistance Program Nos. 93.855, Allergy, Immunology, and Transplantation Research; 93.856, Microbiology and Infectious Diseases Research, National Institutes of Health, HHS)

Dated: September 9, 2015.

David Clary,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–23042 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

National Institute on Minority Health and Health Disparities; Notice of Closed Meeting

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meeting.

The meeting will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable materials, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: National Institute on Minority Health and Health Disparities Special Emphasis Panel; Technologies/Innovations for Improving Population Health and Eliminating Health Disparities (R41/R42, R43/R44).

Date: October 20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Bethesda Marriott Suites, 6711 Democracy Boulevard, Bethesda, MD 20817.

Contact Person: Xinli Nan, MD, Ph.D., Scientific Review Officer, National Institute on Minority Health and Health Disparities, National Institutes of Health, Scientific Review Branch, OERA, 6707 Democracy Blvd., Suite 800, Bethesda, MD 20892, (301) 594–7784, *Xinli.nan@nih.gov.*

Dated: September 9, 2015.

David Clary,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–23043 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Center for Scientific Review; Notice of Closed Meeting

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meeting.

The meeting will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), Title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable material, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: Center for Scientific Review Special Emphasis Panel—Cancer Therapeutics.

Date: September 22, 2015.

Time: 1:00 p.m. to 3:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, 6701 Rockledge Drive, Bethesda, MD 20892 (Telephone Conference Call).

Contact Person: Careen K Tang-Toth, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6214, MSC 7804, Bethesda, MD 20892, (301) 435–3504, *tothct@csr.nih.gov.*

This notice is being published less than 15 days prior to the meeting due to the timing limitations imposed by the review and funding cycle.

(Catalogue of Federal Domestic Assistance Program Nos. 93.306, Comparative Medicine; 93.333, Clinical Research, 93.306, 93.333, 93.337, 93.39–93.396, 93.837–93.844, 93.846–93.878, 93.892, 93.893, National Institutes of Health, HHS)

Dated: September 8, 2015.

Michelle Trout,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–22985 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Submission for OMB Review; 30-Day Comment Request: Population Sciences Biospecimen Catalog (PSBC)

SUMMARY: Under the provisions of Section 3507(a)(1)(D) of the Paperwork Reduction Act of 1995, the National Cancer Institute, the National Institutes of Health, has submitted to the Office of Management and Budget (OMB) a request for review and approval of the information collection listed below. This proposed information collection was previously published in the **Federal Register** on (June 30, 2015 P.37280) and allowed 60-days for public comment. No public comments were received. The purpose of this notice is to allow an additional 30 days for public comment. The National Cancer Institute (NCI), National Institutes of Health, may not conduct or sponsor, and the respondent is not required to respond to, an information collection that has been extended, revised, or implemented on or after October 1, 1995, unless it displays a currently valid OMB control number.

Direct Comments to OMB: Written comments and/or suggestions regarding the item(s) contained in this notice, especially regarding the estimated public burden and associated response time, should be directed to the: Office of Management and Budget, Office of Regulatory Affairs, *OIRA_submission@omb.eop.gov* or by fax to 202–395–6974, Attention: NIH Desk Officer.

Comment Due Date: Comments regarding this information collection are best assured of having their full effect if received within 30 days of the date of this publication.

FOR FURTHER INFORMATION CONTACT: To obtain a copy of the data collection plans and instruments, or request more information on the proposed project, contact: Danielle Carrick, Program Director, Division of Cancer Control and Population Sciences (DCCPS), National Cancer Institute, 9609 Medical Center Dr., Room 4E224, Rockville, MD 20850 or call non-toll-free number (240) 276–6749 or Email your request, including your address to: *Danielle.Carrick@nih.gov.* Formal requests for additional plans and instruments must be requested in writing.

Proposed Collection: Population Sciences Biospecimen Catalog (PSBC) (NCI), 0925—NEW, National Cancer Institute(NCI), National Institutes of Health (NIH).

Need and Use of Information Collection: This is a request for approval of a new collection. The National Cancer Institute (NCI) Division of Cancer Control and Population Sciences (DCCPS) has previously demonstrated that approximately 60% of population based studies funded by the division use existing biospecimens from other collections, and that those studies are more cost and time efficient than studies collecting new specimens. Yet, it is difficult for researchers to identify potentially appropriate sources for biospecimens and accompanying epidemiologic and exposure data. Development of a searchable inventory of population-based biospecimen resources was a major recommendation resulting from an NCI think tank held in August 2013 ("Utilizing Existing Clinical and Population Biospecimen Resources for Discovery or Validation of

Markers for Early Cancer Detection") and would also be directly addressing four of the key recommendations that emerged in an NCI sponsored workshop titled "Trends in 21st Century Epidemiology: From Scientific Discoveries to Population Health" (CEBP, 2013, issue 22, page 508). In response to this, NCI DCCPS is developing a biospecimen inventory and online searchable catalog (or "Population Sciences Biospecimen Catalog (PSBC)"). The PSBC allows scientists in the research community and the NCI to locate specimens appropriate for their population based research projects. It is not NCI's intent to collect biospecimens; rather the collections are descriptions of the available data that can act as a resource and be shared with researchers and scientists who are interested. This submission is via data upload to the secure Web site in order to collect information to manage and improve a program and its resources for the use by all scientists.

OMB approval is requested for 3 years. There are no costs to respondents other than their time. The total estimated annualized burden hours are 80.

ESTIMATED ANNUALIZED BURDEN HOURS

Form name	Type of respondent	Number of respondents	Number of responses per respondent	Average time per response (in hours)	Total annual burden hour
Population Sciences Biospecimen Catalog Initial Request.	Private Sector	30	1	1	30
	State Government	30	1	1	30
Population Sciences Biospecimen Catalog Annual Update.	Private Sector	30	1	20/60	10
	State Government	30	1	20/60	10

Dated: September 1, 2015.

Karla Bailey,

NCI Project Clearance Liaison, National Cancer Institute, NIH.

[FR Doc. 2015–23027 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Submission for OMB Review; 30-Day Comment Request; Characterization of Risk of HIV and HIV Outcomes in the Brazilian Sickle Cell Disease (SCD) Population and Comparison of SCD Outcomes Between HIV Sero-Positive and Negative SCD (NHLBI)

SUMMARY: Under the provisions of Section 3507(a)(1)(D) of the Paperwork Reduction Act of 1995, the National Heart, Lung, and Blood Institute (NHLBI), the National Institutes of Health (NIH) has submitted to the Office of Management and Budget (OMB) a request for review and approval of the information collection listed below. This proposed information collection was previously published in the **Federal Register** on June 8, 2015 (80 FR 32388) and allowed 60-days for public comment. No public comments were received. The purpose of this notice is to allow an additional 30 days for public comment. The National Institutes of Health may not conduct or sponsor, and the respondent is not required to respond to, an information collection that has been extended, revised, or implemented on or after October 1, 1995, unless it displays a currently valid OMB control number.

Direct Comments to OMB: Written comments and/or suggestions regarding the item(s) contained in this notice, especially regarding the estimated public burden and associated response time, should be directed to the: Office of Management and Budget, Office of Regulatory Affairs, *OIRA_submission@omb.eop.gov* or by fax to 202–395–6974, Attention: Desk Officer for NIH.

DATES: *Comments Due Date:* Comments regarding this information collection are best assured of having their full effect if received within 30 days of the date of this publication.

FOR FURTHER INFORMATION CONTACT: To obtain a copy of the data collection plans and instruments or request more information on the proposed project contact: Simone Glynn, MD, Project Officer/ICD Contact, Two Rockledge Center, Suite 9142, 6701 Rockledge Drive, Bethesda, MD 20892, or call 301–435–0065, or Email your request, including your address to: *glynnsa@nhlbi.nih.gov.* Formal requests for additional plans and instruments must be requested in writing.

Proposed Collection: Characterization of risk of HIV and HIV outcomes in the Brazilian Sickle Cell Disease (SCD) population and comparison of SCD outcomes between HIV sero-positive and negative SCD patients 0925–NEW, National Heart, Lung, and Blood Institute (NHLBI), the National Institutes of Health (NIH).

Need and Use of Information Collection: The National Heart, Lung, and Blood Institute (NHLBI) Recipient Epidemiology and Donor Evaluation Study-III (REDS–III) program conducts research focused on the safety of the blood supply, the patients who are in need of transfusions, and the epidemiology of transfusion-transmissible infections such as human immunodeficiency virus (HIV). Sickle cell disease (SCD) is a blood disorder that affects thousands of people in the United States and Brazil. Many patients with SCD need to be chronically transfused with red blood cells and the REDS–III research program has established in Brazil a cohort of patients with SCD to study transfusion outcomes and infectious diseases such as HIV in the SCD population.

Sickle cell disease predominantly affects persons with sub-Saharan Africa and other malaria-endemic regions ancestry because people who carry one sickle cell disease gene (you need 2 to have sickle cell disease) have a survival advantage for malaria. Sub-Saharan Africa, where most people with SCD in the world live, remains one of the regions most severely affected by HIV, with nearly 1 in every 20 adults living with the virus. In the United States, HIV also disproportionately affects persons with African ancestry. Despite the diseases' occurrence in similar populations and the fact that both HIV and SCD are independent predictors of outcomes such as stroke, there is a lack of data to evaluate if patients with SCD and HIV have different illnesses than patients who have SCD- or HIV-only. The proposed study will seek to understand the risk of HIV in the SCD population, describe HIV outcomes in patients with SCD and compare SCD complications between HIV-positive

and HIV-negative patients with SCD using the infrastructure established by the REDS–III SCD Cohort study.

The limited studies focused on HIV in SCD have suggested that HIV may not occur as frequently in patients with SCD as in people who do not have SCD. While it has been hypothesized that perhaps SCD pathophysiology has a unique effect on HIV infection or replication, none of the studies have adequately measured risk factors for HIV in patients with SCD. The first objective of the proposed study is to compare HIV risk factors between 150 patients with SCD (cases) randomly selected from the REDS–III SCD Cohort study and 150 individuals without SCD (controls) from a demographically similar population. An assessment that has been well validated in previous studies has been modified for the SCD population and will be used to collect data regarding HIV risk behaviors. The second objective of the proposed study will seek to enroll approximately 25 patients with SCD and HIV who consent to have detailed information regarding their diseases retrieved from their medical records. This will allow for an in-depth evaluation of how patients with both diseases fare. Additionally, patients who have SCD but not HIV will be compared to patients who have both diseases to better understand how one disease affects the other disease. Information on the HIV-negative patients with SCD has already been collected because they participated in the REDS–III SCD Cohort study. This study will provide critical information to guide the management and future research for patients with HIV and SCD in Brazil, the United States, and worldwide.

OMB approval is requested for 3 years. There are no costs to respondents other than their time. The total estimated annualized burden hours are 325.

Form name	Type of respondents	Number of respondents	Number of responses per respondent	Average burden per response (in hours)	Total annual burden hours
Objective 1, Risk Factor Informed Consents.	Adult SCD cases and controls	300	1	15/60	75
Objective 2, Risk Factor Informed Consent.	Adult previously enrolled REDS–II and III HIV SCD patients.	25	1	15/60	6
Objectives 1 and 2, Risk Factor Assessment.	Adult SCD cases and controls, and Adult previously enrolled REDS–II and III HIV SCD patients.	325	1	45/60	244

Dated: September 8, 2015.

Valery Gheen,

NHLBI Project Clearance Liaison, National Institutes of Health.

[FR Doc. 2015–22975 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Center For Scientific Review; Notice of Closed Meetings

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meetings.

The meetings will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), Title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable material, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: Population Sciences and Epidemiology Integrated Review Group, Behavioral Genetics and Epidemiology Study Section.

Date: October 5, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Marriott Wardman Park Washington DC Hotel, 2600 Woodley Road NW., Washington, DC 20008.

Contact Person: George Vogler, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3140, MSC 7770, Bethesda, MD 20892, (301) 237–2693, *voglergp@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel, PAR14–165: Clinical Studies of Mental Illness Not Involving Treatment, Development, Efficacy, or Effectiveness Trials (Collaborative R01).

Date: October 5, 2015.

Time: 8:30 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Marriott Wardman Park Washington DC Hotel, 2600 Woodley Road NW., Washington, DC 20008.

Contact Person: George Vogler, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3140, MSC 7770, Bethesda, MD 20892, (301) 237–2693, *voglergp@csr.nih.gov.*

Name of Committee: Oncology 2—Translational Clinical Integrated Review Group, Basic Mechanisms of Cancer Therapeutics Study Section.

Date: October 8–9, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Renaissance New Orleans Pere Marquette Hotel, 817 Common Street, New Orleans, LA.

Contact Person: Lambratu Rahman Sesay, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6214, MSC 7804, Bethesda, MD 20892, 301–451–3493, *rahman-sesayl@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel, PAR Panel: Mouse Models for Translational Research.

Date: October 9, 2015.

Time: 12:00 p.m. to 5:30 p.m..

Agenda: To review and evaluate grant applications.

Place: Renaissance Pere Marquette Hotel, New Orleans, 817 Common Street, New Orleans, LA 70112.

Contact Person: Lambratu Rahman Sesay, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6214, MSC 7804, Bethesda, MD 20892, 301–451–3493, *rahmanl@csr.nih.gov.*

Name of Committee: Cell Biology Integrated Review Group, Intercellular Interactions Study Section.

Date: October 13–14, 2015.

Time: 8:00 a.m. to 2:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Residence Inn Bethesda, 7335 Wisconsin Avenue, Bethesda, MD 20814.

Contact Person: Wallace Ip, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 5128, MSC 7840, Bethesda, MD 20892, 301–435–1191, *ipws@mail.nih.gov.*

Name of Committee: Immunology Integrated Review Group, Cellular and Molecular Immunology—B Study Section.

Date: October 15–16, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Sheraton Hotel—Silver Spring, 8777 Georgia Avenue, Silver Spring, MD 20910.

Contact Person: Betty Hayden, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 4206, MSC 7812, Bethesda, MD 20892, 301–435–1223, *haydenb@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel, Fellowships: Sensory and Motor Neurosciences, Cognition and Perception.

Date: October 15–16, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Embassy Suites Alexandria—Old Town, 1900 Diagonal Road, Alexandria, VA 22314.

Contact Person: Sharon S. Low, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 5104, MSC 7846, Bethesda, MD 20892, 301–237–1487, *lowss@csr.nih.gov.*

Name of Committee: Vascular and Hematology Integrated Review Group, Hemostasis and Thrombosis Study Section.

Date: October 15, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Warwick Seattle Hotel, 401 Lenora Street, Seattle, WA 98121.

Contact Person: Bukhtiar H. Shah, Ph.D., DVM, Scientific Review Officer, Vascular and Hematology IRG, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 4120, MSC 7802, Bethesda, MD 20892, (301) 806–7314, *shahb@csr.nih.gov.*

Name of Committee: Cell Biology Integrated Review Group, Biology of the Visual System Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Residence Inn Bethesda, 7335 Wisconsin Avenue, Bethesda, MD 20814.

Contact Person: Michael H. Chaitin, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 5202, MSC 7850, Bethesda, MD 20892, (301) 435–0910, *chaitinm@csr.nih.gov.*

Name of Committee: Oncology 2—Translational Clinical Integrated Review Group, Cancer Immunopathology and Immunotherapy Study Section.

Date: October 19–20, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Crown Plaza Dallas Downtown, 1015 Elm Street, Dallas, TX 75202.

Contact Person: Denise R Shaw, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 6158, MSC 7804, Bethesda, MD 20892, 301–435–0198, *shawdeni@csr.nih.gov.*

Name of Committee: Infectious Diseases and Microbiology Integrated Review Group, Host Interactions with Bacterial Pathogens Study Section.

Date: October 20, 2015.

Time: 8:00 a.m. to 6:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Marriott Wardman Park Washington DC Hotel, 2660 Woodley Road, NW., Washington, DC 20008.

Contact Person: Fouad A El-Zaatari, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 3186, MSC 7808, Bethesda, MD 20892, (301) 435–1149, *elzaataf@csr.nih.gov.*

Name of Committee: Digestive, Kidney and Urological Systems Integrated Review Group, Systemic Injury by Environmental Exposure.

Date: October 21–22, 2015.

Time: 8:00 a.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: Handlery Union Square Hotel, 351 Geary Street, San Francisco, CA 94102.

Contact Person: Patricia Greenwel, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 2178, MSC 7818, Bethesda, MD 20892, 301–435–1169, *greenwep@csr.nih.gov.*

Name of Committee: Center for Scientific Review Special Emphasis Panel, PAR13–325: Development of Appropriate Pediatric Formulations and Pediatric Drug Delivery Systems.

Date: October 21, 2015.

Time: 9:00 a.m. to 4:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, 6701 Rockledge Drive, Bethesda, MD 20892, (Virtual Meeting).

Contact Person: Kristin Kramer, Ph.D., Scientific Review Officer, Center for Scientific Review, National Institutes of Health, 6701 Rockledge Drive, Room 5205, MSC 7846, Bethesda, MD 20892, (301) 437–0911, *kramerkm@csr.nih.gov.*

(Catalogue of Federal Domestic Assistance Program Nos. 93.306, Comparative Medicine; 93.333, Clinical Research, 93.306, 93.333, 93.337, 93.393–93.396, 93.837–93.844, 93.846–93.878, 93.892, 93.893, National Institutes of Health, HHS)

Dated: September 9, 2015.

David Clary,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–23041 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

National Institute of General Medical Sciences; Notice of Closed Meeting

Pursuant to section 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. App.), notice is hereby given of the following meeting.

The meeting will be closed to the public in accordance with the provisions set forth in sections 552b(c)(4) and 552b(c)(6), Title 5 U.S.C., as amended. The grant applications and the discussions could disclose confidential trade secrets or commercial property such as patentable material, and personal information concerning individuals associated with the grant applications, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

Name of Committee: National Institute of General Medical Sciences Special Emphasis Panel; Support of NIGMS Program Project Grants.

Date: October 13, 2015.

Time: 1:00 p.m. to 5:00 p.m.

Agenda: To review and evaluate grant applications.

Place: National Institutes of Health, Natcher Building, 45 Center Drive, Room 3An.12N, Bethesda, MD 20892 (Telephone Conference Call).

Contact Person: Margaret J. Weidman, Ph.D., Scientific Review Officer, Office of Scientific Review, National Institute of General Medical Sciences, National Institutes of Health, 45 Center Drive, Room 3An.12N, Bethesda, MD 20892, 301–594–2048, *weidmanma@nigms.nih.gov.*

(Catalogue of Federal Domestic Assistance Program Nos. 93.375, Minority Biomedical Research Support; 93.821, Cell Biology and Biophysics Research; 93.859, Pharmacology, Physiology, and Biological Chemistry Research; 93.862, Genetics and Developmental Biology Research; 93.88, Minority Access to Research Careers; 93.96, Special Minority Initiatives, National Institutes of Health, HHS)

Dated: September 9, 2015.

Melanie J. Gray,

Program Analyst, Office of Federal Advisory Committee Policy.

[FR Doc. 2015–23026 Filed 9–11–15; 8:45 am]

BILLING CODE 4140–01–P

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

[FWS–R3–EC–2015–N157; FVHC98120300940–XXX–FF03E16000]

Draft Restoration Plan and Programmatic Environmental Impact Statement for Restoration Resulting From the Kalamazoo River Natural Resource Damage Assessment

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of availability; request for comments.

SUMMARY: The U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), the Michigan Department of

Environmental Quality, the Michigan Department of Natural Resources, and the Michigan Attorney General, collectively acting as Trustees for natural resources, announce the availability of the *Draft Restoration Plan and Programmatic Environmental Impact Statement for Restoration Resulting from the Kalamazoo River Natural Resource Damage Assessment.* Publication of this notice begins the public comment period for this Draft Restoration Plan and Programmatic Environmental Impact Statement (Draft RP/PEIS). The purpose of the Draft RP/PEIS is to present the Trustees' proposed approach to restoration to compensate the public for losses to natural resources resulting from the release of polychlorinated biphenyls (PCBs) and to evaluate, in compliance with the National Environmental Policy Act (NEPA), the potential direct, indirect, and cumulative impacts of implementing the alternative programmatic approaches to restoration in the Kalamazoo River watershed.

DATES: Written comments must be received by October 29, 2015.

ADDRESSES: *Submitting Comments:* Written comments for the Trustees to consider should be sent to Lisa Williams, U.S. Fish and Wildlife Service, East Lansing Field Office, 2651 Coolidge Road, East Lansing, MI 48823. Comments may also be submitted electronically to *kzoorivernrda@fws.gov,* with "Kalamazoo River RP/PEIS" in the subject line. For more information, see Public Comments under **SUPPLEMENTARY INFORMATION.**

Viewing the Administrative Record: Contact Judith Alfano, at (517) 373–7402 or *alfanoj@michigan.gov;* selected documents are also available at *http://www.fws.gov/midwest/es/ec/nrda/KalamazooRiver.*

Viewing EPA's Comments on the PEIS: For how to view comments on the PEIS from the Environmental Protection Agency (EPA), or for information on EPA's role in the EIS process, see EPA's Role in the EIS Process under **SUPPLEMENTARY INFORMATION.**

FOR FURTHER INFORMATION CONTACT: Lisa Williams, USFWS, by email at *lisa_williams@fws.gov* or by phone at (517) 351–8324, or Julie Sims, NOAA Restoration Center, by email at *julie.sims@noaa.gov* or by phone at (734) 741–2385.

SUPPLEMENTARY INFORMATION: The U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA), the Michigan Department of Environmental Quality (MDEQ), the Michigan Department of Natural Resources, and the Michigan Attorney General, collectively acting as Trustees for natural resources, have prepared this Draft Restoration Plan and Programmatic Environmental Impact Statement (Draft RP/PEIS) for restoration in the Kalamazoo River watershed pursuant to both CERCLA NRDA regulations and the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321–4347 *et seq.;* NEPA), and its implementing regulations in the Code of Federal Regulations (CFR) at 40 CFR parts 1500–1508. NEPA requires Federal agencies to conduct environmental reviews of proposed actions to consider the potential impacts on the environment.

In the Draft RP/PEIS, the Trustees describe restoration projects that could compensate for injuries to natural resources from polychlorinated biphenyls (PCBs) released at and from the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (Superfund Site). These include both general types of restoration projects as well as two specific projects to restore aquatic connectivity on the Kalamazoo River by removing dams in and near Otsego, Michigan. The public is invited to provide comments to the Trustees on the Draft RP/PEIS, including the proposed restoration projects and techniques, the programmatic restoration alternatives, and the potential impacts of the alternatives on the environment.

Industrial activities in the Kalamazoo area have released PCBs into the environment. Recycling of carbonless copy paper at several area paper mills was the primary source of PCB release. Waste from the recycling of such paper conducted at Kalamazoo-area paper mills also contained PCBs, and the waste was disposed of by several methods that resulted in releases of PCBs into the environment. These PCBs have contaminated sediments, the water column, and biota in and adjacent to downstream sections of Portage Creek, the Kalamazoo River, and Lake Michigan.

Based on the risks that PCBs pose to the environment and to human health, the U.S. Environmental Protection Agency (EPA) listed the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site on the National Priorities List on August 30, 1990. PCBs are listed as hazardous substances under CERCLA. EPA and MDEQ currently describe the site being addressed by the Superfund remedial investigation as including: (1) Five disposal areas and six paper mill properties; (2) a 3-mile stretch of Portage Creek from Cork Street in the City of Kalamazoo to where the creek meets the Kalamazoo River; and (3) an approximately 80-mile stretch of the Kalamazoo River, from Morrow Dam to Lake Michigan, with adjacent floodplains, wetlands, and in-stream sediments.

As defined in the Stage 1 Assessment Report (MDEQ *et al.* 2005; available at *http://www.fws.gov/midwest/es/ec/nrda/KalamazooRiver*), the Trustees are using the term Kalamazoo River Environment (KRE) to represent the entire natural resource damage assessment area. The KRE encompasses the area being addressed by the Superfund remedial investigations for the site's operable units, along with any area where hazardous substances released at or from the Superfund site have come to be located, and areas where natural resources or the services they provide may have been affected by the site-related hazardous substances releases (MDEQ *et al.* 2005).

The Trustees expect to have opportunities to settle natural resource damage claims for the KRE with willing parties. The Draft RP/PEIS will provide an ecological framework, with public input, to maximize the benefits of specific restoration projects to the affected resources in the KRE that might be included in or funded by future settlements or past bankruptcy settlements. The Draft RP/PEIS will provide criteria and guidance for Trustees to use in selecting feasible restoration projects.

In compliance with 40 CFR part 1505 *et seq.,* the Trustees will include in the NRDA Administrative Record (Record) documents that the Trustees rely upon during the development of the Draft RP/PEIS. The hard copy Record is on file at MDEQ (contact Judith Alfano; see **FOR FURTHER INFORMATION CONTACT**).

CERCLA

Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; 42 U.S.C. 9601 *et seq.*), parties responsible for releasing hazardous substances into the environment are liable both for the costs of responding to the release (by cleaning up, containing, or otherwise remediating the release) and for damages arising from injuries to publicly owned or managed natural resources resulting from the release. CERCLA's Natural Resource Damage Assessment (NRDA) regulations (43 CFR 11) describe the process of assessing the nature and extent of the resulting injury, destruction, or loss of natural resources and the services they provide. Carrying out of the NRDA process also includes determining the compensation required to make the public whole for such injuries, destruction, or loss. CERCLA

authorizes certain Federal and State agencies and Indian tribes to act on behalf of the public as Trustees for affected natural resources. Under CERCLA, these agencies and tribes are authorized to assess natural resource injuries and to seek compensation, referred to as damages, from responsible parties, including the costs of performing the damage assessment. The Trustees are required to use recovered damages for the following purposes only: To restore, replace, or acquire the equivalent of the injured or lost resources and services.

EPA's Role in the EIS Process

In addition to this **Federal Register** notice, EPA is publishing a notice announcing the PEIS, as required under section 309 of the Clean Air Act (42 U.S.C. 7401 *et seq.;* CAA).

The EPA is charged under the CAA to review all Federal agencies' EISs and to comment on the adequacy and the acceptability of the environmental impacts of proposed actions in the EISs. EPA also serves as the repository (EIS database) for EISs prepared by Federal agencies and provides notice of their availability in the **Federal Register**. The EIS database provides information about EISs prepared by Federal agencies, as well as EPA's comments concerning the EISs. All EISs are filed with EPA, which publishes a notice of availability on Fridays in the **Federal Register**.

For more information, see *http://www.epa.gov/compliance/nepa/eisdata.html.* You may search for EPA comments on EISs, along with EISs themselves, at *https://cdxnodengn.epa.gov/cdx-enepa-public/action/eis/search.*

Public Comments

Comments are specifically requested regarding the alternatives, proposed restoration techniques and projects, scope of analysis, and assessment of impacts. Please see the **ADDRESSES** section for how to submit information.

Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Dated: August 24, 2015.

Charles Wooley,

Acting Regional Director, Midwest Region, U.S. Fish and Wildlife Service.

[FR Doc. 2015–23016 Filed 9–11–15; 8:45 am]

BILLING CODE 4310–55–P

DEPARTMENT OF THE INTERIOR

Bureau of Indian Affairs

[156A2100DD/AAKC001030/A0A501010.999900 253G]

Renewal of Agency Information Collection for Leases and Permits

AGENCY: Bureau of Indian Affairs, Interior.

ACTION: Notice of request for comments.

SUMMARY: In compliance with the Paperwork Reduction Act of 1995, the Bureau of Indian Affairs (BIA) is seeking comments on the renewal of Office of Management and Budget (OMB) approval for the collection of information for Leases and Permits, 25 CFR 162. The information collection is currently authorized by OMB Control Number 1076–0155. This information collection expires November 30, 2015.

DATES: Submit comments on or before November 13, 2015.

ADDRESSES: You may submit comments on the information collection to Ms. Sharlene Roundface, Office of Trust Services, Bureau of Indian Affairs, 1849 C Street NW., Mailstop 3642—MIB, Washington, DC 20240; email: *Sharlene.Roundface@bia.gov.*

FOR FURTHER INFORMATION CONTACT: Ms. Sharlene Roundface, telephone: (202) 208–5831.

SUPPLEMENTARY INFORMATION:

I. Abstract

The Bureau of Indian Affairs (BIA) is seeking renewal of the approval for information collection conducted under 25 CFR 162, Leases and Permits, for the review and approval of leases and permits on land the United States holds in trust or restricted status for individual Indians and Indian tribes. This information collection allows BIA to review applications for leases and permits, modifications, and assignments, and to determine:

(a) Whether or not a lease may be approved or granted;

(b) The value of each lease;

(c) The appropriate compensation to landowners; and

(d) Provisions for violations of trespass.

A response is required to obtain or retain a benefit.

II. Request for Comments

The BIA requests your comments on this collection concerning: (a) The necessity of this information collection for the proper performance of the functions of the agency, including whether the information will have practical utility; (b) The accuracy of the agency's estimate of the burden (hours and cost) of the collection of information, including the validity of the methodology and assumptions used; (c) Ways we could enhance the quality, utility, and clarity of the information to be collected; and (d) Ways we could minimize the burden of the collection of the information on the respondents.

Please note that an agency may not conduct or sponsor, and an individual need not respond to, a collection of information unless it has a valid OMB Control Number.

It is our policy to make all comments available to the public for review at the location listed in the **ADDRESSES** section. Before including your address, phone number, email address or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

III. Data

OMB Control Number: 1076–0155.

Title: Leases and Permits, 25 CFR 162.

Brief Description of Collection: Generally, trust and restricted land may be leased by Indian landowners with the approval of the Secretary of the Interior, except when specified by statute. Submission of this information allows BIA to review applications for obtaining, modifying and assigning leases and permits of land that the United States holds in trust or restricted status for individual Indians and Indian tribes. The information is used to determine approval of a lease, amendment, assignment, sublease, mortgage or related document. Response is required to obtain or retain a benefit.

Type of Review: Extension without change of currently approved collection.

Respondents: Individual Indians and Indian tribes seeking to lease their trust or restricted land and businesses that lease trust and restricted land.

Estimated Number of Respondents: 127,110.

Frequency of Response: One approval per lease, other collections occur fewer than once per lease, on average, upon

request for modification or assignment or upon a trespass violation.

Estimated Time per Response: Ranges from 15 minutes to 3 hours.

Estimated Total Annual Hour Burden: 108,975 hours.

Estimated Total Annual Non-Hour Dollar Cost: $1,813,000.

Elizabeth K. Appel,

Director, Office of Regulatory Affairs and Collaborative Action—Indian Affairs.

[FR Doc. 2015–22962 Filed 9–11–15; 8:45 am]

BILLING CODE 4337–15–P

DEPARTMENT OF THE INTERIOR

Bureau of Indian Affairs

[156A2100DD/AAKC001030/A0A501010.999900 253G]

Renewal of Agency Information Collection for Class III Gaming; Tribal Revenue Allocation Plans; Gaming on Trust Lands

AGENCY: Bureau of Indian Affairs, Interior.

ACTION: Notice of request for comments.

SUMMARY: In compliance with the Paperwork Reduction Act of 1995, the Assistant Secretary—Indian Affairs is seeking comments on the renewal of Office of Management and Budget (OMB) approval for the collection of information for Class III Gaming Procedures authorized by OMB Control Number 1076–0149, Tribal Revenue Allocation Plans authorized by OMB Control Number 1076–0152, and Gaming on Trust Lands Acquired After October 17, 1988 authorized by OMB Control Number 1076–0158. These information collections expire January 31, 2016.

DATES: Submit comments on or before November 13, 2015.

ADDRESSES: You may submit comments on the information collection to Paula Hart, U.S. Department of the Interior, Office of Indian Gaming, 1849 C Street NW., Mail Stop 3657, Washington, DC 20240; email: *indiangaming@bia.gov.*

FOR FURTHER INFORMATION CONTACT: Paula Hart, (202) 219–4066.

SUPPLEMENTARY INFORMATION:

I. Abstract

The Assistant Secretary—Indian Affairs is seeking comments on the Class III Gaming Procedures, Tribal Revenue Allocation Plans, and Gaming on Trust Lands Acquired After October 17, 1988, as we prepare to renew these collections are required by the Paperwork Reduction Act of 1995. This information is necessary for the Office of Indian Gaming, to ensure that the applicable requirements for the Indian Gaming Regulatory Act (IGRA), 25 U.S.C. 2701 *et seq.,* are met with regard to Class III gaming procedures, tribal revenue allocation plans, and applications for gaming on trust lands acquired after October 17, 1988.

II. Request for Comments

The Assistant Secretary—Indian Affairs requests your comments on this collection concerning: (a) The necessity of this information collection for the proper performance of the functions of the agency, including whether the information will have practical utility; (b) The accuracy of the agency's estimate of the burden (hours and cost) of the collection of information, including the validity of the methodology and assumptions used; (c) Ways we could enhance the quality, utility, and clarity of the information to be collected; and (d) Ways we could minimize the burden of the collection of the information on the respondents.

Please note that an agency may not conduct or sponsor, and an individual need not respond to, a collection of information unless it displays a valid OMB Control Number.

It is our policy to make all comments available to the public for review at the location listed in the **ADDRESSES** section. Before including your address, phone number, email address or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

III. Data

OMB Control Number: 1076–0149.

Title: Class III Gaming Procedures, 25 CFR 291.

Brief Description of Collection: The collection of information will ensure that the provisions of IGRA and other applicable requirements are met when federally recognized tribes submit Class III procedures for review and approval by the Secretary of the Interior. Sections 291.4, 291.10, 291.12 and 291.15 of 25 CFR part 291, Class III Gaming Procedures, specify the information collection requirement. An Indian tribe must ask the Secretary to issue Class III gaming procedures. The information to be collected includes: The name of the tribe, the name of the State, tribal documents, State documents, regulatory schemes, the proposed procedures, and other documents deemed necessary.

Type of Review: Extension without change of currently approved collection.

Respondents: Federally recognized Indian tribes.

Number of Respondents: 12.

Estimated Time per Response: 320 hours.

Estimated Total Annual Hour Burden: 3,840 hours.

Estimated Total Annual Non-Hour Dollar Cost: $0.

OMB Control Number: 1076–0152.

Title: Tribal Revenue Allocation Plans, 25 CFR 290.

Brief Description of Collection: An Indian tribe must ask the Secretary to approve a tribal revenue allocation plan. In order for Indian tribes to distribute net gaming revenues in the form of per capita payments, information is needed by the BIA to ensure that tribal revenue allocation plans include (1) Assurances that certain statutory requirements are met, (2) a breakdown of the specific uses to which net gaming revenues will be allocated, (3) eligibility requirements for participation, (4) tax liability notification, and (5) the assurance of the protection and preservation of the per capita share of minors and legal incompetents. Sections 290.12, 290.17, 290.24 and 290.26 of 25 CFR part 290, Tribal Revenue Allocation Plans, specify the information collection requirement. The information to be collected includes: the name of the tribe, tribal documents, the allocation plan, and other documents deemed necessary.

Type of Review: Extension without change of currently approved collection.

Respondents: Federally recognized Indian tribes.

Number of Respondents: 20.

Estimated Time per Response: 100 hours.

Estimated Total Annual Hour Burden: 2,000 hours.

Estimated Total Annual Non-Hour Dollar Cost: $0.

OMB Control Number: 1076–0158.

Title: Gaming on Trust Lands Acquired After October 17, 1988, 25 CFR 292.

Brief Description of Collection: The collection of information will ensure that the provisions of IGRA, Federal law, and the trust obligations of the United States are met when federally recognized tribes submit an application under 25 CFR part 292. The applications covered by this OMB Control No. are those seeking a Secretarial determination that a gaming establishment on land acquired in trust after October 17, 1988 would be in the

best interest of the Indian tribe and its members, and would not be detrimental to the surrounding community.

Type of Review: Extension without change of currently approved collection.

Respondents: Federally recognized Indian tribes.

Number of Respondents: 2.

Estimated Time per Response: 1,000 hours.

Frequency of Response: Once.

Estimated Total Annual Burden: 2,000 hours.

Estimated Total Annual Non-Hour Dollar Cost: $0.

Elizabeth K. Appel,

Director, Office of Regulatory Affairs and Collaborative Action—Indian Affairs.

[FR Doc. 2015–22960 Filed 9–11–15; 8:45 am]

BILLING CODE 4337–15–P

DEPARTMENT OF THE INTERIOR

Bureau of Indian Affairs

[156A2100DD/AAKC001030/A0A501010.999900 253G]

Revision of Agency Information Collection for Indian Reservation Roads

AGENCY: Bureau of Indian Affairs, Interior.

ACTION: Notice of submission to OMB.

SUMMARY: In compliance with the Paperwork Reduction Act of 1995, the Bureau of Indian Affairs (BIA) is submitting to the Office of Management and Budget (OMB) a request for approval for the collection of information for Indian Reservation Roads (IRR). The information collection is currently authorized by OMB Control Number 1076–0161, which expires September 30, 2015.

DATES: Interested persons are invited to submit comments on or before October 14, 2015.

ADDRESSES: You may submit comments on the information collection to the Desk Officer for the Department of the Interior at the Office of Management and Budget, by facsimile to (202) 395–5806 or you may send an email to: *OIRA_Submission@omb.eop.gov.* Please send a copy of your comments to: Mr. LeRoy Gishi, Chief, Division of Transportation, Bureau of Indian Affairs, 1849 C Street NW., MS–4513–MIB, Washington, DC 20240; facsimile: (202) 208–4696; email: *LeRoy.Gishi@bia.gov.*

FOR FURTHER INFORMATION CONTACT: Mr. LeRoy Gishi, (202) 513–7711. You may review the information collection request online at *http://www.reginfo.gov.* Follow the instructions to review Department of the Interior collections under review by OMB.

SUPPLEMENTARY INFORMATION:

I. Abstract

The Bureau of Indian Affairs is currently in the process of revising the regulations governing the Indian Reservations Roads (IRR) program. The proposed rule was published in the **Federal Register** on December 19, 2014 (79 FR 76192), which will update the Indian Reservation Roads program to the Tribal Transportation Program. The request for approval for this information collection does not include the suggestions and feedback on the proposed regulations, but instead will allow current participants to submit information required under the current regulations, pending the finalization and effective date of any revisions. In addition, there is a reduction in burden hours due to the elimination of the IRR High Priority Projects program under 23 U.S.C. 202(b)(3)(ii). All other programs identified under 25 CFR part 170 are valid. For this reason, the BIA is requesting approval for the revision to the information collection conducted under 25 CFR part 170.

This collection allows federally recognized tribal governments to participate in the Indian Reservation Roads (IRR) program as defined in 25 U.S.C. 202. The information collection determines the allocation of the IRR program funds to Indian tribes as described in 25 U.S.C. 202(b).

II. Request for Comments

On June 10, 2015, BIA published a notice announcing the renewal of this information collection and provided a 60-day comment period in the **Federal Register** (80 FR 32976). There were no comments received in response to this notice.

The BIA requests your comments on this collection concerning: (a) The necessity of this information collection for the proper performance of the functions of the agency, including whether the information will have practical utility; (b) The accuracy of the agency's estimate of the burden (hours and cost) of the collection of information, including the validity of the methodology and assumptions used; (c) Ways we could enhance the quality, utility, and clarity of the information to be collected; and (d) Ways we could minimize the burden of the collection of the information on the respondents.

Please note that an agency may not conduct or sponsor, and an individual need not respond to, a collection of information unless it displays a valid OMB Control Number.

It is our policy to make all comments available to the public for review at the location listed in the **ADDRESSES** section. Before including your address, phone number, email address or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

III. Data

OMB Control Number: 1076–0161.

Title: Indian Reservation Roads, 25 CFR part 170.

Brief Description of Collection: Some of the information such as the road inventory updates (25 CFR 170.443), the development of a long range transportation plan (25 CFR 170.411 and 170.412), the development of a tribal transportation improvement program and priority list (25 CFR 170.420 and 170.421) are mandatory for consideration of projects and for program funding form the formula. Some of the information, such as public hearing requirements, is necessary for public notification and involvement (25 CFR 170.437 and 170.439). While other information, such as data appeals (25 CFR 170.231) and requests for design exceptions (25 CFR 170.456), are voluntary.

Type of Review: Revision of currently approved collection.

Respondents: Federally recognized Indian tribal governments who have transportation needs associated with the IRR Program as described in 25 CFR part 170.

Number of Respondents: 1,369.

Frequency of Response: Annually or on an as needed basis.

Estimated Time per Response: Reports require from 30 minutes to 40 hours to complete. An average would be 16 hours.

Estimated Total Annual Hour Burden: 18,028 hours.

Estimated Total Annual Non-Hour Dollar Cost: $0.

Elizabeth K. Appel,

Director, Office of Regulatory Affairs and Collaborative Action—Indian Affairs.

[FR Doc. 2015–22992 Filed 9–11–15; 8:45 am]

BILLING CODE 4337–15–P

DEPARTMENT OF THE INTERIOR

Bureau of Indian Affairs

[156A2100DD/AAKC001030/A0A501010.999900 253G]

Renewal of Agency Information Collection for Student Transportation Form

AGENCY: Bureau of Indian Affairs, Interior.

ACTION: Notice of request for comments.

SUMMARY: In compliance with the Paperwork Reduction Act of 1995, the Bureau of Indian Education (BIE) is seeking comments on the renewal of Office of Management and Budget (OMB) approval for the collection of information for Student Transportation Form. This information collection is currently authorized by OMB Control Number 1076–0134, which expires September 30, 2015.

DATES: Interested persons are invited to submit comments on or before October 14, 2015.

ADDRESSES: You may submit comments on the information collection to the Desk Officer for the Department of the Interior at the Office of Management and Budget, by facsimile to (202) 395–5806 or you may send an email to: *OIRA_Submission@omb.eop.gov.* Please send a copy of your comments to: Dr. Joe Herrin, Bureau of Indian Education, 1951 Constitution Avenue, MS–312–SIB, Washington, DC 20240; facsimile: (202) 208–3271; email: *Joe.Herrin@BIE.edu.*

FOR FURTHER INFORMATION CONTACT: Dr. Joe Herrin, phone: (202) 208–7658. You may review the information collection request online at *http://www.reginfo.gov.* Follow the instructions to review Department of the Interior collections under review by OMB.

SUPPLEMENTARY INFORMATION:

I. Abstract

The BIE is requesting renewal of OMB approval for the Student Transportation Form. The Student Transportation regulations in 25 CFR part 39, subpart G, contain the program eligibility and criteria that govern the allocation of transportation funds. Information collected from the schools will be used to determine the rate per mile. The information collection provides transportation mileage for Bureau-funded schools, which determines the allocation of transportation funds. This information is collected using a web-based system, Office of Indian Education Programs (OIEP) MultiWeb Intranet/WebET Intranet. Response is required to obtain a benefit.

II. Request for Comments

On June 10, 2015, the BIE published a notice announcing the renewal of this information collection and provided a 60-day comment period in the **Federal Register** (80 FR 32975). There were no comments received in response to this notice.

The BIE requests your comments on this collection concerning: (a) The necessity of this information collection for the proper performance of the functions of the agency, including whether the information will have practical utility; (b) The accuracy of the agency's estimate of the burden (hours and cost) of the collection of information, including the validity of the methodology and assumptions used; (c) Ways we could enhance the quality, utility, and clarity of the information to be collected; and (d) Ways we could minimize the burden of the collection of the information on the respondents.

Please note that an agency may not conduct or sponsor, and an individual need not respond to, a collection of information unless it displays a valid OMB Control Number.

It is our policy to make all comments available to the public for review at the location listed in the **ADDRESSES** section. Before including your address, phone number, email address or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

III. Data

OMB Control Number: 1076–0134.

Title: Student Transportation Form, 25 CFR 39.

Brief Description of Collection: This annual collection provides pertinent data concerning the school's bus transportation mileage and related long distance travel mileage to determine funding levels for school transportation. This information is collected using the web-based system, OIEP MultiWeb Intranet/WebET Intranet and the Indian School Equalization Program (ISEP) Student Transportation form.

Type of Review: Extension without change of currently approved collection.

Respondents: Contract and Grant schools; Bureau-operated schools.

Number of Respondents: 183 per year, on average.

Total Number of Responses: 183 per year, on average.

Frequency of Response: Once per year.

Estimated Time per Response: 2 hours.

Estimated Total Annual Hour Burden: 366 hours.

Estimated Total Annual Non-Hour Dollar Cost: $0.

Elizabeth K. Appel,

Director, Office of Regulatory Affairs and Collaborative Action—Indian Affairs.

[FR Doc. 2015–22961 Filed 9–11–15; 8:45 am]

BILLING CODE 4337–15–P

DEPARTMENT OF THE INTERIOR

Bureau of Land Management

[LLWYD03000.L51100000.GN0000.LVEMK10CW580–WYW–184415]

Notice of Intent To Prepare an Environmental Impact Statement for the Proposed Lost Creek Uranium In-Situ Recovery Project Amendments, Sweetwater County, WY

AGENCY: Bureau of Land Management, Interior.

ACTION: Notice.

SUMMARY: In compliance with the National Environmental Policy Act of 1969 (NEPA), as amended, and the Federal Land Policy and Management Act of 1976, as amended, the Bureau of Land Management (BLM) Rawlins Field Office, Rawlins, Wyoming, intends to prepare an Environmental Impact Statement (EIS), and by this notice is announcing the beginning of the scoping process to solicit public comments and identify issues.

DATES: This notice initiates the public scoping process for the EIS. Comments on issues may be submitted in writing until 45 days after the date of publication in the **Federal Register**. The date(s) and location(s) of any scoping meetings will be announced at least 15 days in advance through local media, newspapers and the BLM Web site at: *http://www.blm.gov/wy/st/en/info/NEPA/documents/rfo/lostcreek.html.* In order to be included in the Draft EIS, all comments must be received prior to the close of the 45-day scoping period or 15 days after the last public meeting, whichever is later. We will provide additional opportunities for public participation upon publication of the Draft EIS.

ADDRESSES: You may submit comments related to the Lost Creek Uranium *In-Situ* Recovery Project Amendments by any of the following methods:

- *Web site: http://www.blm.gov/wy/st/en/info/NEPA/documents/rfo/lostcreek.html.*
- *Email: Lost_Crk_Mine_WY@blm.gov.*
- *Fax:* 307–328–4224.
- *Mail:* John Russell, Project Manager, BLM Rawlins Field Office, 1300 North Third Street, P.O. Box 2407, Rawlins, WY 82301–2407
- Documents pertinent to this proposal may be examined at the BLM Rawlins Field Office.

FOR FURTHER INFORMATION CONTACT: John Russell, Project Manager, telephone 307–328–4224; address Bureau of Land Management, Rawlins Field Office, 1300 N. Third Street, P.O. Box 2407, Rawlins, Wyoming 82301; email *Lost_Crk_Mine_WY@blm.gov.* Contact Mr. Russell to have your name added to our mailing list. Persons who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 1–800–877–8339 to contact the above individual during normal business hours. The FIRS is available 24 hours a day, 7 days a week, to leave a message or question with the above individual. You will receive a reply during normal business hours.

SUPPLEMENTARY INFORMATION: The applicant, Lost Creek ISR, LLC, (LCI), a wholly owned subsidiary of Ur-Energy Inc., has requested to modify their Lost Creek Uranium *In-Situ* Recovery Project, 43 CFR 3809 Plan of Operations, approved October 5, 2012. The proposed plan amendments (Lost Creek East, KM Horizon, and secondary objectives received September 29, 2014) would expand uranium production by in-situ recovery methods and increase associated milling facilities, located in T. 25 N., R. 92 W.; and T. 25 N., R. 93 W., 6th P.M., Sweetwater County, Wyoming.

The Lost Creek East amendment would add approximately 5,750 acres to the existing Lost Creek Project area of approximately 4,254 acres for a new total project area of approximately 10,000 acres. LCI's proposed KM Horizon amendment would allow in-situ mining of uranium from the KM horizon, and increases the extent of mining in the existing HJ horizon within the existing project area, approved October 5, 2012. Development of the proposed amendments would result in approximately 650 acres of new surface disturbance including 5 new mine units, additional Class 1 deep disposal well pads, roads, pipelines, power lines, header houses, and mud pits. LCI also requested the BLM approve an increase of the overall production rate from 1.0 million pounds of uranium per year to 2.2 million pounds of uranium per year. This includes an increase of 0.2 million pounds of uranium per year from the facility well fields, plus an increase of 1 million pounds of uranium per year from the toll milling resin or slurry from other off-site facilities. The purpose of the public scoping process is to determine relevant issues that will influence the scope of the environmental analysis, including alternatives, and guide the process for developing the EIS. At present, the BLM has identified the following preliminary issues: (1) Potential impacts to range, water, recreation, wild horses, and wildlife resources (*e.g.,* Greater Sage-Grouse, Wyoming Pocket Gopher); (2) the need to identify opportunities to apply mitigation hierarchy strategies for on-site, regional, and compensatory mitigation efforts; and, (3) the need to apply landscape-level conservation and management actions that are appropriate to the size of the project in order to achieve resource objectives.

The BLM will use NEPA public participation requirements to assist the agency in satisfying the public involvement requirements under section 106 of the National Historic Preservation Act (NHPA) (16 U.S.C. 470(f)) pursuant to 36 CFR 800.2(d)(3). The information about historic and cultural resources within the area potentially affected by the proposed plan amendments will assist the BLM in identifying and evaluating impacts to such resources in the context of both NEPA and section 106 of the NHPA.

The BLM will consult with Indian tribes on a government-to-government basis in accordance with Executive Order 13175 and other policies. Tribal concerns, including impacts on Indian trust assets and potential impacts to cultural resources, will be given due consideration. Federal, State, and local agencies, along with tribes and other stakeholders that may be interested in or affected by the proposed plan amendments that the BLM is evaluating, are invited to participate in the scoping process and, if eligible, may request or be requested by the BLM to participate in the development of the environmental analysis as a cooperating agency.

The Nuclear Regulatory Commission and the State of Wyoming will be cooperating agencies for this project. Others are pending. Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you may ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Authority: 40 CFR 1501.7.

Larry Claypool,

Acting, State Director.

[FR Doc. 2015–23059 Filed 9–11–15; 8:45 am]

BILLING CODE 4310–22–P

DEPARTMENT OF THE INTERIOR

Bureau of Land Management

[15XL.LLIDT01000.L10200000.DR0000. LXSSD0080000.241A 4500080108]

Notice of Availability of Record of Decision for the Jarbidge Resource Management Plan Final Environmental Impact Statement

AGENCY: Bureau of Land Management, Interior.

ACTION: Notice of availability.

SUMMARY: The Bureau of Land Management (BLM) announces the availability of the Record of Decision (ROD) for the Approved Resource Management Plan (RMP) for the Jarbidge Field Office located in the Twin Falls District (Idaho and Nevada). The Idaho State Director signed the ROD on September 2, 2015, which constitutes the final decision of the BLM and makes the Approved RMP effective immediately.

ADDRESSES: Copies of the ROD/Approved RMP are available upon request from the Field Manager, Jarbidge Field Office, Bureau of Land Management, 2536 Kimberly Road, Twin Falls, Idaho 83301 and online at *http://www.blm.gov/id/st/en/prog/nepa_register/jarbidge-rmp-revision.html.* Copies of the ROD/Approved RMP are also available for public inspection at 2536 Kimberly Road, Twin Falls, Idaho 83301.

FOR FURTHER INFORMATION CONTACT: Elliot Traher, Jarbidge Field Manager, or Heidi Whitlach, Jarbidge RMP Project Manager, telephone 208–736–2350; address Jarbidge Field Office, 2536 Kimberly Road, Twin Falls, Idaho 83301; email *blm_id_jarbidgermp@blm.gov.* Persons who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 1–800–877–8339 to contact the above individual during normal business hours. The FIRS is available 24 hours a day, 7 days a week, to leave a message or question with the above individual. You will receive a reply during normal business hours.

SUPPLEMENTARY INFORMATION: The Approved RMP was developed with public participation through a collaborative planning process in accordance with the Federal Land Policy and Management Act of 1976, as amended, and the National Environmental Policy Act of 1969, as amended. The Approved RMP addresses the management of resources and resource uses on about 1,371,000 acres of public land surface; 1,497,000 acres of Federal mineral estate; and 1,463,000 acres of livestock grazing (including 1,371,000 acres of public land surface and an additional 92,000 acres on the US Air Force Saylor Creek Training Range) in Elmore, Owyhee, and Twin Falls Counties in Idaho and Elko County in Nevada. The Approved RMP describes the landscape-level conservation and management actions needed to meet desired resource conditions and regional mitigation objectives for vegetation, wild horses, livestock grazing, recreation, energy development, and Areas of Critical Environmental Concern (ACECs).

In the Draft RMP/Environmental Impact Statement (EIS), Alternative IV–B was selected as the BLM's Preferred Alternative. As a result of public comment, internal review, and cooperating agency coordination on the Draft RMP/EIS, Alternative IV–B was adjusted to become Alternative VI (Proposed RMP) and analyzed in the Proposed RMP/Final EIS. The Proposed RMP/Final EIS was published in the**Federal Register**on August 22, 2014 (79 FR 49774).

The BLM received 8 protest letters during the 30-day protest period. The BLM Director denied all protest issues as reported in the Director's Protest Resolution Report, which can be reviewed at the following Web site:http://www.blm.gov/wo/st/en/prog/planning/planning_overview/protest_resolution/protestreports.html.

While the Approved RMP contains some conservation management measures for greater sage-grouse habitat, final decisions on how to manage habitat within the Jarbidge Field Office will be made in the Records of Decision for the Idaho/Southwest (SW) Montana Greater Sage-Grouse Plan Amendment and the Nevada/Northeast (NE) California Greater Sage-Grouse Plan Amendment. The Idaho/SW Montana and Nevada/NE California Greater Sage-grouse Plan Amendment EISs will fully analyze applicable greater sage-grouse conservation measures, consistent with BLM Instruction Memorandum No. 2012–044. The BLM expects to make a comprehensive set of decisions for managing greater sage-grouse on lands administered by the Jarbidge Field Office in the Records of Decision for the Idaho/SW Montana and Nevada/NE California Greater Sage-Grouse Plan Amendments.

During the Governor's consistency review process, the Idaho Governor's Office identified discrepancies between the Jarbidge Proposed RMP and laws, plans, policies and programs of the State of Idaho. The discrepancies mostly concerned greater sage-grouse direction and conservation actions in the Proposed RMP and Governor C.L. "Butch" Otter's "Alternative for Federal Lands for Greater Sage-grouse Management in Idaho" and the Idaho Department of Lands Greater Sage-grouse Conservation Plan for State Endowment Lands. The issues raised by the State of Idaho were responded to by letter from the BLM Idaho State Director. The Governor's Office did not appeal the State Director's decision to the BLM Director. The Nevada Governor's Office did not submit a response to the BLM during the Governor's consistency review period.

Authority: 40 CFR 1506.6.

Timothy M. Murphy,

BLM Idaho State Director.

[FR Doc. 2015–23060 Filed 9–11–15; 8:45 am]

BILLING CODE 4310–GG–P

DEPARTMENT OF THE INTERIOR

Bureau of Ocean Energy Management

[MMAA 104000]

Notice of Availability of the Proposed Notice of Sale for Central Gulf of Mexico Planning Area Outer Continental Shelf Oil and Gas Lease Sale 241

AGENCY: Bureau of Ocean Energy Management (BOEM), Interior.

ACTION: Notice of availability of the proposed notice of sale for CPA sale 241.

SUMMARY: BOEM announces the availability of the Proposed Notice of Sale (NOS) for the proposed Central Gulf of Mexico Planning Area (CPA) Outer Continental Shelf (OCS) Oil and Gas Lease Sale 241 (CPA Sale 241). This Notice is published pursuant to 30 CFR 556.29(c) as a matter of information to the public. With regard to oil and gas leasing on the OCS, the Secretary of the Interior, pursuant to section 19 of the OCS Lands Act, provides affected States the opportunity to review the Proposed NOS. The Proposed NOS sets forth the proposed terms and conditions of the sale, including minimum bids, royalty rates, and rental rates.

DATES: Affected States may comment on the size, timing, and location of proposed CPA Sale 241 within 60 days following their receipt of the Proposed NOS. The Final NOS will be published in the **Federal Register** at least 30 days prior to the date of bid opening. Bid opening currently is scheduled for March 23, 2016.

SUPPLEMENTARY INFORMATION: The Proposed NOS for CPA Sale 241 and a Proposed NOS Package containing information essential to potential bidders may be obtained from the Public Information Unit, Gulf of Mexico Region, Bureau of Ocean Energy Management, 1201 Elmwood Park Boulevard, New Orleans, Louisiana 70123–2394. Telephone: (504) 736–2519. The Proposed NOS and Proposed NOS Package also are available on BOEM's Web site at *http://www.boem.gov/Sale-241/.*

Agency Contact: David Diamond, Chief, Leasing Division, *David.Diamond@boem.gov.*

Dated: September 3, 2015.

Abigail Ross Hopper,

Director, Bureau of Ocean Energy Management.

[FR Doc. 2015–23104 Filed 9–11–15; 8:45 am]

BILLING CODE 4310– MR–P

DEPARTMENT OF THE INTERIOR

Bureau of Ocean Energy Management

[MMAA 104000]

Notice of Availability of the Proposed Notice of Sale for Eastern Gulf of Mexico Planning Area Outer Continental Shelf Oil and Gas Lease Sale 226

AGENCY: Bureau of Ocean Energy Management (BOEM), Interior.

ACTION: Notice of availability of the proposed notice of sale for EPA sale 226.

SUMMARY: BOEM announces the availability of the Proposed Notice of Sale (NOS) for the proposed Eastern Gulf of Mexico Planning Area (EPA) Outer Continental Shelf (OCS) Oil and Gas Lease Sale 226 (EPA Sale 226). This Notice is published pursuant to 30 CFR 556.29(c) as a matter of information to the public. With regard to oil and gas leasing on the OCS, the Secretary of the Interior, pursuant to section 19 of the OCS Lands Act, provides affected States the opportunity to review the Proposed NOS. The Proposed NOS sets forth the proposed terms and conditions of the

sale, including minimum bids, royalty rates, and rental rates.

DATES: Affected States may comment on the size, timing, and location of proposed EPA Sale 226 within 60 days following their receipt of the Proposed NOS. The Final NOS will be published in the **Federal Register** at least 30 days prior to the date of bid opening. Bid opening is currently scheduled for March 23, 2016.

SUPPLEMENTARY INFORMATION: The Proposed NOS for EPA Sale 226 and a Proposed NOS Package containing information essential to potential bidders may be obtained from the Public Information Unit, Gulf of Mexico Region, Bureau of Ocean Energy Management, 1201 Elmwood Park Boulevard, New Orleans, Louisiana 70123–2394. Telephone: (504) 736–2519. The Proposed NOS and Proposed NOS Package also are available on BOEM's Web site at *http://www.boem.gov/Sale-226/.*

Agency Contact: David Diamond, Chief, Leasing Division, *david.diamond@boem.gov.*

Dated: September 3, 2015.

Abigail Ross Hopper,

Director, Bureau of Ocean Energy Management.

[FR Doc. 2015–23105 Filed 9–11–15; 8:45 am]

BILLING CODE 4310–MR–P

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[Notice: (15–075)]

Notice of Information Collection

AGENCY: National Aeronautics and Space Administration (NASA).

ACTION: Notice of information collection.

SUMMARY: The National Aeronautics and Space Administration, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995 (Pub. L. 104–13, 44 U.S.C. 3506(c)(2)(A)).

DATES: All comments should be submitted within 30 calendar days from the date of this publication.

ADDRESSES: Interested persons are invited to submit written comments regarding the proposed information collection to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 7th Street NW., Washington, DC 20543. Attention: Desk Officer for NASA.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the information collection instrument(s) and instructions should be directed to Fran Teel, NASA PRA Officer, NASA Headquarters, 300 E Street SW., Mail Code JF000, Washington, DC 20546, (202) 358–2225 or *frances.c.teel@nasa.gov.*

SUPPLEMENTARY INFORMATION:

I. Abstract

The National Aeronautics and Space Administration (NASA) Office of Diversity and Equal Opportunity, in accordance with title VII of the Civil Rights Act of 1964, the Age Discrimination Act of 1975 and 42 U.S.C. 2000e–16; 29 CFR 1614.106 and 1614.108, is authorized to collect information on issues and allegations of a complaint of discrimination based on race, color, sex (including sexual harassment, religion, national origin, disability (physical or mental), reprisal, sexual orientation, gender identity, status as a parent or genetic information. This requirement for assurance of non-discrimination is long-standing and derives from civil rights implementing regulations. This information collection includes complaint investigations.

II. Method of Collection

Electronic Form.

III. Data

Title: NASA Complaint of Discrimination Form.

OMB Number: 2700–XXXX.

Type of review: Existing collection in use without an OMB control number.

Affected Public: Individuals.

Estimated Number of Respondents: 85.

Estimated Annual Responses: 80 per year.

Estimated Time per Response: 30 minutes.

Estimated Total Annual Burden Hours: 60 hours.

Estimated Total Annual Cost: $500.00.

IV. Request for Comments

Comments are invited on: (1) Whether the proposed collection of information is necessary for the proper performance of the functions of NASA, including whether the information collected has practical utility; (2) the accuracy of NASA's estimate of the burden (including hours and cost) of the proposed collection of information; (3) ways to enhance the quality, utility, and clarity of the information to be collected; and (4) ways to minimize the burden of the collection of information on respondents, including automated collection techniques or the use of other forms of information technology.

Frances Teel,

NASA PRA Clearance Officer.

[FR Doc. 2015–23000 Filed 9–11–15; 8:45 am]

BILLING CODE 7510–13–P

NATIONAL SCIENCE FOUNDATION

Management Fee Policy

AGENCY: National Science Foundation.

ACTION: Notice.

SUMMARY: On December 30, 2014, the National Science Foundation (NSF) published at 79 FR 78497 a notice and request for comments on NSF's revised policy on management fee. The payment of a small but appropriate management fee has been a long standing practice at NSF in limited circumstances related to the construction and operation of major facility projects. NSF has strengthened both the criteria used to establish such fees and the controls that may be necessary to ensure that uses of fees are consistent with those established criteria. These efforts resulted in the revised policy that was sent for public comment. On June 16, 2015, NSF received OMB approval under the Paperwork Reduction Act for the Large Facilities Manual (3145–0239) which included NSF's final policy on management fee under Section 4.2.2.2.

FOR FURTHER INFORMATION CONTACT: Suzanne Plimpton on (703) 292–7556 or send email to *splimpto@nsf.gov.* Individuals who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 1–800–877–8339, which is accessible 24 hours a day, 7 days a week, 365 days a year (including federal holidays).

SUPPLEMENTARY INFORMATION: The following final Management Fee Policy can be found in NSF's Large Facilities Manual:

4.2.2.2 Management Fee

Management fee is an amount of money paid to a recipient in excess of a cooperative agreement's or cooperative support agreement's allowable costs. Generally, NSF does not permit the payment of fee (profit) to organizations under financial assistance. However, a management fee may be authorized for awards in the limited circumstances of construction or operations of a large facility as the responsible organization is likely to incur certain legitimate business expenses that may not be reimbursable under the governing cost principles. NSF provides for a

management fee in these limited circumstances, as appropriate, recognizing that the awardee would only incur such expenses as a result of its support of the NSF-funded activity.

Prior Approval of Management Fees—A management fee proposal must be submitted to NSF that provides sufficient visibility into each expense category to identify its intended purpose. Agreement on management fee amounts shall be completed and a specific dollar amount established prior to the initiation of work under an award, or any subsequent period not authorized as part of the initial award. Any amount negotiated shall be expressly set forth in the terms and conditions of the award. Awardees may draw down the management fee in proportion to the amount incurred during the performance period. Fee established for a period longer than one year shall be subject to adjustment in the event of a significant change to the budget or work scope.

The following expense categories will be used in the negotiation and award of a management fee:

- Working capital necessary to fund operations under an award—An amount for working capital may be necessary to ensure a level of retained earnings available to the organization in order to secure credit and borrowing to assure the financial health of the organization.
- Facilities capital necessary to acquire assets for performance—An amount for facilities capital may be necessary to allow the organization to acquire major assets and to address expenses that require immediate substantive financial outlays but that are only reimbursed through depreciation or amortization over a period of years.
- Other ordinary and necessary expenses for business operations that are not otherwise reimbursable under the governing cost principles—An amount for other expenses that are ordinary and necessary but not otherwise reimbursable may be necessary to provide a reasonable allowance for management initiative and investments that will directly or indirectly benefit the NSF-funded activity. Inclusion of amounts under this category warrants careful consideration of the benefits that may be obtained when providing management fee. Examples of potential appropriate needs include expenses related to contract terminations and losses, certain appropriate educational and public outreach activities, and financial incentives to obtain and retain high caliber staff.
- Prohibited Use of Management Fees—Although not an exhaustive list, the following are examples of expenses that are not appropriate uses of a management fee:
  - Alcoholic beverages
  - Tickets to concerts, sporting and other events
  - Vacation or other travel for non-business purposes
  - Social or sporting club memberships
  - Meals or social activities for non-business purposes
  - Meals or social activities for business purposes that are so extravagant as to constitute entertainment
  - Luxury or personal items
  - Lobbying as set forth at 2 CFR 200.450 and FAR 31.205–22, as appropriate to the recipient type

In addition, costs incurred under the award that are otherwise allowable under the governing cost principles must be classified as direct or indirect charges to the award and shall not be included as proposed management fee elements.

Documentation Requirements on Use of Management Fees—Even though the management fee represents an amount in excess of allowable cost and is therefore not subject to the governing cost principles, NSF, as a matter of policy, has determined that review of appropriate use of such funds is necessary. Information available on actual uses of management fee previously awarded by NSF in the preceding five-year period under any award shall be included in the proposing organization's fee proposal. As a term and condition of the award, the awardee will be required to provide information (typically annually) on the actual use(s) of the management fee. NSF will conduct reviews of this information regarding the extent to which the awardee fee proposals have proven reliable when compared with actual uses of management fee (both as to the fee amount as well as the planned uses of the fee). Unexplained failure to reasonably adhere to planned uses of fee will result in reduction of future management fee amounts under the award.

Dated: September 9, 2015.

Suzanne H. Plimpton,

Reports Clearance Officer, National Science Foundation.

[FR Doc. 2015–23015 Filed 9–11–15; 8:45 am]

BILLING CODE 7555–01–P

NUCLEAR REGULATORY COMMISSION

[Docket Nos. 50–336 and EA–13–188; NRC–2015–0217]

In the Matter of Dominion Nuclear Connecticut, Inc. (Millstone Power Station Unit 2)

AGENCY: Nuclear Regulatory Commission.

ACTION: Confirmatory order; issuance.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) and the Dominion Nuclear Connecticut, Inc. (DNC) engaged in mediation as part of the NRC's Alternative Dispute Resolution Program which resulted in a settlement agreement as reflected in the confirmatory order relating to Millstone Unit 2.

DATES: *Effective Date:* August 26, 2015.

ADDRESSES: Please refer to Docket ID NRC–2015–0217 when contacting the NRC about the availability of information regarding this document. You may obtain publicly-available information related to this document using any of the following methods:

- *Federal Rulemaking Web site:* Go to *http://www.regulations.gov* and search for Docket ID NRC–2015–0217. Address questions about NRC dockets to Carol Gallagher; telephone: 301–415–3463; email: *Carol.Gallagher@nrc.gov.* For questions about this Order, contact the individual listed in the **FOR FURTHER INFORMATION CONTACT** section of this document.
- *NRC's Agencywide Documents Access and Management System (ADAMS):* You may obtain publicly-available documents online in the ADAMS Public Documents collection at *http://www.nrc.gov/reading-rm/adams.html.* To begin the search, select "*ADAMS Public Documents*" and then select "*Begin Web-based ADAMS Search.*" For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1–800–397–4209, 301–415–4737, or by email to *pdr.resource@nrc.gov.* The ADAMS accession number for each document referenced (if it available in ADAMS) is provided the first time that a document is referenced.
- *NRC's PDR:* You may examine and purchase copies of public documents at the NRC's PDR, Room O1–F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

FOR FURTHER INFORMATION CONTACT: Richard Guzman, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001; telephone: 301–415–1030, email: *Richard.Guzman@nrc.gov.*

SUPPLEMENTARY INFORMATION: The text of the Order is attached.

Dated at Rockville, Maryland, this 3rd day of September 2015.

For the Nuclear Regulatory Commission.

Dave J. Vito,

Acting Chief, Concerns Resolution Branch, Office of Enforcement.

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of Dominion Nuclear Connecticut, Inc. (Millstone Power Station Unit 2)

Docket No. 50–336
License No. DPR–65
EA–13–188

CONFIRMATORY ORDER MODIFYING LICENSE

(EFFECTIVE IMMEDIATELY)

I.

Dominion Nuclear Connecticut, Inc. (DNC or Licensee) is the holder of Facility Operating License No. DPR–65 issued by the Nuclear Regulatory Commission (NRC or Commission) pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) part 50 on September 26, 1975. The license authorizes the operation of Millstone Power Station (Millstone) Unit 2 in accordance with conditions specified therein. Millstone Power Station Unit 2 is located in the vicinity of Waterford, Connecticut.

This Confirmatory Order is the result of an agreement reached during an alternative dispute resolution (ADR) mediation process which included one meeting on July 14, 2015, and two follow up teleconferences on July 16, 2015 and July 24, 2015.

II.

On May 23, 2013, the NRC's Office of Investigations (OI) completed an investigation to determine if DNC staff at Millstone deliberately violated NRC requirements in section 50.59 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Changes, Tests, and Experiments," when implementing changes to documents related to the Millstone Unit 2 chemical and volume control system (CVCS) charging pumps and spent fuel decay time limits. The investigation also evaluated whether DNC staff deliberately submitted inaccurate and incomplete information to the NRC pertaining to these changes.

Based on the evidence developed during this investigation, the NRC concluded that three apparent violations occurred, two of which were considered for escalated enforcement action. The first apparent violation (AV) involved changes made by DNC to Section 14.6.1 of the Millstone Unit 2 Updated Final Safety Analysis Report (UFSAR) that removed credit for the CVCS charging pump flow in the mitigation of the design basis accident involving the inadvertent opening of pressurizer power operated relief valves (PORVs), without obtaining prior NRC approval. The NRC found that willfulness was associated with this apparent violation. DNC does not agree that willfulness was associated with this apparent violation.

The second AV involved the failure by DNC to provide complete and accurate information to the NRC in reports and other documents pertaining to the aforementioned UFSAR change, including a failure to notify the Commission of information having significant implications for public health and safety. Willfulness was not associated with this apparent violation.

The third AV involved changes made by DNC to Chapter 9 of the Millstone Unit 2 UFSAR and Section 3/4.9.3 of the Technical Specification Bases that decreased the required amount of irradiated fuel decay time from 150 to 100 hours prior to fuel movement in the reactor vessel, without obtaining prior NRC approval. Willfulness was not associated with this apparent violation.

In a letter dated April 29, 2015, the NRC provided DNC the results of the investigation, informed DNC that escalated enforcement action was being considered for two of the three apparent violations, and offered DNC the opportunity to attend a predecisional enforcement conference or to participate in ADR in which a neutral mediator with no decision-making authority would facilitate discussions between the NRC and DNC. The neutral mediator would assist the NRC and DNC in reaching an agreement, if possible. DNC chose to participate in ADR. This Confirmatory Order is issued pursuant to the agreement reached during the ADR process.

III.

In response to the NRC's offer, DNC requested use of the NRC ADR process to resolve differences it had with the NRC. During that ADR process, a preliminary settlement agreement was reached the terms of which are set forth in Section IV below.

Based on those commitments, the NRC agreed not to take further enforcement action on the three apparent violations identified in the NRC April 29, 2015, letter.

On August 20, 2015, DNC consented to issuing this Confirmatory Order with the commitments, as described in Section IV below. DNC further agreed that this Confirmatory Order is to be effective upon issuance and that it has waived its right to a hearing.

I find that the DNC's commitments as set forth in Section IV are acceptable and necessary and conclude that with these commitments the plant's safety is reasonably assured. In view of the foregoing, I have determined that public health and safety require that DNC's commitments be confirmed by this Confirmatory Order. Based on the above and DNC's consent, this Confirmatory Order is effective upon issuance. By no later than thirty (30) days after the completion of the commitments in Section IV, DNC is required to notify the NRC in writing and summarize its actions.

IV.

Accordingly, pursuant to Sections 104b, 161b, 161i, 161o, 182 and 186 of the Atomic Energy Act of 1954, as amended, and the Commission's regulations in 10 CFR 2.202 and 10 CFR part 50, IT IS HEREBY ORDERED THAT LICENSE NO. DPR–65 IS MODIFIED AS FOLLOWS:

Compliance.

1. Within sixty (60) calendar days of the date of this Confirmatory Order, DNC will:

a. Revise, as necessary, Standing Order 14–016 dated May 11, 2014, to incorporate applicable Millstone Unit 2 Technical Specifications (TSs); limiting conditions of operations (LCOs); actions; and surveillances that reflect the safety analysis of the inadvertent opening of the PORVs prior to implementation of Amendment No. 283. This revision of the standing order will be made available for NRC review prior to implementation.

b. Complete an operability evaluation for the use of charging pumps in accordance with Standing Order 14–016, as revised by paragraph 1.a., associated with the inadvertent opening of PORVs and make the operability evaluation available to NRC for review; and

c. Evaluate the effect of three pump charging pump operation (*i.e.*, three charging pumps auto start and provide flow) with the current plant configuration. If the evaluation concludes no adverse effect, revised Standing Order 14–016 will be changed to require that three charging pumps auto start and provide flow. This evaluation will be made available for NRC review.

2. By no later than February 15, 2016, DNC will submit a license amendment request to the NRC addressing the use of charging pumps in the analysis of the inadvertent opening of PORVs. If DNC

does not submit a license amendment request by February 15, 2016, the Millstone Unit 2 design and licensing basis for the operation of charging pumps to mitigate the inadvertent opening of PORVs that was in place prior to Amendment No. 283 (dated September 9, 2004) will be reinstated by this Confirmatory Order, and DNC will take all actions necessary to conform Millstone Unit 2 to the reinstated design and licensing basis.

3. DNC's Standing Order 14–016 (Rev. 0, dated May 11, 2014), as revised in accordance with paragraph 1 above, will remain in place until the NRC makes a final determination on the license amendment request submitted under paragraph 2 above.

4. If the NRC denies the license amendment request submitted under paragraph 2 above, or the licensee withdraws the license amendment request, the Millstone Unit 2 design and licensing basis for the operation of charging pumps to mitigate the inadvertent opening of PORVs that was in place prior to implementation of Amendment No. 283 (dated September 9, 2004) will be reinstated by this Confirmatory Order, and DNC will take all actions necessary to conform Millstone Unit 2 to the reinstated design and licensing basis.

5. By no later than February 15, 2016, DNC will submit a license amendment request seeking NRC approval of the spent fuel pool heat load analysis and any associated technical specification changes. This will be treated as a high priority review by the NRC.

6. DNC's Standing Order 14–021 (Rev. 0 dated July 9, 2014) will remain in place until the NRC makes a final determination on the license amendment request submitted under paragraph 5 above.

7. If the NRC denies the license amendment request submitted under paragraph 5 above, or the licensee withdraws the license amendment request, TS 3/4.9.3.1 in the Millstone Unit 2 license will be revised by this Confirmatory Order to require 150 hours of decay time before moving irradiated fuel from the reactor to the spent fuel pool, and changes made by Licensing Basis Document Change Request 10–MP2–007 (dated June 22, 2010) to Chapter 9 of the Millstone Unit 2 UFSAR and to the TS Bases will be replaced by the prior content of those documents. DNC will take all actions necessary to conform Millstone Unit 2 to the requirements of the revised TS and UFSAR.

Assessment.

8. By no later than June 30, 2016, DNC will complete a self-assessment of its 10 CFR 50.59 program and procedures (including applicability, screening and evaluations) including a review of procedures, implementation, initial training, continuing training, and safety review committee activities. A majority of the self-assessment team will be comprised of a combination of non-Dominion industry experts and peers. The assessment will also address the Millstone Nuclear Oversight organization's responsibilities and the effectiveness of the execution of those responsibilities regarding the 10 CFR 50.59 program.

a. DNC shall make available to the NRC, upon request, the results of the assessment and any corrective actions DNC will take to address the results.

b. DNC will complete corrective actions resulting from findings of the assessment consistent with the requirements of the Millstone Corrective Action Program.

9. DNC has conducted two apparent cause evaluations to address the issues included in this Confirmatory Order.

a. The results of these evaluations will be made available to the NRC for review.

10. By no later than March 1, 2016, DNC will complete a common cause evaluation of 10 CFR 50.59 issues that have been identified after July 1, 2012, with emphasis on any underlying culture-related issues that specifically may exist in the Millstone Power Station Engineering and Licensing groups and the Facility Safety Review Committee. The team will include a member trained in cultural issues. Interviews of a sample of the staff members from the above groups will be included in the evaluation. In regard to this evaluation, DNC shall:

a. Make the results of the evaluation available to the NRC.

b. Communicate to Millstone Power Station employees the results of the evaluation within three (3) months of receiving the evaluation results.

c. Review the results of the common cause evaluation and initiate corrective actions as appropriate within 30 days of receiving evaluation results.

Extent of Condition.

11. By no later than June 30, 2016, DNC will complete a formal sampling program, using MIL Standard 105 or similar, of products (applicability determinations, screenings, and evaluations) completed using the DNC 10 CFR 50.59 programs and procedures.

a. The reviewers conducting the sampling program will be third party independent reviewers.

b. Applicability determinations, screenings, and evaluations will be sampled as separate populations.

c. For each population, the sampling time period will begin in 2002 and end as of the date of this Confirmatory Order.

d. DNC will enter any identified deficiencies into DNC's corrective action program.

e. Pursuant to Section 3.3 of the NRC Enforcement Policy, the NRC will consider exercising enforcement discretion to refrain from issuing a Notice of Violation or civil penalty for any non-willful Severity Level II, III, or IV violation identified as part of the sampling program described above, if the violation meets all of the following criteria:

(1) the violation has the same or similar cause as the apparent violations of 10 CFR 50.59 that are the subject of this Confirmatory Order;

(2) the violation is a newly-found violation that occurred prior to issuance of this Confirmatory Order;

(3) the violation does not substantially change the safety significance or the character of the regulatory concerns arising out of the apparent violations that underlie this Confirmatory Order; and

(4) the violation is corrected, by both immediate corrective action(s) and long-term comprehensive corrective action(s), within a reasonable time following identification.

f. The NRC will also consider discretion for any DNC-identified performance deficiencies that meet the criteria listed in paragraph 11.e and are categorized as a Green or White finding under the NRC's Reactor Oversight Program.

Communication.

12. By no later than thirty (30) calendar days after the issuance of this Confirmatory Order, DNC's Chief Nuclear Officer will issue a fleet-wide communication (written or recorded) to reinforce the importance of providing complete and accurate information to the NRC, including requirements for updating out-of-date information, and the potential consequences of a failure to comply with these requirements. The communication, whether written or recorded, and any associated materials or references, will be made available to the NRC.

13. By no later than December 31, 2016, DNC will provide a presentation at an industry forum to discuss the events that led to this Confirmatory Order, the lessons learned, and actions taken. The presentation and any associated material will be made available to the NRC.

Training.

14. DNC will review its plant access training and revise it as necessary to

ensure that it includes training on compliance with NRC requirements, including, but not limited to, 10 CFR 50.5 and 50.9. Any revisions will be made available to the NRC.

15. Notwithstanding that NRC and DNC disagree about whether a willful violation occurred, DNC will develop and provide focused training to Dominion corporate Engineering and Licensing personnel who perform work for Millstone and to DNC Engineering and Licensing personnel, to ensure awareness of the importance of complying with regulatory requirements, and the potential consequences of a failure to comply, including what constitutes a willful violation of NRC requirements. DNC will provide this training by April 1, 2016, and will repeat it 12 months after the initial training session. The training and any associated training materials will be made available to the NRC.

16. DNC will develop and provide focused training to Dominion corporate Engineering and Licensing personnel performing work for Millstone and to DNC Engineering and Licensing personnel, covering the requirements of 10 CFR 50.9, emphasizing the importance of providing complete and accurate information to the NRC and of informing the NRC promptly upon discovery of inaccurate information or omissions associated with pending NRC licensing actions or other information submitted to the NRC. DNC will provide this training by April 1, 2016. The training and any associated training materials will be made available to the NRC.

Other Considerations.

17. The NRC agrees not to pursue any further enforcement action relating to the notice of apparent violations (Case no. EA–13–188, Inspection Report 05000336/2015201, Office of Investigations Report No. 1–2012–008), dated April 29, 2015.

18. This Confirmatory Order will not be considered an escalated enforcement action by the NRC for future assessment of violations occurring at Millstone Power Station Unit 2.

19. In the event of the transfer of the operating license of Millstone Power Station Unit 2 to another entity, the commitments hereunder shall survive any transfer of ownership and will be binding on the new licensee.

The Director, Office of Enforcement, may, in writing, relax or rescind any of the above conditions upon demonstration by the Licensee of good cause.

V.

Any person adversely affected by this Confirmatory Order, other than DNC, may request a hearing within 30 days of issuance. Where good cause is shown, consideration will be given to extending the time to request a hearing. A request for extension of time must be made in writing to the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, Washington, DC 20555, and include a statement of good cause for the extension.

All documents filed in NRC adjudicatory proceedings, including a request for hearing, a petition for leave to intervene, any motion or other document filed in the proceeding prior to the submission of a request for hearing or petition to intervene, and documents filed by interested governmental entities participating under 10 CFR 2.315(c), must be filed in accordance with the NRC E-Filing rule (72 FR 49139, August 28, 2007). The E-Filing process requires participants to submit and serve all adjudicatory documents over the internet, or in some cases to mail copies on electronic storage media. Participants may not submit paper copies of their filings unless they seek an exemption in accordance with the procedures described below.

To comply with the procedural requirements of E-Filing, at least ten (10) days prior to the filing deadline, the participant should contact the Office of the Secretary by email at *hearing.docket@nrc.gov*, or by telephone at 301–415–1677, to (1) request a digital ID certificate, which allows the participant (or its counsel or representative) to digitally sign documents and access the E-Submittal server for any proceeding in which it is participating; and (2) advise the Secretary that the participant will be submitting a request or petition for hearing (even in instances in which the participant, or its counsel or representative, already holds an NRC-issued digital ID certificate). Based upon this information, the Secretary will establish an electronic docket for the hearing in this proceeding if the Secretary has not already established an electronic docket.

Information about applying for a digital ID certificate is available on NRC's public Web site at *http://www.nrc.gov/site-help/e-submittals/apply-certificates.html*. System requirements for accessing the E-Submittal server are detailed in NRC's "Guidance for Electronic Submission," which is available on the agency's public Web site at *http://www.nrc.gov/site-help/e-submittals.html*. Participants may attempt to use other software not listed on the Web site, but should note that the NRC's E-Filing system does not support unlisted software, and the NRC Meta System Help Desk will not be able to offer assistance in using unlisted software.

If a participant is electronically submitting a document to the NRC in accordance with the E-Filing rule, the participant must file the document using the NRC's online, Web-based submission form. Further information on the Web-based submission form is available on the NRC's public Web site at *http://www.nrc.gov/site-help/e-submittals.html*.

Once a participant has obtained a digital ID certificate and a docket has been created, the participant can then submit a request for hearing or petition for leave to intervene. Submissions should be in Portable Document Format (PDF) in accordance with NRC guidance available on the NRC public Web site at *http://www.nrc.gov/site-help/e-submittals.html*. A filing is considered complete at the time the documents are submitted through the NRC's E-Filing system. To be timely, an electronic filing must be submitted to the E-Filing system no later than 11:59 p.m. Eastern Time on the due date. Upon receipt of a transmission, the E-Filing system time-stamps the document and sends the submitter an email notice confirming receipt of the document. The E-Filing system also distributes an email notice that provides access to the document to the NRC Office of the General Counsel and any others who have advised the Office of the Secretary that they wish to participate in the proceeding, so that the filer need not serve the documents on those participants separately. Therefore, applicants and other participants (or their counsel or representative) must apply for and receive a digital ID certificate before a hearing request/petition to intervene is filed so that they can obtain access to the document via the E-Filing system.

A person filing electronically using the agency's adjudicatory E-Filing system may seek assistance by contacting the NRC Electronic Filing Help Desk through the "Contact Us" link located on the NRC Web site at *http://www.nrc.gov/site-help/e-submittals.html*, by email at *MSHD.Resource@nrc.gov*, or by a toll-free call at (866) 672–7640. The NRC Electronic Filing Help Desk is available between 8 a.m. and 8 p.m., Eastern Time, Monday through Friday, excluding government holidays.

Participants who believe that they have a good cause for not submitting documents electronically must file an exemption request, in accordance with 10 CFR 2.302(g), with their initial paper filing requesting authorization to continue to submit documents in paper format. Such filings must be submitted by: (1) first class mail addressed to the Office of the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001, Attention: Rulemaking and Adjudications Staff; or (2) courier, express mail, or expedited delivery service to the Office of the Secretary, Sixteenth Floor, One White Flint North, 11555 Rockville Pike, Rockville, Maryland, 20852, Attention: Rulemaking and Adjudications Staff. Participants filing a document in this manner are responsible for serving the document on all other participants. Filing is considered complete by first-class mail as of the time of deposit in the mail, or by courier, express mail, or expedited delivery service upon depositing the document with the provider of the service. A presiding officer, having granted an exemption request from using E-Filing, may require a participant or party to use E-Filing if the presiding officer subsequently determines that the reason for granting the exemption from use of E-Filing no longer exists.

Documents submitted in adjudicatory proceedings will appear in NRC's electronic hearing docket which is available to the public at *http://ehd1.nrc.gov/ehd/*, unless excluded pursuant to an order of the Commission, or the presiding officer. Participants are requested not to include personal privacy information, such as social security numbers, home addresses, or home phone numbers in their filings, unless an NRC regulation or other law requires submission of such information. With respect to copyrighted works, except for limited excerpts that serve the purpose of the adjudicatory filings and would constitute a Fair Use application, participants are requested not to include copyrighted materials in their submission.

If a person (other than DNC) requests a hearing, that person shall set forth with particularity the manner in which his interest is adversely affected by this Confirmatory Order and shall address the criteria set forth in 10 CFR 2.309(d) and (f).

If a hearing is requested by a person whose interest is adversely affected, the Commission will issue an order designating the time and place of any hearing. If a hearing is held, the issue to be considered at such hearing shall be whether this Confirmatory Order should be sustained.

In the absence of any request for hearing, or written approval of an extension of time in which to request a hearing, the provisions specified in Section IV above shall be final 30 days from the date of issuance without further order or proceedings. If an extension of time for requesting a hearing has been approved, the provisions specified in Section IV shall be final when the extension expires if a hearing request has not been received.

Dated at Rockville, Maryland, this 26th day of August 2015.

For the Nuclear Regulatory Commission.

Scott A. Morris,

Director, Division of Inspection and Regional Support, Office of Nuclear Reactor Regulation

[FR Doc. 2015–22951 Filed 9–11–15; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

[NRC–2015–0001]

Sunshine Act Meeting Notice

DATE: September 14, 21, 28, October 5, 12, 19, 2015.

PLACE: Commissioners' Conference Room, 11555 Rockville Pike, Rockville, Maryland.

STATUS: Public and Closed.

Week of September 14, 2015

There are no meetings scheduled for the week of September 14, 2015.

Week of September 21, 2015—Tentative

Tuesday, September 22, 2015

9:30 a.m. Discussion of Management and Personnel Issues (Closed—Ex. 2 & 6).

Thursday, September 24, 2015

9:30 a.m. Strategic Programmatic Overview of the New Reactors Business Line (Public Meeting); (Contact: Donna Williams: 301–415–1322).

This meeting will be webcast live at the Web address—*http://www.nrc.gov/.*

Week of September 28, 2015—Tentative

Monday, September 28, 2015

1:30 p.m. NRC All Employees Meeting (Public Meeting), Marriott Bethesda North Hotel, 5701 Marinelli Road, Rockville, MD 20852.

Thursday, October 1, 2015

9:00 a.m. Strategic Programmatic Overview of the Decommissioning and Low-Level Waste and Spent Fuel Storage and Transportation Business Lines (Public Meeting); (Contact: Damaris Marcano: 301–415–7328).

This meeting will be webcast live at the Web address—*http://www.nrc.gov/.*

Week of October 5, 2015—Tentative

There are no meetings scheduled for the week of October 5, 2015.

Week of October 12, 2015—Tentative

There are no meetings scheduled for the week of October 12, 2015.

Week of October 19, 2015—Tentative

Monday, October 19, 2015

9:30 a.m. Briefing on Security Issues (Closed—Ex. 1).

Wednesday, October 21, 2015

9:00 a.m. Joint Meeting of the Federal Energy Regulatory Commission and the Nuclear Regulatory Commission (Public Meeting); (Contact: Tania Martinez-Navedo: 301–415–6561).

* * * * *

The schedule for Commission meetings is subject to change on short notice. For more information or to verify the status of meetings, contact Glenn Ellmers at 301–415–0442 or via email at *Glenn.Ellmers@nrc.gov.*

* * * * *

The NRC Commission Meeting Schedule can be found on the Internet at: *http://www.nrc.gov/public-involve/public-meetings/schedule.html.*

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The NRC provides reasonable accommodation to individuals with disabilities where appropriate. If you need a reasonable accommodation to participate in these public meetings, or need this meeting notice or the transcript or other information from the public meetings in another format (*e.g.* braille, large print), please notify Kimberly Meyer, NRC Disability Program Manager, at 301–287–0727, by videophone at 240–428–3217, or by email at *Kimberly.Meyer-Chambers@nrc.gov.* Determinations on requests for reasonable accommodation will be made on a case-by-case basis.

* * * * *

Members of the public may request to receive this information electronically. If you would like to be added to the distribution, please contact the Nuclear Regulatory Commission, Office of the Secretary, Washington, DC 20555 (301–415–1969), or email *Brenda.Akstulewicz@nrc.gov* or *Patricia.Jimenez@nrc.gov.*

Dated: September 10, 2015.

Glenn Ellmers,

Policy Coordinator, Office of the Secretary.

[FR Doc. 2015–23173 Filed 9–10–15; 4:15 pm]

BILLING CODE 7590–01–P

SECURITIES AND EXCHANGE COMMISSION

[SEC File No. 270–442, OMB Control No. 3235–0498]

Proposed Collection; Comment Request

Upon Written Request, Copies Available From: Securities and Exchange Commission, Office of FOIA Services, 100 F Street NE., Washington, DC 20549–2736.

Extension: Rule 17a–12/Form X–17A–5 Part IIB.

Notice is hereby given that pursuant to the Paperwork Reduction Act of 1995 ("PRA") (44 U.S.C. 3501 *et seq.*), the Securities and Exchange Commission ("Commission") is soliciting comments on the existing collection of information provided for in Rule 17a–12 (17 CFR 240.17a–12) and Part IIB of Form X–17A–5 (17 CFR 249.617) under the Securities Exchange Act of 1934 (15 U.S.C. 78a *et seq.*). The Commission plans to submit this existing collection of information to the Office of Management and Budget ("OMB") for extension and approval.

Rule 17a–12 is the reporting rule tailored specifically for over-the-counter ("OTC") derivatives dealers registered with the Commission, and Part IIB of Form X–17A–5, the Financial and Operational Combined Uniform Single ("FOCUS") Report, is the basic document for reporting the financial and operational condition of OTC derivatives dealers. Rule 17a–12 requires registered OTC derivatives dealers to file Part IIB of the FOCUS Report quarterly. Rule 17a–12 also requires that OTC derivatives dealers file audited financial statements annually.

There are currently four registered OTC derivatives dealers. The staff expects that one additional firm will register as an OTC derivatives dealer within the next three years. The staff estimates that the average amount of time necessary to prepare and file the quarterly reports required by the rule is eighty hours per OTC derivatives dealer [1] and that the average amount of time to prepare and file the annual audit report is 100 hours per OTC derivatives dealer per year, for a total reporting burden of 180 hours per OTC derivatives dealer annually. Thus the staff estimates that the total industry-wide reporting burden to comply with the requirements of Rule 17a–12 is 900 hours per year (180 × 5). Further, the Commission estimates that the total internal compliance cost associated with this requirement is approximately $255,000 per year.[2] The average annual reporting cost per broker-dealer for an independent public accountant to examine the financial statements is approximately $46,300 per broker-dealer. Thus, the total industry-wide annual reporting cost is approximately $231,500 ($46,300 × 5).

Written comments are invited on: (a) Whether the proposed collection of information is necessary for the proper performance of the functions of the Commission, including whether the information shall have practical utility; (b) the accuracy of the Commission's estimate of the burden of the proposed collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology. Consideration will be given to comments and suggestions submitted in writing within 60 days of this publication.

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information under the PRA unless it displays a currently valid OMB control number.

Please direct your written comments to: Pamela Dyson, Director/Chief Information Officer, Securities and Exchange Commission, c/o Remi Pavlik-Simon, 100 F Street NE., Washington, DC 20549, or send an email to: *PRA_Mailbox@sec.gov.*

[1] Based upon an average of 4 responses per year and an average of 20 hours spent preparing each response.

[2] Based on staff experience, an OTC derivatives dealer likely would have a Compliance Manager gather the necessary information and prepare and file the quarterly reports and annual audit report and supporting schedules. According to the Securities Industry and Financial Markets Association Report on Management and Professional Earnings in the Securities Industry dated October 2013, which provides base salary and bonus information for middle-management and professional positions within the securities industry, the hourly cost of a compliance manager, which the Commission staff has modified to account for an 1800-hour work year and multiplied by 5.35 to account for bonuses, firm size, employee benefits, and overhead, is approximately $283/hour. $283/hour times 900 hours = $254,700, rounded to $255,000.

Dated: September 8, 2015.

Robert W. Errett,

Deputy Secretary.

[FR Doc. 2015–22976 Filed 9–11–15; 8:45 am]

BILLING CODE 8011–01–P

SECURITIES AND EXCHANGE COMMISSION

[Release No. 34–75856; File No. SR–MIAX–2015–53]

Self-Regulatory Organizations; Miami International Securities Exchange LLC; Notice of Filing and Immediate Effectiveness of a Proposed Rule Change To Amend Its Fee Schedule

September 8, 2015.

Pursuant to the provisions of Section 19(b)(1) of the Securities Exchange Act of 1934 ("Act"),[1] and Rule 19b–4 thereunder,[2] notice is hereby given that on August 28, 2015, Miami International Securities Exchange LLC ("MIAX" or "Exchange") filed with the Securities and Exchange Commission ("Commission") a proposed rule change as described in Items I, II, and III below, which Items have been prepared by the Exchange. The Commission is publishing this notice to solicit comments on the proposed rule change from interested persons.

I. Self-Regulatory Organization's Statement of the Terms of Substance of the Proposed Rule Change

The Exchange is filing a proposal to amend the MIAX Options Fee Schedule (the "Fee Schedule").

The text of the proposed rule change is available on the Exchange's Web site at *http://www.miaxoptions.com/filter/wotitle/rule_filing,* at MIAX's principal office, and at the Commission's Public Reference Room.

II. Self-Regulatory Organization's Statement of the Purpose of, and Statutory Basis for, the Proposed Rule Change

In its filing with the Commission, the Exchange included statements concerning the purpose of and basis for the proposed rule change and discussed any comments it received on the proposed rule change. The text of these statements may be examined at the places specified in Item IV below. The Exchange has prepared summaries, set forth in sections A, B, and C below, of the most significant aspects of such statements.

[1] 15 U.S.C. 78s(b)(1).

[2] 17 CFR 240.19b–4.

A. Self-Regulatory Organization's Statement of the Purpose of, and Statutory Basis for, the Proposed Rule Change

1. Purpose

The Exchange proposes to amend its Fee Schedule to increase the transaction fee rebate for Priority Customer[3] orders submitted by Members that meet certain percentage thresholds of national customer volume in multiply-listed option classes listed on MIAX in the Priority Customer Rebate Program (the "Program").[4]

Priority Customer Rebate Program

Currently, the Exchange credits each Member the per contract amount resulting from each Priority Customer order transmitted by that Member that is executed electronically on the Exchange in all multiply-listed option classes (excluding Qualified Contingent Cross Orders,[5] mini-options,[6] Priority Customer-to-Priority Customer Orders, PRIME Auction Or Cancel Responses, PRIME Contra-side Orders, PRIME Orders for which both the Agency and Contra-side Order are Priority Customers,[7] and executions related to contracts that are routed to one or more exchanges in connection with the Options Order Protection and Locked/Crossed Market Plan referenced in MIAX Rule 1400), provided the Member meets certain tiered percentage thresholds in a month as described in the Priority Customer Rebate Program table.[8] For each Priority Customer order transmitted by that Member and executed electronically on the Exchange, MIAX will continue to credit each member at the per contract rate for option classes that are not in MIAX Select Symbols (as defined below). For each Priority Customer order transmitted by that Member and executed electronically on the Exchange in MIAX Select Symbols (as defined below), MIAX will continue to credit each Member at the separate per contract rate for MIAX Select Symbols.[9] For each Priority Customer order submitted into the PRIME Auction as a PRIME Agency Order, MIAX will continue to credit each member at the separate per contract rate for PRIME Agency Orders.[10] The volume thresholds are calculated based on the customer volume over the course of the month. Volume will be recorded for and credits will be delivered to the Member Firm that submits the order to the Exchange.

The amount of the rebate is calculated beginning with the first executed contract at the applicable threshold per contract credit with rebate payments made at the highest achieved volume tier for each contract traded in that month. For example, under the current Program, a Member that executes a number of Priority Customer contracts above 1.75% of the national customer volume in multiply-listed options during a particular calendar month currently receives a credit of $0.17 for each Priority Customer contract (other than Select Symbols) executed during that month, even though there are lower incremental percentages for lower volume tiers leading up to the 1.75% volume threshold. In addition, all contracts (other than Select Symbols) traded in a particular month in excess of 1.75% of the national volume receive a supplemental rebate of $0.03 per contract.

The current Priority Customer Rebate Program table designates the following monthly volume tiers and corresponding per contract credits:

Percentage thresholds of national customer volume in multiply-listed options classes listed on MIAX (monthly)	Per contract credit (non-select symbols)	Per contract credit in MIAX select symbols	Per contract credit for PRIME agency order
Tier 1—0.00%–0.50%	$0.00	$0.00	$0.10
Tier 2—Above 0.50%–1.00%	0.10	0.10	0.10
Tier 3—Above 1.00%–1.75%–1.75% [sic]	0.15	0.20	0.10
Tier 4—Above 1.75%	0.17	0.20	0.10

The $0.17 per contract credit described in Tier 4 is applied to each contract traded in non-Select Symbols in that month, beginning with the first contract executed in a particular month if the Tier 4 volume threshold is achieved. In addition to the $0.17 rebate, a supplemental rebate of $0.03 per contract is applied to contracts executed in excess of 1.75% of the monthly national volume in non-Select Symbols.

Proposal

The Exchange proposes to increase the per contract credit for transactions in non-Select Symbols for Tier 4. As stated above, all contracts (other than Select Symbols) traded in a particular month when the Tier 4 volume threshold of 1.75% of the national monthly customer volume is exceeded receive a credit of $0.17 per contract for qualifying Priority Customer transactions on MIAX. The Exchange

[3] The term "Priority Customer" means a person or entity that (i) is not a broker or dealer in securities, and (ii) does not place more than 390 orders in listed options per day on average during a calendar month for its own beneficial accounts(s). *See* Exchange Rule 100.

[4] *See* Securities Exchange Act Release Nos. 75631 (August 5 [sic], 2015), 80 FR 48382 (August 6 [sic], 2015) (SR–MIAX–2015–51); 74758 (April 17, 2015), 80 FR 22756 (April 23, 2015) (SR–MIAX–2015–27); 74007 (January 9 [sic], 2015), 80 FR 1537 (January 12, 2015) (SR–MIAX–2014–69); 72799 (August 8, 2014), 79 FR 47698 (August 14, 2014) (SR–MIAX–2014–40); 72355 (June 10, 2014), 79 FR 34368 (June 16, 2014) (SR–MIAX–2014–25); 71698 (March 12, 2014), 79 FR 15185 (March 18, 2014) (SR–MIAX–2014–12); 71283 (January 10, 2014), 79 FR 2914 (January 16, 2014) (SR–MIAX–2013–63); 71009 (December 6, 2013), 78 FR 75629 (December 12, 2013) (SR–MIAX–2013–56).

[5] A Qualified Contingent Cross Order is comprised of an originating order to buy or sell at least 1,000 contracts, or 10,000 mini-option contracts, that is identified as being part of a qualified contingent trade, as that term is defined in Interpretations and Policies .01 below, coupled with a contra-side order or orders totaling an equal number of contracts. A Qualified Contingent Cross Order is not valid during the opening rotation process described in Rule 503. *See* Exchange Rule 516(j).

[6] A mini-option is a series of option contracts with a 10 share deliverable on a stock, Exchange Traded Fund share, Trust Issued Receipt, or other Equity Index-Linked Security. *See* Exchange Rule 404, Interpretations and Policies .08.

[7] The MIAX Price Improvement Mechanism ("PRIME") is a process by which a Member may electronically submit for execution ("Auction") an order it represents as agent ("Agency Order") against principal interest, and/or an Agency Order against solicited interest. For a complete description of PRIME and of PRIME order types and responses, *see* Exchange Rule 515A.

[8] *See* Fee Schedule Section (1)(a)(iii).

[9] *See* Securities Exchange [sic] Release Nos. 75631 (August 5 [sic], 2015), 80 FR 48382 (August 6 [sic], 2015) (SR–MIAX–2015–51); 74291 (February 18, 2015), 80 FR 9841 (February 24, 2015) (SR–MIAX–2015–09); 74288 (February 18, 2015), 80 FR 9837 (February 24, 2015) (SR–MIAX–2015–08); 71700 (March 12, 2014), 79 FR 15188 (March 18, 2014) (SR–MIAX–2014–13); 72356 (June 10, 2014), 79 FR 34384 (June 16, 2014) (SR–MIAX–2014–26); 72567 (July 8, 2014), 79 FR 40818 (July 14, 2014) (SR–MIAX–2014–34); 73328 (October 9, 2014), 79 FR 62230 (October 16, 2014) (SR–MIAX–2014–50).

[10] *See* Securities Exchange [sic] Release No. 72943 (August 28, 2014), 79 FR 52785 (September 4, 2014) (SR–MIAX–2014–45).

proposes to increase this per contract credit for Priority Customer transactions in non-Select Symbols in Tier 4 to $0.21. Contracts executed in non-Select Symbols in excess of 1.75% of national monthly customer volume currently receive a supplemental rebate of $0.03 per contract. The Exchange proposes to eliminate this additional $0.03 rebate per contract.

The Exchange also proposes to increase the per contract credit for transactions in MIAX Select Symbols for tiers 3 and 4. Currently, the Exchange credits $0.20 per contract for qualifying Priority Customer transactions in MIAX Select Symbols in tiers 3 and 4. The Exchange proposes to increase the per contract credit for transactions in MIAX Select Symbols to $0.21 for the tier 3 and 4 volume thresholds.

Specifically, the new per contract credits will be as set forth in the following table:

Percentage thresholds of national customer volume in multiply-listed options classes listed on MIAX (monthly)	Per contract credit (non-select symbols)	Per contract credit in MIAX select symbols	Per contract credit for PRIME agency order
Tier 1—0.00%–0.50%	$0.00	$0.00	$0.10
Tier 2—Above 0.50%–1.00%	0.10	0.10	0.10
Tier 3—Above 1.00%–1.75%	0.15	0.21	0.10
Tier 4—Above 1.75%	0.21	0.21	0.10

The Exchange believes that the proposed new monthly credits should provide incentives for Members to direct greater Priority Customer trade volume to the Exchange.

MIAX Select Symbols

The proposed new monthly per contract credits will apply to MIAX Select Symbols,[11] with the per contract credit increasing for certain monthly volume thresholds. The monthly per contract rebate will increase to $0.21 for all contracts executed in Select Symbols in tiers 3 and 4.

MIAX Non-Select Symbols

Proposed new monthly per contract credits will apply to non-Select Symbols with the per contract credit increasing for certain monthly volume thresholds. The monthly per contract credit will increase to $0.21 for all contracts executed in non-Select Symbols in tier 4. The Exchange also proposes to eliminate the current additional rebate of $0.03 per contract for non-Select Symbol contracts executed in excess of the Tier 4 monthly volume of 1.75% of the national customer volume. Under the proposal, all contracts (other than Select Symbols) traded in a particular month when the Tier 4 volume threshold of 1.75% of the national monthly customer volume is exceeded will receive a credit of $0.21, and contracts executed in non-Select Symbols in excess of 1.75% of national monthly customer volume will no longer receive a supplemental rebate of $0.03 per contract. The Exchange believes that this new, increased rebate which is calculated beginning with the first executed contract at the applicable threshold per contract credit with rebate payments made at $0.21 for each contract trade or [sic] that month obviates the need for the supplemental rebate.

All other aspects of the Program will remain unchanged. The Exchange is not proposing any change to the per contract credit for PRIME Agency Orders. Consistent with the current Fee Schedule, the Exchange will continue to aggregate the contracts resulting from Priority Customer orders transmitted and executed electronically on the Exchange from affiliated Members for purposes of the thresholds above, provided there is at least 75% common ownership between the firms as reflected on each firm's Form BD, Schedule A. In the event of a MIAX System outage or other interruption of electronic trading on MIAX, the Exchange will adjust the national customer volume in multiply-listed options for the duration of the outage. A Member may request to receive its credit under the Priority Customer Rebate Program as a separate direct payment.

The purpose of the proposed rule change is to encourage Members to direct greater Priority Customer trade volume to the Exchange and to compete with other options exchanges that have a similar rebate.[12] The Exchange believes that increased Priority Customer volume will attract more liquidity to the Exchange, which benefits all market participants. Increased retail customer order flow should attract professional liquidity providers (Market Makers), which in turn should make the MIAX marketplace an attractive venue where Market Makers will submit narrow quotations with greater size, deepening and enhancing the quality of the MIAX marketplace. This should provide more trading opportunities and tighter spreads for other market participants and result in a corresponding increase in order flow from such other market participants.

The specific volume thresholds of the Program's tiers are set based upon business determinations and an analysis of current volume levels. The volume thresholds are intended to incentivize firms to increase the number of Priority Customer orders they send to the Exchange so that they can achieve the next threshold, and to encourage new participants to send Priority Customer orders as well. Increasing the number of orders sent to the Exchange will in turn provide tighter and more liquid markets, and therefore attract more business overall. Similarly, the different credit rates at the different tier levels are based on an analysis of current revenue and volume levels and are intended to provide increasing "rewards" to MIAX participants for increasing the volume of Priority Customer orders sent to, and Priority Customer contracts executed on, the Exchange. The specific amounts of the tiers and rates are set in order to encourage suppliers of Priority Customer order flow to reach for higher tiers.

The credits paid out as part of the program will be drawn from the general revenues of the Exchange.[13] The Exchange calculates volume thresholds on a monthly basis.

[11] The term "MIAX Select Symbols" means options overlying AA, AAL, AAPL, AIG, AMAT, AMD, AMZN, BA, BABA, BBRY, BIDU, BP, C, CAT, CBS, CELG, CLF, CVX, DAL, EBAY, EEM, FB, FCX, GE, GILD, GLD, GM, GOOGL, GPRO, HAL, HTZ, INTC, IWM, JCP, JNJ, JPM, KMI, KO, MO, MRK, NFLX, NOK, NQ, ORCL, PBR, PFE, PG, QCOM, QQQ, RIG, S, SPY, SUNE, T, TSLA, USO, VALE, VXX, WBA, WFC, WMB, WY, X, XHB, XLE, XLF, XLP, XOM, XOP and YHOO. *See* Fee Schedule, note 13.

[12] See, e.g., Securities Exchange Act Release No. 75702 (August 14, 2015), 80 FR 50685 (August 20, 2015) (SR–PHLX–2015–68).

[13] Despite providing credits under the Program, the Exchange represents that it will continue to have adequate resources to fund its regulatory program and fulfill its responsibilities as a self-regulatory organization while the Program is in effect.

2. Statutory Basis

The Exchange believes that its proposal to amend its fee schedule is consistent with Section 6(b) of the Act[14] in general, and furthers the objectives of Section 6(b)(4) of the Act[15] in particular, in that it is an equitable allocation of reasonable fees and other charges among Exchange members.

The Exchange believes that the proposal is equitable and not unfairly discriminatory. The Program and the proposed increase in the per contract rebate is reasonably designed because it will encourage providers of Priority Customer order flow to send that Priority Customer order flow to the Exchange in order to receive an increasing per contract credit with each volume tier achieved. The Exchange believes that the proposed increase in the per contract rate should improve market quality for all market participants. The proposed changes to the rebate program are fair and equitable and not unreasonably discriminatory because they apply equally to all Priority Customer orders. All similarly situated Priority Customer orders are subject to the same rebate schedule, and access to the Exchange is offered on terms that are not unfairly discriminatory. Furthermore, the proposed increase in credits is equitable and not unfairly discriminatory because the proposed rates and changes encourage Members to direct increased amounts of Priority Customer contracts to the Exchange. Market participants want to trade with Priority Customer order flow. To the extent Priority Customer order flow is increased by the proposal, market participants will increasingly compete for the opportunity to trade on the Exchange including sending more orders and providing narrower and larger sized quotations in the effort to trade with such Priority Customer order flow. The resulting increased volume and liquidity will benefit all Exchange participants by providing more trading opportunities and tighter spreads.

B. Self-Regulatory Organization's Statement on Burden on Competition

The Exchange does not believe that the proposed rule change will impose any burden on competition not necessary or appropriate in furtherance of the purposes of the Act. The Exchange believes that the proposed change would increase both intermarket and intramarket competition by encouraging Members to direct their Priority Customer orders to the Exchange, which should enhance the quality of quoting and increase the volume of contracts traded on MIAX. Respecting the competitive position of non-Priority Customers, the Exchange believes that this rebate program should provide additional liquidity that enhances the quality of its markets and increases the number of trading opportunities on MIAX for all participants, including non-Priority Customers, who will be able to compete for such opportunities. This should benefit all market participants and improve competition on the Exchange.

The Exchange notes that it operates in a highly competitive market in which market participants can readily favor competing venues if they deem fee levels at a particular venue to be excessive. In such an environment, the Exchange must continually adjust its fees and rebates to remain competitive with other exchanges and to attract order flow to the Exchange. The Exchange believes that the proposed rule change reflects this competitive environment because it increases rebates and thus encourages market participants to direct their customer order flow, to provide liquidity, and to attract additional transaction volume to the Exchange. Given the robust competition for volume among options markets, many of which offer the same products, enhancing the existing volume based customer rebate program to attract order flow is consistent with the goals of the Act. The Exchange believes that the proposal will enhance competition, because market participants will have another additional pricing consideration in determining where to execute orders and post liquidity if they factor the benefits of the proposed rebate program into the determination.

C. Self-Regulatory Organization's Statement on Comments on the Proposed Rule Change Received From Members, Participants, or Others

Written comments were neither solicited nor received.

III. Date of Effectiveness of the Proposed Rule Change and Timing for Commission Action

The foregoing rule change has become effective pursuant to Section 19(b)(3)(A)(ii) of the Act.[16] At any time within 60 days of the filing of the proposed rule change, the Commission summarily may temporarily suspend such rule change if it appears to the Commission that such action is necessary or appropriate in the public interest, for the protection of investors, or otherwise in furtherance of the purposes of the Act. If the Commission takes such action, the Commission shall institute proceedings to determine whether the proposed rule should be approved or disapproved.

IV. Solicitation of Comments

Interested persons are invited to submit written data, views, and arguments concerning the foregoing, including whether the proposed rule change is consistent with the Act. Comments may be submitted by any of the following methods:

Electronic Comments

- Use the Commission's Internet comment form (*http://www.sec.gov/rules/sro.shtml*); or
- Send an email to *rule-comments@sec.gov*. Please include File Number SR–MIAX–2015–53 on the subject line.

Paper Comments

- Send paper comments in triplicate to Brent J. Fields, Secretary, Securities and Exchange Commission, 100 F Street NE., Washington, DC 20549–1090.

All submissions should refer to File Number SR–MIAX–2015–53. This file number should be included on the subject line if email is used. To help the Commission process and review your comments more efficiently, please use only one method. The Commission will post all comments on the Commission's Internet Web site (*http://www.sec.gov/rules/sro.shtml*). Copies of the submission, all subsequent amendments, all written statements with respect to the proposed rule change that are filed with the Commission, and all written communications relating to the proposed rule change between the Commission and any person, other than those that may be withheld from the public in accordance with the provisions of 5 U.S.C. 552, will be available for Web site viewing and printing in the Commission's Public Reference Room, 100 F Street NE., Washington, DC 20549 on official business days between the hours of 10:00 a.m. and 3:00 p.m. Copies of such filing also will be available for inspection and copying at the principal office of the Exchange. All comments received will be posted without change; the Commission does not edit personal identifying information from submissions. You should submit only information that you wish to make available publicly. All submissions should refer to File Number SR–MIAX–2015–53, and should be submitted on or before October 5, 2015.

[14] 15 U.S.C. 78f(b).

[15] 15 U.S.C. 78f(b)(4).

[16] 15 U.S.C. 78s(b)(3)(A)(ii).

For the Commission, by the Division of Trading and Markets, pursuant to delegated authority.[17]

Robert W. Errett,

Deputy Secretary.

[FR Doc. 2015–22977 Filed 9–11–15; 8:45 am]

BILLING CODE 8011–01–P

SMALL BUSINESS ADMINISTRATION

Regulatory Fairness Hearing; Region IX—Springerville, Arizona; Cancellation

AGENCY: U.S. Small Business Administration (SBA).

ACTION: Notice of open hearing of Region IX Small Business Owners and Business Leaders in Springerville, Arizona, cancellation.

Federal Register Citation of Previous Announcement: 80 FR 49296, August 17, 2015.

Previously Announced Time and Date of The Meeting: Wednesday, September 9, 2015, 8:30 a.m.–5:00 p.m. (MST).

Changes in the Meeting: Hearing Canceled: Due to budgetary constraints and logistical issues, the hearing on Wednesday, September 9, 2015, in Springerville, AZ from 8:30 a.m. to 5:00 p.m. (MST) must be postponed to a later date.

Contact Person for More Information: José Méndez, Case Management Specialist, Office of the National Ombudsman, 409 3rd Street SW., Suite 7125, Washington, DC 20416, by fax (202) 481–5719, by email at *ombudsman-events@sba.gov,* by phone (202) 205–6178.

Dated: September 3, 2015.

Miguel J. L'Heureux,

SBA Committee Management Officer.

[FR Doc. 2015–22981 Filed 9–11–15; 8:45 am]

BILLING CODE P

DEPARTMENT OF STATE

[Public Notice 9267]

60-Day Notice of Proposed Information Collection: Application Under the Hague Convention on the Civil Aspects of International Child Abduction

ACTION: Notice of request for public comment.

SUMMARY: The Department of State is seeking Office of Management and Budget (OMB) approval for the information collection described below. In accordance with the Paperwork Reduction Act of 1995, we are requesting comments on this collection from all interested individuals and organizations. The purpose of this notice is to allow 60 days for public comment preceding submission of the collection to OMB.

DATES: The Department will accept comments from the public up to November 13, 2015.

ADDRESSES: You may submit comments by any of the following methods:

- *Web:* Persons with access to the Internet may comment on this notice by going to *www.Regulations.gov.* You can search for the document by entering Docket Number: DOS–2015–0035 in the search field. Then click the "Comment Now" button and complete the comment form.
- *Email: mailto:Shawkm@state.gov.*
- *Regular Mail:* Send written comments to: U.S. Department of State, CA/OCS/PMO, SA–17, 10th Floor, Washington, DC 20036.
- *Fax:* 202–736–9111.
- *Hand Delivery or Courier:* U.S. Department of State, CA/OCS/PMO, 600 19th St. NW., 10th Floor, Washington, DC 20036.

You must include the DS form number (if applicable), information collection title, and the OMB control number in any correspondence.

FOR FURTHER INFORMATION CONTACT: Direct requests for additional information regarding the collection listed in this notice, including requests for copies of the proposed collection instrument and supporting documents, to Kaye Shaw, Bureau of Consular Affairs, Overseas Citizens Services (CA/OCS/PMO), U.S. Department of State, SA–17, 10th Floor, Washington, DC 20036 or at *mailto:shawkm@state.gov.*

SUPPLEMENTARY INFORMATION:

- *Title of Information Collection:* Application Under the Hague Convention on the Civil Aspects of International Child Abduction.
- *OMB Control Number:* 1405–0076.
- *Type of Request:* Extension.
- *Originating Office:* CA/OCS/L.
- *Form Number:* DS–3013, 3013–s.
- *Respondents:* Person seeking return of or access to child.
- *Estimated Number of Respondents:* 565.
- *Estimated Number of Responses:* 565.
- *Average Time per Response:* 1 hour.
- *Total Estimated Burden Time:* 565 hours.
- *Frequency:* On Occasion.
- *Obligation to Respond:* Voluntary.

We are soliciting public comments to permit the Department to:

- Evaluate whether the proposed information collection is necessary for the proper functions of the Department.
- Evaluate the accuracy of our estimate of the time and cost burden for this proposed collection, including the validity of the methodology and assumptions used.
- Enhance the quality, utility, and clarity of the requests for information to be collected.
- Minimize the reporting burden on those who are to respond, including the use of automated collection techniques or other forms of information technology.

Please note that comments submitted in response to this Notice are public record. Before including any detailed personal information, you should be aware that your comments as submitted, including your personal information, will be available for public review.

Abstract of proposed collection: The Application Under the Hague Convention on the Civil Aspects of International Child Abduction (DS–3013 and DS 3013–s) is used by parents or legal guardians who are requesting the State Department's assistance in seeking the return of, or access to, a child or children alleged to have been wrongfully removed from or retained outside of the child's habitual residence and currently located in another country that is also party to the Hague Convention on the Civil Aspects of International Child Abduction (the Convention). The application requests information regarding the identities of the applicant, the child or children, and the person alleged to have wrongfully removed or retained the child or children. In addition, the application requires that the applicant provide the circumstances of the alleged wrongful removal or retention and the legal justification for the request for return or access. The State Department, as the U.S. Central Authority for the Convention, uses this information to establish, if possible, the applicants' claims under the Convention; to inform applicants about available remedies under the Convention; and to provide the information necessary to the foreign Central Authority in its efforts to locate the child or children, and to facilitate return of or access to the child or children pursuant to the Convention. 42 U.S.C. 11608 is the legal authority that permits the Department to gather this information.

Methodology: The completed form DS–3013 and DS 3013–s may be submitted to the Office of Children's Issues by mail, by fax, or electronically accessed through *www.travel.state.gov.*

[17] 17 CFR 200.30–3(a)(12).

Dated: September 1, 2015.

Michelle Bernier-Toth,

Managing Director, Bureau of Consular Affairs, Department of State.

[FR Doc. 2015–23064 Filed 9–11–15; 8:45 am]

BILLING CODE 4710–06–P

DEPARTMENT OF STATE

[Public Notice 9268]

Meeting of Advisory Committee on International Communications and Information Policy

The Department of State's Advisory Committee on International Communications and Information Policy (ACICIP) will hold a public meeting on Friday, October 2, 2015 from 2:00 p.m. to 5:00 p.m. in the Loy Henderson Auditorium of the Harry S Truman (HST) Building of the U.S. Department of State. The Truman Building is located at 2201 C Street NW., Washington, DC 20520.

The committee provides a formal channel for regular consultation and coordination on major economic, social and legal issues and problems in international communications and information policy, especially as these issues and problems involve users of information and communications services, providers of such services, technology research and development, foreign industrial and regulatory policy, the activities of international organizations with regard to communications and information, and developing country issues.

The meeting will be led by Ambassador Daniel A. Sepulveda, U.S. Coordinator for International Communications and Information Policy. The meeting's agenda will include discussions pertaining to various upcoming international telecommunications meetings and conferences, as well as efforts focused on technology and international development and the Information and Communications Technology (ICT) aspects of international disaster response.

Members of the public may submit suggestions and comments to the ACICIP. Comments concerning topics to be addressed in the agenda should be received by the ACICIP Executive Secretary (contact information below) at least ten working days prior to the date of the meeting. All comments must be submitted in written form and should not exceed one page. Resource limitations preclude acknowledging or replying to submissions. While the meeting is open to the public, admittance to the building is only by means of a pre-clearance. For placement on the pre-clearance list, please submit the following information no later than 5:00 p.m. on Tuesday, September 29, 2015. (Please note that this information is required by Diplomatic Security for each entrance into HST and must therefore be re-submitted for each ACICIP meeting):

I. State That You Are Requesting Pre-Clearance to a Meeting

II. Provide the Following Information

1. Name of meeting and its date and time
2. Visitor's full name
3. Visitor's organization/company affiliation
4. Date of Birth
5. Citizenship
6. Acceptable forms of identification for entry into the building include:
   - U.S. driver's license with photo
   - Passport
   - U.S. government agency ID
7. ID number on the form of ID that the visitor will show upon entry
8. Whether the visitor has a need for reasonable accommodation. Such requests received after September 17, 2015, might not be possible to fulfill. Send the above information to Joseph Burton by fax (202) 647–5957 or email *BurtonKJ@state.gov.*

Please note that registrations will be accepted to the capacity of the meeting room. All visitors for this meeting must use the 23rd Street entrance. The valid ID bearing the number provided with your pre-clearance request will be required for admittance. Non-U.S. government attendees must be escorted by Department of State personnel at all times when in the building. Personal data is requested pursuant to Public Law 99–399 (Omnibus Diplomatic Security and Antiterrorism Act of 1986), as amended; Public Law 107–56 (USA PATRIOT Act); and Executive Order 13356. The purpose of the collection is to validate the identity of individuals who enter Department facilities. The data will be entered into the Visitor Access Control System (VACS–D) database. Please see the Security Records System of Records Notice (State–36) at *http://www.state.gov/documents/organization/103419.pdf* for additional information.

For further information, please contact Joseph Burton, Executive Secretary of the Committee, at (202) 647–5231 or *BurtonKJ@state.gov.*

General information about ACICIP and the mission of International Communications and Information Policy is available at: *http://www.state.gov/e/eb/adcom/acicip/index.htm.*

Dated: September 4, 2015.

Joseph Burton,

ACICIP Executive Secretary, Department of State.

[FR Doc. 2015–23065 Filed 9–11–15; 8:45 am]

BILLING CODE 4710–07–P

DEPARTMENT OF STATE

[Public Notice: 9265]

U.S. Advisory Panel to the U.S. Section of the North Pacific Anadromous Fish Commission; Notice of Renewal

The Department of State has renewed the Charter of the U.S. Advisory Panel to the U.S. Section of the North Pacific Anadromous Fish Commission (NPAFC) for another two years.

The NPAFC was established by the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, signed on February 12, 1992, by Canada, Japan, the Russian Federation, and the United States, and entered into force on February 16, 1993. The U.S. Advisory Panel will continue to work with the U.S. Section to promote the conservation of anadromous fish stocks, particularly salmon, throughout their migratory range in the North Pacific Ocean, as well as ecologically related species.

The U.S. Section of the Commission is composed of three Commissioners who are appointed by the President. Each Commissioner is appointed for a term not to exceed 4 years, but is eligible for reappointment. The Secretary of State, in consultation with the Secretary of Commerce, may designate alternate commissioners. The Advisory Panel to the U.S. Section is composed of 14 members, 11 of whom are appointed by the Secretary of State in consultation with the Secretary of Commerce. Advisory Panel members serve for a term not to exceed 4 years, and may not serve more than two consecutive terms.

The Advisory Panel will continue to follow the procedures prescribed by the Federal Advisory Committee Act (FACA). Meetings will continue to be open to the public unless a determination is made in accordance with section 10 of the Federal Advisory Committee Act and 5 U.S.C. 552b(c) that a meeting or a portion of the meeting should be closed to the public. For further information on the renewal of the Advisory Panel, please contact Michael Clark, Office of Marine Conservation in the Department of State, (202) 647–3010.

Dated: August 20, 2015.

David A. Balton,

Deputy Assistant Secretary for Oceans and Fisheries, Department of State.

[FR Doc. 2015–23063 Filed 9–11–15; 8:45 am]

BILLING CODE 4710–05–P

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Sixteenth Meeting: NextGen Advisory Committee (NAC)

AGENCY: Federal Aviation Administration (FAA), U.S. Department of Transportation (DOT).

ACTION: Notice of Sixteenth NextGen Advisory committee meeting.

SUMMARY: The FAA is issuing this notice to advise the public of the sixteenth NextGen Advisory Committee meeting.

DATES: The meeting will be held October 8th from 9:00 a.m.–3:00 p.m.

ADDRESSES: The meeting will be held at FedEx Express Headquarters, 3855 Airways Boulevard, Module D, 3rd Floor, Memphis, TN 38116, Tel: (202) 330–0652.

FOR FURTHER INFORMATION CONTACT: The RTCA Secretariat, 1150 18th Street NW., Suite 910, Washington, DC 20036, or by telephone at (202) 833–9339, fax at (202) 833–9434, or Web site at *http://www.rtca.org* or Andy Cebula, NAC Secretary, RTCA, Inc., *acebula@rtca.org,* (202) 330–0652.

SUPPLEMENTARY INFORMATION: Pursuant to section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463, 5 U.S.C., App.), notice is hereby given for a meeting of the NextGen Advisory Committee. The agenda will include the following:

Thursday, October 8, 2015

1. Opening of Meeting/Introduction of NAC Members—Chairman Richard Anderson, Chief Executive Officer, Delta Air Lines, Inc.
2. Official Statement of Designated Federal Official—The Honorable Mike Whitaker, FAA Deputy Administrator
3. Review and Approval of June 5, 2015 Meeting Summary
4. Chairman's Report—Chairman Anderson
5. FAA Report—Mr. Whitaker
6. NextGen Integration Working Group (NIWG) Reports & Discussion—DataComm, Multiple Runway Operations, Performance Based Navigation, Surface
7. Metrics: Measuring Effects of Implementations—Overview of Reporting Process; FAA Actions on Performance Reporting; Industry Performance Tracking–vendor presentation
8. ADS–B—Status of implementation; Spaced based deployment, oceanic surveillance, common weather picture
9. Performance Based Navigation (PBN) National Airspace System Navigation Strategy
10. NextGen Plan
11. Summary of meeting and next steps—DFO and NAC Chairman Closing Comments
12. Other business
13. Adjourn

Attendance is open to the interested public but limited to space availability. With the approval of the chairman, members of the public may present oral statements at the meeting. Persons wishing to present statements or obtain information should contact the person listed in the **FOR FURTHER INFORMATION CONTACT** section. Contact Betty Reschenberg at (901) 224–5470 or *bareschenberg@fedex.com* to register. In order for US Citizens to pre-register, please provide your first and last name (as it appears on your state Driver's License or Identification); employer's name and address; and phone number. In order to Non-US Citizens to pre-register, please provide your full name (as it appears on your passport); country of citizenship; passport and Visa numbers, type and expiration date; employer name and address; and phone number. Members of the public may present a written statement to the committee at any time.

Issued in Washington, DC, on September 10, 2015.

Latasha Robinson,

Management & Program Analyst, Next Generation, Enterprise Support Services Division, Federal Aviation Administration.

[FR Doc. 2015–23071 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

Federal Motor Carrier Safety Administration

[Docket No. FMCSA–2014–0382]

Qualification of Drivers; Exemption Applications; Epilepsy and Seizure Disorders

AGENCY: Federal Motor Carrier Safety Administration (FMCSA), DOT.

ACTION: Notice of final disposition.

SUMMARY: FMCSA announces its decision to grant requests from 14 individuals for exemptions from the regulatory requirement that interstate commercial motor vehicle (CMV) drivers have "no established medical history or clinical diagnosis of epilepsy or any other condition which is likely to cause loss of consciousness or any loss of ability to control a CMV." The regulation and the associated advisory criteria published in the Code of Federal Regulations as the "Instructions for Performing and Recording Physical Examinations" have resulted in numerous drivers being prohibited from operating CMVs in interstate commerce based on the fact that they have had one or more seizures and are taking anti-seizure medication, rather than an individual analysis of their circumstances by a qualified medical examiner. The Agency concluded that granting exemptions for these CMV drivers will provide a level of safety that is equivalent to or greater than the level of safety maintained without the exemptions. FMCSA grants exemptions that will allow these 14 individuals to operate CMVs in interstate commerce for a 2-year period. The exemptions preempt State laws and regulations and may be renewed.

DATES: The exemptions are effective September 14, 2015. The exemptions expire on September 14, 2017.

FOR FURTHER INFORMATION CONTACT: Charles A. Horan, III, Director, Office of Carrier, Driver and Vehicle Safety, (202) 366–4001, or via email at *fmcsamedical@dot.gov,* or by letter to FMCSA, Department of Transportation, 1200 New Jersey Avenue SE., Room W64–224, Washington, DC 20590–0001. Office hours are 8:30 a.m. to 5 p.m., Monday through Friday, except Federal holidays.

SUPPLEMENTARY INFORMATION:

A. Electronic Access

You may see all the comments online through the Federal Document Management System (FDMS) at: *http://www.regulations.gov.*

Docket: For access to the docket to read background documents or comments, go to *www.regulations.gov* and/or Room W12–140 on the ground level of the West Building, 1200 New Jersey Avenue SE., Washington DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, including any personal information the commenter provides, to *www.regulations.gov,* as described in the system of records

notice (DOT/ALL–14 FDMS), which can be reviewed at *www.dot.gov/privacy.*

B. Background

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the safety regulations for a 2-year period if it finds "such exemption would likely achieve a level of safety that is equivalent to or greater than the level that would be achieved absent such exemption." The statute also allows the Agency to renew exemptions at the end of the 2-year period.

FMCSA grants 14 individuals an exemption from the regulatory requirement in § 391.41(b)(8), to allow these individuals who take anti-seizure medication to operate CMVs in interstate commerce for a 2-year period. The Agency's decision on these exemption applications is based on an individualized assessment of each applicant's medical information, including the root cause of the respective seizure(s), the length of time elapsed since the individual's last seizure, and each individual's treatment regimen. In addition, the Agency reviewed each applicant's driving record found in the Commercial Driver's License Information System (CDLIS) [1] for commercial driver's license (CDL) holders, and interstate and intrastate inspections recorded in Motor Carrier Management Information System (MCMIS).[2] For non-CDL holders, the Agency reviewed the driving records from the State licensing agency. The Agency acknowledges the potential consequences of a driver experiencing a seizure while operating a CMV. However, the Agency believes the drivers covered by the exemptions granted here have demonstrated that they are unlikely to have a seizure and their medical condition does not pose a risk to public safety.

In reaching the decision to grant these exemption requests, the Agency considered both current medical literature and information and the 2007 recommendations of the Agency's Medical Expert Panel (MEP). The Agency previously gathered evidence for potential changes to the regulation at 49 CFR 391.41(b)(8) by conducting a comprehensive review of scientific literature that was compiled into the "*Evidence Report on Seizure Disorders and Commercial Vehicle Driving*" (*Evidence Report*) [CD–ROM HD TL230.3 .E95 2007]. The Agency then convened a panel of medical experts in the field of neurology (the MEP) on May 14–15, 2007, to review 49 CFR 391.41(b)(8) and the advisory criteria regarding individuals who have experienced a seizure, and the 2007 *Evidence Report.* The *Evidence Report* and the MEP recommendations are published on-line at *http://www.fmcsa.dot.gov/regulations/medical/reports-how-medical-conditions-impact-driving,* under Seizure Disorders, and are in the docket for this notice.

MEP Criteria for Evaluation

On October 15, 2007, the MEP issued the following recommended criteria for evaluating whether an individual with epilepsy or a seizure disorder should be allowed to operate a CMV.[3] The MEP recommendations are included in previously published dockets.

Epilepsy diagnosis. If there is an *epilepsy diagnosis,* the applicant should be seizure-free for *8 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with an epilepsy diagnosis should be performed every year.

Single unprovoked seizure. If there is a *single unprovoked seizure* (*i.e.,* there is no known trigger for the seizure), the individual should be seizure-free for *4 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with a single unprovoked seizure should be performed every 2 years.

Single provoked seizure. If there is a *single provoked seizure* (*i.e.,* there is a known reason for the seizure), the Agency should consider specific criteria that fall into the following two categories: low-risk factors for recurrence and moderate-to-high risk factors for recurrence.

- *Examples of low-risk factors for recurrence* include seizures that were caused by a medication; by non-penetrating head injury with loss of consciousness less than or equal to 30 minutes; by a brief loss of consciousness not likely to recur while driving; by metabolic derangement not likely to recur; and by alcohol or illicit drug withdrawal.
- *Examples of moderate-to-high-risk factors for recurrence* include seizures caused by non-penetrating head injury with loss of consciousness or amnesia greater than 30 minutes, or penetrating head injury; intracerebral hemorrhage associated with a stroke or trauma; infections; intracranial hemorrhage; post-operative complications from brain surgery with significant brain hemorrhage; brain tumor; or stroke.

The MEP report indicates individuals with moderate to high-risk conditions should not be certified. Drivers with a history of a single provoked seizure with low risk factors for recurrence should be recertified every year.

Medical Review Board Recommendations and Agency Decision

FMCSA presented the MEP's findings and the *Evidence Report* to the Medical Review Board (MRB) for consideration. The MRB reviewed and considered the 2007 "Seizure Disorders and Commercial Driver Safety" evidence report and the 2007 MEP recommendations. The MRB recommended maintaining the current advisory criteria, which provide that "drivers with a history of epilepsy/seizures off anti-seizure medication and seizure-free for 10 years may be qualified to drive a CMV in interstate commerce. Interstate drivers with a history of a single unprovoked seizure may be qualified to drive a CMV in interstate commerce if seizure-free and off anti-seizure medication for a 5 year period or more" [Advisory criteria to 49 CFR 391.43(f)].

The Agency acknowledges the MRB's position on the issue but believes relevant current medical evidence supports a less conservative approach. The medical advisory criteria for epilepsy and other seizure or loss of consciousness episodes was based on the 1988 "Conference on Neurological Disorders and Commercial Drivers" (NITS Accession No. PB89–158950/AS). A copy of the report can be found in the docket referenced in this notice.

The MRB's recommendation treats all drivers who have experienced a seizure the same, regardless of individual medical conditions and circumstances. In addition, the recommendation to continue prohibiting drivers who are

[1] *Commercial Driver License Information System* (CDLIS) is an information system that allows the exchange of commercial driver licensing information among all the States. CDLIS includes the databases of fifty-one licensing jurisdictions and the CDLIS Central Site, all connected by a telecommunications network.

[2] *Motor Carrier Management Information System* (MCMIS) is an information system that captures data from field offices through SAFETYNET, CAPRI, and other sources. It is a source for FMCSA inspection, crash, compliance review, safety audit, and registration data.

[3] Engel, J., Fisher, R.S., Krauss, G.L., Krumholz, A., and Quigg, M.S., "Expert Panel Recommendations: Seizure Disorders and Commercial Motor Vehicle Driver Safety," FMCSA, October 15, 2007.

taking anti-seizure medication from operating a CMV in interstate commerce does not consider a driver's actual seizure history and time since the last seizure. The Agency has decided to use the 2007 MEP recommendations as the basis for evaluating applications for an exemption from the seizure regulation on an individual, case-by-case basis.

C. Exemptions

Following individualized assessments of the exemption applications, including a review of detailed follow-up information requested from each applicant, FMCSA is granting exemptions from 49 CFR 391.41(b)(8) to 14 individuals. Under current FMCSA regulations, all of the 14 drivers receiving exemptions from 49 CFR 391.41(b)(8) would have been considered physically qualified to drive a CMV in interstate commerce except that they presently take or have recently stopped taking anti-seizure medication. For these 14 drivers, the primary obstacle to medical qualification was the FMCSA Advisory Criteria for Medical Examiners, based on the 1988 "Conference on Neurological Disorders and Commercial Drivers," stating that a driver should be off anti-seizure medication in order to drive in interstate commerce. In fact, the Advisory Criteria have little if anything to do with the actual risk of a seizure and more to do with assumptions about individuals who are taking anti-seizure medication.

In addition to evaluating the medical status of each applicant, FMCSA evaluated the crash and violation data for the 14 drivers, some of whom currently drive a CMV in intrastate commerce. The CDLIS and MCMIS were searched for crash and violation data on the 14 applicants. For non-CDL holders, the Agency reviewed the driving records from the State licensing agency.

These exemptions are contingent on the driver maintaining a stable treatment regimen and remaining seizure-free during the 2-year exemption period. The exempted drivers must submit annual reports from their treating physicians attesting to the stability of treatment and that the driver has remained seizure-free. The driver must undergo an annual medical examination by a medical examiner, as defined by 49 CFR 390.5, following the FCMSA's regulations for the physical qualifications for CMV drivers.

FMCSA published a notice of receipt of application and requested public comment during a 30-day public comment period in a **Federal Register** notice for each of the applicants. A short summary of the applicants' qualifications follows this section. For applicants who were denied an exemption, a notice was previously published.

D. Comments

Docket #FMCSA–2014–0382

On April 13, 2015, FMCSA published a notice of receipt of exemption applications and requested public comment on 19 individuals (80 FR 19730; Docket number FMCSA–2015–08392). The comment period ended on May 13, 2015. No commenters responded to this **Federal Register** notice. Of the 19 applicants, five were denied. The Agency has determined that the following 14 applicants should be granted an exemption.

Daryl Charles Anderson

Mr. Anderson is a 61 year-old class A CDL holder in Michigan. He has a history of a seizure disorder and has remained seizure free since 1989. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Anderson receiving an exemption.

Ronald J. Bennett

Mr. Bennett is a 58 year-old class B CDL holder in New York. He has a history of epilepsy and has remained seizure free since 2002. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Bennett receiving an exemption.

Don Carrol Darbyshire

Mr. Darbyshire is a 51 year-old class B CDL holder in Iowa. He has a history of epilepsy and has remained seizure free since 1993. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Darbyshire receiving an exemption.

Monte James DeRocini

Mr. DeRocini is a 53 year-old class A CDL holder in Pennsylvania. He has a history of a single seizure in 2011. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. DeRocini receiving an exemption.

Martin L. Ford

Mr. Ford is a 57 year-old class C CDL holder in Mississippi. He has a history of seizures and has remained seizure free since 2003. He takes anti-seizure medication with the dosage and frequency remaining the same since 2008. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Ford receiving an exemption.

Roger Green

Mr. Green is a 60 year-old class A CDL holder in Pennsylvania. He has a history of a seizure disorder and has remained seizure free since 1971. He takes anti-seizure medication with the dosage and frequency remaining the same since 2004. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Green receiving an exemption.

Susie B. Harvey

Ms. Harvey is a 64 year-old class B CDL holder in Virginia. She has a history of epilepsy and has remained seizure free since 1985. She takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, she would like to drive a CMV. Her physician states that he is supportive of Ms. Harvey receiving an exemption.

Timothy G. Huntley

Mr. Huntley is a 40 year-old class B CDL holder in Maine. He has a history of a seizure disorder and has remained seizure free since 2000. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Huntley receiving an exemption.

Chance Joseph O'Mary

Mr. O'Mary is a 29 year-old class A CDL holder in Alaska. He has a history of a seizure disorder and has remained seizure free since 2005. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. O'Mary receiving an exemption.

Robert D. Richter, Sr.

Mr. Richter is a 58 year-old driver in Pennsylvania. He has a history of a seizure disorder and has remained seizure free since 1976. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he

would like to drive a CMV. His physician states that he is supportive of Mr. Richter receiving an exemption.

Michael Scott Shumake

Mr. Shumake is a 37 year-old driver in Virginia. He has a history of a seizure disorder and has remained seizure free since 2000. He takes anti-seizure medication with the dosage and frequency remaining the same since 2001. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Shumake receiving an exemption.

Charles Ray Taylor

Mr. Taylor is a 49 year-old class A CDL holder in Mississippi. He has a history of a single seizure in 2009. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Taylor receiving an exemption.

Karin Hawley Wagasy

Ms. Wagasy is a 58 year-old driver in Tennessee. She has a history of a seizure disorder and has remained seizure free since 1975. She takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, she would like to drive a CMV. Her physician states that he is supportive of Ms. Wagasy receiving an exemption.

Trever A. Williams

Mr. Williams is a 44 year-old class A CDL holder in Minnesota. He has a history of a single seizure in 1983 which occurred postoperatively, after a surgical procedure to remove a foreign body from his head. He takes anti-seizure medication with the dosage and frequency remaining the same since 2006. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Williams receiving an exemption.

E. Basis for Exemption

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the epilepsy/seizure standard in 49 CFR 391.41(b)(8) if the exemption is likely to achieve an equivalent or greater level of safety than would be achieved without the exemption. Without the exemption, applicants will continue to be restricted to intrastate driving. With the exemption, applicants can drive in interstate commerce. Thus, the Agency's analysis focuses on whether an equal or greater level of safety is likely to be achieved by permitting each of these drivers to drive in interstate commerce as opposed to restricting the driver to driving in intrastate commerce.

Conclusion

The Agency is granting exemptions from the epilepsy standard, 49 CFR 391.41(b)(8), to 14 individuals based on a thorough evaluation of each driver's safety experience and medical condition. Safety analysis of information relating to these 14 applicants meets the burden of showing that granting the exemptions would achieve a level of safety that is equivalent to or greater than the level that would be achieved without the exemption. By granting the exemptions, the interstate CMV industry will gain 14 highly trained and experienced drivers. In accordance with 49 U.S.C. 31315(b)(1), each exemption will be valid for 2 years, with annual recertification required unless revoked earlier by FMCSA. The exemption will be revoked if the following occurs: (1) The person fails to comply with the terms and conditions of the exemption; (2) the exemption has resulted in a lower level of safety than was maintained prior to being granted; or (3) continuation of the exemption would not be consistent with the goals and objectives of 49 U.S.C. 31136 and 31315.

FMCSA exempts the following 14 drivers for a period of 2 years with annual medical certification required: Daryl Charles Anderson (MI); Ronald J. Bennett (NY); Don Carrol Darbyshire (IA); Monte James DeRocini (PA); Martin L. Ford (MS); Roger Green (PA); Susie B. Harvey (VA); Timothy G. Huntley (ME); Chance Joseph O'Mary (AK); Robert D. Richter, Sr. (PA); Michael Scott Shumake (VA); Charles Ray Taylor (MS); Karin Hawley Wagasy (TN); and Trever A. Williams (MN) from the prohibition of CMV operations by persons with a clinical diagnosis of epilepsy or seizures. If the exemption is still in effect at the end of the 2-year period, the person may apply to FMCSA for a renewal under procedures in effect at that time.

Issued on: September 2, 2015.

Larry W. Minor,

Associate Administrator for Policy.

[FR Doc. 2015–23035 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–EX–P

DEPARTMENT OF TRANSPORTATION

Federal Motor Carrier Safety Administration

[Docket No. FMCSA–2014–0379]

Qualification of Drivers; Exemption Applications; Epilepsy and Seizure Disorders

AGENCY: Federal Motor Carrier Safety Administration (FMCSA), DOT.

ACTION: Notice of final disposition.

SUMMARY: FMCSA announces its decision to grant requests from 6 individuals for exemptions from the regulatory requirement that interstate commercial motor vehicle (CMV) drivers have "no established medical history or clinical diagnosis of epilepsy or any other condition which is likely to cause loss of consciousness or any loss of ability to control a CMV." The regulation and the associated advisory criteria published in the Code of Federal Regulations as the "Instructions for Performing and Recording Physical Examinations" have resulted in numerous drivers being prohibited from operating CMVs in interstate commerce based on the fact that they have had one or more seizures and are taking anti-seizure medication, rather than an individual analysis of their circumstances by a qualified medical examiner. The Agency concluded that granting exemptions for these CMV drivers will provide a level of safety that is equivalent to or greater than the level of safety maintained without the exemptions. FMCSA grants exemptions that will allow these 6 individuals to operate CMVs in interstate commerce for a 2-year period. The exemptions preempt State laws and regulations and may be renewed.

DATES: The exemptions are effective September 14, 2015. The exemptions expire on September 14, 2017.

FOR FURTHER INFORMATION CONTACT: Charles A. Horan, III, Director, Office of Carrier, Driver and Vehicle Safety, (202) 366–4001, or via email at *fmcsamedical@dot.gov,* or by letter to FMCSA, Department of Transportation, 1200 New Jersey Avenue SE., Room W64–224, Washington, DC 20590–0001. Office hours are 8:30 a.m. to 5 p.m., Monday through Friday, except Federal holidays.

SUPPLEMENTARY INFORMATION:

A. Electronic Access

You may see all the comments online through the Federal Document Management System (FDMS) at: *http://www.regulations.gov.*

Docket: For access to the docket to read background documents or comments, go to *www.regulations.gov* and/or Room W12–140 on the ground level of the West Building, 1200 New Jersey Avenue SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, including any personal information the commenter provides, to *www.regulations.gov,* as described in the system of records notice (DOT/ALL–14 FDMS), which can be reviewed at *www.dot.gov/privacy.*

B. Background

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the safety regulations for a 2-year period if it finds "such exemption would likely achieve a level of safety that is equivalent to or greater than the level that would be achieved absent such exemption." The statute also allows the Agency to renew exemptions at the end of the 2-year period.

FMCSA grants 6 individuals an exemption from the regulatory requirement in § 391.41(b)(8), to allow these individuals who take anti-seizure medication to operate CMVs in interstate commerce for a 2-year period. The Agency's decision on these exemption applications is based on an individualized assessment of each applicant's medical information, including the root cause of the respective seizure(s), the length of time elapsed since the individual's last seizure, and each individual's treatment regimen. In addition, the Agency reviewed each applicant's driving record found in the Commercial Driver's License Information System (CDLIS) [1] for commercial driver's license (CDL) holders, and interstate and intrastate inspections recorded in Motor Carrier Management Information System (MCMIS).[2] For non-CDL holders, the Agency reviewed the driving records from the State licensing agency. The Agency acknowledges the potential consequences of a driver experiencing a seizure while operating a CMV. However, the Agency believes the drivers covered by the exemptions granted here have demonstrated that they are unlikely to have a seizure and their medical condition does not pose a risk to public safety.

In reaching the decision to grant these exemption requests, the Agency considered both current medical literature and information and the 2007 recommendations of the Agency's Medical Expert Panel (MEP). The Agency previously gathered evidence for potential changes to the regulation at 49 CFR 391.41(b)(8) by conducting a comprehensive review of scientific literature that was compiled into the "*Evidence Report on Seizure Disorders and Commercial Vehicle Driving*" (*Evidence Report*) [CD–ROM HD TL230.3 .E95 2007]. The Agency then convened a panel of medical experts in the field of neurology (the MEP) on May 14–15, 2007, to review 49 CFR 391.41(b)(8) and the advisory criteria regarding individuals who have experienced a seizure, and the 2007 *Evidence Report.* The *Evidence Report* and the MEP recommendations are published on-line at *http://www.fmcsa.dot.gov/regulations/medical/reports-how-medical-conditions-impact-driving,* under Seizure Disorders, and are in the docket for this notice.

MEP Criteria for Evaluation

On October 15, 2007, the MEP issued the following recommended criteria for evaluating whether an individual with epilepsy or a seizure disorder should be allowed to operate a CMV.[3] The MEP recommendations are included in previously published dockets.

Epilepsy diagnosis. If there is an *epilepsy diagnosis,* the applicant should be seizure-free for *8 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with an epilepsy diagnosis should be performed every year.

Single unprovoked seizure. If there is a *single unprovoked seizure* (*i.e.,* there is no known trigger for the seizure), the individual should be seizure-free for *4 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with a single unprovoked seizure should be performed every 2 years.

Single provoked seizure. If there is a *single provoked seizure* (*i.e.,* there is a known reason for the seizure), the Agency should consider specific criteria that fall into the following two categories: low-risk factors for recurrence and moderate-to-high risk factors for recurrence.

- *Examples of low-risk factors for recurrence* include seizures that were caused by a medication; by non-penetrating head injury with loss of consciousness less than or equal to 30 minutes; by a brief loss of consciousness not likely to recur while driving; by metabolic derangement not likely to recur; and by alcohol or illicit drug withdrawal.
- *Examples of moderate-to-high-risk factors for recurrence* include seizures caused by non-penetrating head injury with loss of consciousness or amnesia greater than 30 minutes, or penetrating head injury; intracerebral hemorrhage associated with a stroke or trauma; infections; intracranial hemorrhage; post-operative complications from brain surgery with significant brain hemorrhage; brain tumor; or stroke. The MEP report indicates individuals with moderate to high-risk conditions should not be certified. Drivers with a history of a single provoked seizure with low risk factors for recurrence should be recertified every year.

Medical Review Board Recommendations and Agency Decision

FMCSA presented the MEP's findings and the *Evidence Report* to the Medical Review Board (MRB) for consideration. The MRB reviewed and considered the 2007 "Seizure Disorders and Commercial Driver Safety" evidence report and the 2007 MEP recommendations. The MRB recommended maintaining the current advisory criteria, which provide that "drivers with a history of epilepsy/seizures off anti-seizure medication and seizure-free for 10 years may be qualified to drive a CMV in interstate commerce. Interstate drivers with a history of a single unprovoked seizure may be qualified to drive a CMV in interstate commerce if seizure-free and off anti-seizure medication for a 5 year period or more" [Advisory criteria to 49 CFR 391.43(f)].

The Agency acknowledges the MRB's position on the issue but believes relevant current medical evidence

[1] *Commercial Driver License Information System* (CDLIS) is an information system that allows the exchange of commercial driver licensing information among all the States. CDLIS includes the databases of fifty-one licensing jurisdictions and the CDLIS Central Site, all connected by a telecommunications network.

[2] *Motor Carrier Management Information System* (MCMIS) is an information system that captures data from field offices through SAFETYNET, CAPRI, and other sources. It is a source for FMCSA inspection, crash, compliance review, safety audit, and registration data.

[3] Engel, J., Fisher, R.S., Krauss, G.L., Krumholz, A., and Quigg, M.S., "Expert Panel Recommendations: Seizure Disorders and Commercial Motor Vehicle Driver Safety," FMCSA, October 15, 2007.

supports a less conservative approach. The medical advisory criteria for epilepsy and other seizure or loss of consciousness episodes was based on the 1988 "Conference on Neurological Disorders and Commercial Drivers" (NITS Accession No. PB89–158950/AS). A copy of the report can be found in the docket referenced in this notice.

The MRB's recommendation treats all drivers who have experienced a seizure the same, regardless of individual medical conditions and circumstances. In addition, the recommendation to continue prohibiting drivers who are taking anti-seizure medication from operating a CMV in interstate commerce does not consider a driver's actual seizure history and time since the last seizure. The Agency has decided to use the 2007 MEP recommendations as the basis for evaluating applications for an exemption from the seizure regulation on an individual, case-by-case basis.

C. Exemptions

Following individualized assessments of the exemption applications, including a review of detailed follow-up information requested from each applicant, FMCSA is granting exemptions from 49 CFR 391.41(b)(8) to 6 individuals. Under current FMCSA regulations, all of the 6 drivers receiving exemptions from 49 CFR 391.41(b)(8) would have been considered physically qualified to drive a CMV in interstate commerce except that they presently take or have recently stopped taking anti-seizure medication. For these 6 drivers, the primary obstacle to medical qualification was the FMCSA Advisory Criteria for Medical Examiners, based on the 1988 "Conference on Neurological Disorders and Commercial Drivers," stating that a driver should be off anti-seizure medication in order to drive in interstate commerce. In fact, the Advisory Criteria have little if anything to do with the actual risk of a seizure and more to do with assumptions about individuals who are taking anti-seizure medication.

In addition to evaluating the medical status of each applicant, FMCSA evaluated the crash and violation data for the 6 drivers, some of whom currently drive a CMV in intrastate commerce. The CDLIS and MCMIS were searched for crash and violation data on the 6 applicants. For non-CDL holders, the Agency reviewed the driving records from the State licensing agency.

These exemptions are contingent on the driver maintaining a stable treatment regimen and remaining seizure-free during the 2-year exemption period. The exempted drivers must submit annual reports from their treating physicians attesting to the stability of treatment and that the driver has remained seizure-free. The driver must undergo an annual medical examination by a medical examiner, as defined by 49 CFR 390.5, following the FCMSA's regulations for the physical qualifications for CMV drivers.

FMCSA published a notice of receipt of application and requested public comment during a 30-day public comment period in a **Federal Register** notice for each of the applicants. A short summary of the applicants' qualifications and a discussion of the comments received follows this section. For applicants who were denied an exemption, a notice was previously published.

D. Comments

Docket #FMCSA–2014–0379

On November 24, 2014, FMCSA published a notice of receipt of exemption applications and requested public comment on 12 individuals (79 FR 69981; Docket number FMCSA–2014–27755). The comment period ended on December 24, 2014. Two commenters responded to this notice expressing support for the epilepsy standard and the duty to keep our roads safe. Of the 12 applicants, six were denied. The Agency has determined that the following six applicants should be granted an exemption.

Theodore C. Banet

Mr. Banet is a 43 year-old driver in Pennsylvania. He has a history of epilepsy and has remained seizure free since 2004. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted an exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Banet receiving an exemption.

David S. Campbell

Mr. Campbell is a 70 year-old driver in Massachusetts. He has a history of seizures and has remained seizure free since 2005. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted an exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Campbell receiving an exemption.

Lewis R. Holbrook

Mr. Holbrook is a 43 year-old driver in North Carolina. He has a history of a seizure disorder and has remained seizure free since 2004. He takes anti-seizure medication with the dosage and frequency remaining the same since 2005. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Holbrook receiving an exemption.

Dominick Rezza

Mr. Rezza is a 58 year-old class A CDL holder in Texas. He has a history of a seizure disorder and has remained seizure free since 1995. He takes anti-seizure medication with the dosage and frequency remaining the same since 1996. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Rezza receiving an exemption.

Edgar A. Snapp

Mr. Snapp is a 52 year-old class B CDL holder in Indiana. He has a history of a seizure disorder and has remained seizure free since 1988. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Snapp receiving an exemption.

Gregory W. Young

Mr. Young is a 50 year-old class A CDL holder in South Carolina. He has a history of seizure and has remained seizure free since 1983. He takes anti-seizure medication with the dosage and frequency remaining the same since 2004. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Young receiving an exemption.

E. Basis for Exemption

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the epilepsy/seizure standard in 49 CFR 391.41(b)(8) if the exemption is likely to achieve an equivalent or greater level of safety than would be achieved without the exemption. Without the exemption, applicants will continue to be restricted to intrastate driving. With the exemption, applicants can drive in interstate commerce. Thus, the Agency's analysis focuses on whether an equal or greater level of safety is likely to be achieved by permitting each of these drivers to drive in interstate commerce as opposed to restricting the driver to driving in intrastate commerce.

Conclusion

The Agency is granting exemptions from the epilepsy standard, 49 CFR 391.41(b)(8), to 6 individuals based on a thorough evaluation of each driver's safety experience, and medical condition. Safety analysis of information relating to these 6 applicants meets the burden of showing

that granting the exemptions would achieve a level of safety that is equivalent to or greater than the level that would be achieved without the exemption. By granting the exemptions, the interstate CMV industry will gain 6 highly trained and experienced drivers. In accordance with 49 U.S.C. 31315(b)(1), each exemption will be valid for 2 years, with annual recertification required unless revoked earlier by FMCSA. The exemption will be revoked if the following occurs: (1) The person fails to comply with the terms and conditions of the exemption; (2) the exemption has resulted in a lower level of safety than was maintained prior to being granted; or (3) continuation of the exemption would not be consistent with the goals and objectives of 49 U.S.C. 31136 and 31315.

FMCSA exempts the following 6 drivers for a period of 2 years with annual medical certification required: Theodore Banet (PA); David Campbell (MA); Lewis Holbrook (NC); Dominick Rezza (TX); Edgar Snapp (IN); and Gregory Young (SC) from the prohibition of CMV operations by persons with a clinical diagnosis of epilepsy or seizures. If the exemption is still in effect at the end of the 2-year period, the person may apply to FMCSA for a renewal under procedures in effect at that time.

Issued on: September 3, 2015.

Larry W. Minor,

Associate Administrator for Policy.

[FR Doc. 2015–23036 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–EX–P

DEPARTMENT OF TRANSPORTATION

Federal Motor Carrier Safety Administration

[Docket No. FMCSA–2015–0116]

Qualification of Drivers; Exemption Applications; Epilepsy and Seizure Disorders

AGENCY: Federal Motor Carrier Safety Administration (FMCSA), DOT.

ACTION: Notice of final disposition.

SUMMARY: FMCSA announces its decision to grant requests from 9 individuals for exemptions from the regulatory requirement that interstate commercial motor vehicle (CMV) drivers have "no established medical history or clinical diagnosis of epilepsy or any other condition which is likely to cause loss of consciousness or any loss of ability to control a CMV." The regulation and the associated advisory criteria published in the Code of Federal Regulations as the "Instructions for Performing and Recording Physical Examinations" have resulted in numerous drivers being prohibited from operating CMVs in interstate commerce based on the fact that they have had one or more seizures and are taking anti-seizure medication, rather than an individual analysis of their circumstances by a qualified medical examiner. The Agency concluded that granting exemptions for these CMV drivers will provide a level of safety that is equivalent to or greater than the level of safety maintained without the exemptions. FMCSA grants exemptions that will allow these 9 individuals to operate CMVs in interstate commerce for a 2-year period. The exemptions preempt State laws and regulations and may be renewed.

DATES: The exemptions are effective September 14, 2015. The exemptions expire on September 14, 2017.

FOR FURTHER INFORMATION CONTACT: Charles A. Horan, III, Director, Office of Carrier, Driver and Vehicle Safety, (202) 366–4001, or via email at *fmcsamedical@dot.gov,* or by letter to FMCSA, Department of Transportation, 1200 New Jersey Avenue SE., Room W64–224, Washington, DC 20590–0001. Office hours are 8:30 a.m. to 5 p.m., Monday through Friday, except Federal holidays.

SUPPLEMENTARY INFORMATION:

A. Electronic Access

You may see all the comments online through the Federal Document Management System (FDMS) at: *http://www.regulations.gov.*

Docket: For access to the docket to read background documents or comments, go to *http://www.regulations.gov* and/or Room W12–140 on the ground level of the West Building, 1200 New Jersey Avenue SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

Privacy Act: In accordance with 5 U.S.C. 553(c), DOT solicits comments from the public to better inform its rulemaking process. DOT posts these comments, without edit, including any personal information the commenter provides, to *www.regulations.gov,* as described in the system of records notice (DOT/ALL–14 FDMS), which can be reviewed at *www.dot.gov/privacy.*

B. Background

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the safety regulations for a 2-year period if it finds "such exemption would likely achieve a level of safety that is equivalent to or greater than the level that would be achieved absent such exemption." The statute also allows the Agency to renew exemptions at the end of the 2-year period.

FMCSA grants 9 individuals an exemption from the regulatory requirement in § 391.41(b)(8), to allow these individuals who take anti-seizure medication to operate CMVs in interstate commerce for a 2-year period. The Agency's decision on these exemption applications is based on an individualized assessment of each applicant's medical information, including the root cause of the respective seizure(s), the length of time elapsed since the individual's last seizure, and each individual's treatment regimen. In addition, the Agency reviewed each applicant's driving record found in the Commercial Driver's License Information System (CDLIS) [1] for commercial driver's license (CDL) holders, and interstate and intrastate inspections recorded in Motor Carrier Management Information System (MCMIS).[2] For non-CDL holders, the Agency reviewed the driving records from the State licensing agency. The Agency acknowledges the potential consequences of a driver experiencing a seizure while operating a CMV. However, the Agency believes the drivers covered by the exemptions granted here have demonstrated that they are unlikely to have a seizure and their medical condition does not pose a risk to public safety.

In reaching the decision to grant these exemption requests, the Agency considered both current medical literature and information and the 2007 recommendations of the Agency's Medical Expert Panel (MEP). The Agency previously gathered evidence for potential changes to the regulation at 49 CFR 391.41(b)(8) by conducting a comprehensive review of scientific literature that was compiled into the "*Evidence Report on Seizure Disorders and Commercial Vehicle Driving*" (*Evidence Report*) [CD–ROM HD TL230.3 .E95 2007]. The Agency then convened a panel of medical experts in the field of neurology (the MEP) on May

[1] *Commercial Driver License Information System* (CDLIS) is an information system that allows the exchange of commercial driver licensing information among all the States. CDLIS includes the databases of fifty-one licensing jurisdictions and the CDLIS Central Site, all connected by a telecommunications network.

[2] *Motor Carrier Management Information System* (MCMIS) is an information system that captures data from field offices through SAFETYNET, CAPRI, and other sources. It is a source for FMCSA inspection, crash, compliance review, safety audit, and registration data.

14–15, 2007, to review 49 CFR 391.41(b)(8) and the advisory criteria regarding individuals who have experienced a seizure, and the 2007 *Evidence Report.* The *Evidence Report* and the MEP recommendations are published on-line at *http://www.fmcsa.dot.gov/regulations/medical/reports-how-medical-conditions-impact-driving,* under Seizure Disorders, and are in the docket for this notice.

MEP Criteria for Evaluation

On October 15, 2007, the MEP issued the following recommended criteria for evaluating whether an individual with epilepsy or a seizure disorder should be allowed to operate a CMV.[3] The MEP recommendations are included in previously published dockets.

Epilepsy diagnosis. If there is an *epilepsy diagnosis,* the applicant should be seizure-free for *8 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with an epilepsy diagnosis should be performed every year.

Single unprovoked seizure. If there is a *single unprovoked seizure* (*i.e.,* there is no known trigger for the seizure), the individual should be seizure-free for *4 years, on or off medication.* If the individual is taking anti-seizure medication(s), the plan for medication should be stable for *2 years.* Stable means no changes in medication, dosage, or frequency of medication administration. Recertification for drivers with a single unprovoked seizure should be performed every 2 years.

Single provoked seizure. If there is a *single provoked seizure* (*i.e.,* there is a known reason for the seizure), the Agency should consider specific criteria that fall into the following two categories: low-risk factors for recurrence and moderate-to-high risk factors for recurrence.

- *Examples of low-risk factors for recurrence* include seizures that were caused by a medication; by non-penetrating head injury with loss of consciousness less than or equal to 30 minutes; by a brief loss of consciousness not likely to recur while driving; by metabolic derangement not likely to recur; and by alcohol or illicit drug withdrawal.

- *Examples of moderate-to-high-risk factors for recurrence* include seizures caused by non-penetrating head injury with loss of consciousness or amnesia greater than 30 minutes, or penetrating head injury; intracerebral hemorrhage associated with a stroke or trauma; infections; intracranial hemorrhage; post-operative complications from brain surgery with significant brain hemorrhage; brain tumor; or stroke.

The MEP report indicates individuals with moderate to high-risk conditions should not be certified. Drivers with a history of a single provoked seizure with low risk factors for recurrence should be recertified every year.

Medical Review Board Recommendations and Agency Decision

FMCSA presented the MEP's findings and the *Evidence Report* to the Medical Review Board (MRB) for consideration. The MRB reviewed and considered the 2007 "Seizure Disorders and Commercial Driver Safety" evidence report and the 2007 MEP recommendations. The MRB recommended maintaining the current advisory criteria, which provide that "drivers with a history of epilepsy/seizures off anti-seizure medication and seizure-free for 10 years may be qualified to drive a CMV in interstate commerce. Interstate drivers with a history of a single unprovoked seizure may be qualified to drive a CMV in interstate commerce if seizure-free and off anti-seizure medication for a 5 year period or more" [Advisory criteria to 49 CFR 391.43(f)].

The Agency acknowledges the MRB's position on the issue but believes relevant current medical evidence supports a less conservative approach. The medical advisory criteria for epilepsy and other seizure or loss of consciousness episodes was based on the 1988 "Conference on Neurological Disorders and Commercial Drivers" (NITS Accession No. PB89–158950/AS). A copy of the report can be found in the docket referenced in this notice.

The MRB's recommendation treats all drivers who have experienced a seizure the same, regardless of individual medical conditions and circumstances. In addition, the recommendation to continue prohibiting drivers who are taking anti-seizure medication from operating a CMV in interstate commerce does not consider a driver's actual seizure history and time since the last seizure. The Agency has decided to use the 2007 MEP recommendations as the basis for evaluating applications for an exemption from the seizure regulation on an individual, case-by-case basis.

C. Exemptions

Following individualized assessments of the exemption applications, including a review of detailed follow-up information requested from each applicant, FMCSA is granting exemptions from 49 CFR 391.41(b)(8) to 9 individuals. Under current FMCSA regulations, all of the 9 drivers receiving exemptions from 49 CFR 391.41(b)(8) would have been considered qualified physically to drive a CMV in interstate commerce except that they presently take or have recently stopped taking anti-seizure medication. For these 9 drivers, the primary obstacle to medical qualification was the FMCSA Advisory Criteria for Medical Examiners, based on the 1988 "Conference on Neurological Disorders and Commercial Drivers," stating that a driver should be off anti-seizure medication in order to drive in interstate commerce. In fact, the Advisory Criteria have little if anything to do with the actual risk of a seizure and more to do with assumptions about individuals who are taking anti-seizure medication.

In addition to evaluating the medical status of each applicant, FMCSA evaluated the crash and violation data for the 9 drivers, some of whom currently drive a CMV in intrastate commerce. The CDLIS and MCMIS were searched for crash and violation data on the 9 applicants. For non-CDL holders, the Agency reviewed the driving records from the State licensing agency.

These exemptions are contingent on the driver maintaining a stable treatment regimen and remaining seizure-free during the 2-year exemption period. The exempted drivers must submit annual reports from their treating physicians attesting to the stability of treatment and that the driver has remained seizure-free. The driver must undergo an annual medical examination by a medical examiner, as defined by 49 CFR 390.5, following the FCMSA's regulations for the physical qualifications for CMV drivers.

FMCSA published a notice of receipt of application and requested public comment during a 30-day public comment period in a **Federal Register** notice for each of the applicants. A short summary of the applicants' qualifications and a discussion of the comments received follows this section. For applicants who were denied an exemption, a notice was previously published.

D. Comments

Docket # FMCSA–2015–0116

On July 13, 2015, FMCSA published a notice of receipt of exemption

[3] Engel, J., Fisher, R.S., Krauss, G.L., Krumholz, A., and Quigg, M.S., "Expert Panel Recommendations: Seizure Disorders and Commercial Motor Vehicle Driver Safety," FMCSA, October 15, 2007.

applications and requested public comment on 21 individuals (80 FR 40127; Docket number FMCSA–2015–17022). The comment period ended on August 12, 2015. Ten commenters responded to this notice, seven of whom specifically expressed support for applicant Daniel Dellaserra. Paula Johnson expressed support for her son Kristopher Fraser because he has been seizure free for over eight years, compliant with his treatment, and desires to advance in his career. Michael Muise, a certified medical examiner expressed support for drivers with seizure disorders driving commercially if controlled with medication similar to diabetics on insulin. The Agency has determined that the following 9 applicants should be granted an exemption.

William Howard Brown

Mr. Brown is a 58 year-old class A CDL holder in North Carolina. He has a history of epilepsy and has remained seizure free since 1999. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Brown receiving an exemption.

Daniel Dellaserra

Mr. Dellaserra is a 54 year-old class A CDL holder in California. He has a history of seizures and has remained seizure free since 1998. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Dellaserra receiving an exemption.

Thomas A. Granese

Mr. Granese is a 70 year-old class A CDL holder in Massachusetts. He has a history of seizure disorder and has remained seizure free since 2003. He takes anti-seizure medication with the dosage and frequency remaining the same since 2010. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Granese receiving an exemption.

Paul E. Granger

Mr. Granger is a 50 year-old chauffeur license holder in Michigan. He has a history of a seizure disorder and has remained seizure free since 1987. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, she would like to drive a CMV. His physician states that he is supportive of Mr. Granger receiving an exemption.

Charles Terrell Gray

Mr. Gray is a 69 year-old driver in Oklahoma. He has a history of a single unprovoked seizure and has remained seizure free since 1993. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Gray receiving an exemption.

David Allen Griggs

Mr. Griggs is a 55 year-old class A CDL holder in Minnesota. He has a history of a seizure disorder and has remained seizure free since 1987. He takes anti-seizure medication with the dosage and frequency remaining the same since April 2013. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Griggs receiving an exemption.

Dennis Edward Klamm

Mr. Klamm is a 52 year-old class C CDL holder in Minnesota. He has a history of a seizure disorder and has remained seizure free since 1987. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Klamm receiving an exemption.

Christina L. Petti

Ms. Petti is a 45 year-old class B CDL holder in New Jersey. She has a history of a seizure disorder and has remained seizure free since 1985. She takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, she would like to drive a CMV. Her physician states that he is supportive of Ms. Petti receiving an exemption.

Christopher L. Phillips

Mr. Phillips is a 46 year-old class A CDL holder in Pennsylvania. He has a history of a seizure disorder and has remained seizure free since 1989. He takes anti-seizure medication with the dosage and frequency remaining the same since that time. If granted the exemption, he would like to drive a CMV. His physician states that he is supportive of Mr. Phillips receiving an exemption.

E. Basis for Exemption

Under 49 U.S.C. 31136(e) and 31315(b), FMCSA may grant an exemption from the epilepsy/seizure standard in 49 CFR 391.41(b)(8) if the exemption is likely to achieve an equivalent or greater level of safety than would be achieved without the exemption. Without the exemption, applicants will continue to be restricted to intrastate driving. With the exemption, applicants can drive in interstate commerce. Thus, the Agency's analysis focuses on whether an equal or greater level of safety is likely to be achieved by permitting each of these drivers to drive in interstate commerce as opposed to restricting the driver to driving in intrastate commerce.

Conclusion

The Agency is granting exemptions from the epilepsy standard, 49 CFR 391.41(b)(8), to 9 individuals based on a thorough evaluation of each driver's safety experience, and medical condition. Safety analysis of information relating to these 9 applicants meets the burden of showing that granting the exemptions would achieve a level of safety that is equivalent to or greater than the level that would be achieved without the exemption. By granting the exemptions, the interstate CMV industry will gain 9 highly trained and experienced drivers. In accordance with 49 U.S.C. 31315(b)(1), each exemption will be valid for 2 years, with annual recertification required unless revoked earlier by FMCSA. The exemption will be revoked if the following occurs: (1) The person fails to comply with the terms and conditions of the exemption; (2) the exemption has resulted in a lower level of safety than was maintained prior to being granted; or (3) continuation of the exemption would not be consistent with the goals and objectives of 49 U.S.C. 31136 and 31315.

FMCSA exempts the following 9 drivers for a period of 2 years with annual medical certification required: William Howard Brown (NC); Daniel Dellaserra (CA); Thomas A. Granese (MA); Paul E. Granger (MI); Charles Terrell Gray (OK); David Allen Griggs (MN); Dennis Edward Klamm (MN); Christina L. Petti (NJ); and Christopher L. Phillips (PA) from the prohibition of CMV operations by persons with a clinical diagnosis of epilepsy or seizures. If the exemption is still in effect at the end of the 2-year period, the person may apply to FMCSA for a renewal under procedures in effect at that time.

Issued on: September 3, 2015.

Larry W. Minor,

Associate Administrator for Policy.

[FR Doc. 2015–23034 Filed 9–11–15; 8:45 am]

BILLING CODE 4910–EX–P

DEPARTMENT OF TRANSPORTATION

Surface Transportation Board

[Docket No. AB 57 (Sub-No. 62X]

Soo Line Railroad Company—Abandonment Exemption—in Hennepin County, Minn.

Soo Line Railroad Company d/b/a Canadian Pacific (Soo Line) has filed a verified notice of exemption under 49 CFR 1152 subpart F–*Exempt Abandonments* to abandon a 0.4-mile line of railroad between milepost 0.59 +/− (approximately 100 feet southeast of the bridge that crosses Interstate 94) and milepost 0.99 +/− at or near Essex Street, SE. (East side spur) in Hennepin County, Minn. (the Line). The Line traverses United States Postal Service Zip Code 55414.

Soo Line has certified that: (1) No local traffic has moved over the Line for at least two years; (2) any overhead traffic can be and has been rerouted over other lines; (3) no formal complaint filed by a user of rail service on the Line (or by a state or local government entity acting on behalf of such user) regarding cessation of service over the Line either is pending with the Surface Transportation Board (Board) or with any U.S. District Court or has been decided in favor of complainant within the two-year period; and (4) the requirements at 49 CFR 1105.7(c) (environmental report), 49 CFR 1105.11 (transmittal letter), 49 CFR 1105.12 (newspaper publication), and 49 CFR 1152.50(d)(1) (notice to governmental agencies) have been met.

As a condition to this exemption, any employee adversely affected by the abandonment shall be protected under *Oregon Short Line Railroad—Abandonment Portion Goshen Branch Between Firth & Ammon, in Bingham & Bonneville Counties, Idaho,* 360 I.C.C. 91 (1979). To address whether this condition adequately protects affected employees, a petition for partial revocation under 49 U.S.C. 10502(d) must be filed.

Provided no formal expression of intent to file an offer of financial assistance (OFA) has been received, this exemption will be effective on October 14, 2015, unless stayed pending reconsideration. Petitions to stay that do not involve environmental issues,[1] formal expressions of intent to file an OFA under 49 CFR 1152.27(c)(2),[2] and trail use/rail banking requests under 49 CFR 1152.29 must be filed by September 24, 2015. Petitions to reopen or requests for public use conditions under 49 CFR 1152.28 must be filed by October 5, 2015, with the Surface Transportation Board, 395 E Street, SW., Washington, DC 20423–0001.

A copy of any petition filed with the Board should be sent to Soo Line's representative: W. Karl Hansen, Stinson Leonard Street LLP, 150 South Fifth Street, Suite 2300, Minneapolis, Minn. 55402.

If the verified notice contains false or misleading information, the exemption is void *ab initio.*

Soo Line has filed environmental and historic reports that address the effects, if any, of the abandonment on the environment and historic resources. OEA will issue an environmental assessment (EA) by September 18, 2015. Interested persons may obtain a copy of the EA by writing to OEA (Room 1100, Surface Transportation Board, Washington, DC 20423–0001) or by calling OEA at (202) 245–0305. Assistance for the hearing impaired is available through the Federal Information Relay Service at (800) 877–8339. Comments on environmental and historic preservation matters must be filed within 15 days after the EA becomes available to the public.

Environmental, historic preservation, public use, or trail use/rail banking conditions will be imposed, where appropriate, in a subsequent decision.

Pursuant to the provisions of 49 CFR 1152.29(e)(2), Soo Line shall file a notice of consummation with the Board to signify that it has exercised the authority granted and fully abandoned the Line. If consummation has not been effected by Soo Line's filing of a notice of consummation by September 14, 2016, and there are no legal or regulatory barriers to consummation, the authority to abandon will automatically expire.

Board decisions and notices are available on our Web site at *www.stb.dot.gov.*

[1] The Board will grant a stay if an informed decision on environmental issues (whether raised by a party or by the Board's Office of Environmental Analysis (OEA) in its independent investigation) cannot be made before the exemption's effective date. *See Exemption of Out-of-Serv. Rail Lines,* 5 I.C.C. 2d 377 (1989). Any request for a stay should be filed as soon as possible so that the Board may take appropriate action before the exemption's effective date.

[2] Each OFA must be accompanied by the filing fee, which is currently set at $1,600. *See* 49 CFR 1002.2(f)(25).

Decided: September 9, 2015.

By the Board, Rachel D. Campbell, Director, Office of Proceedings.

Jeffrey Herzig,

Clearance Clerk.

[FR Doc. 2015–23047 Filed 9–11–15; 8:45 am]

BILLING CODE 4915–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Form 4876–A

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning Form 4876–A, Election to Be Treated as an Interest Charge DISC.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Martha Brinson, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the form and instructions should be directed to Kerry Dennis, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet at *Kerry.Dennis@irs.gov.*

SUPPLEMENTARY INFORMATION:

Title: Election To Be Treated as an Interest Charge DISC.

OMB Number: 1545–0190.

Form Number: 4876–A.

Abstract: A domestic corporation and its shareholders must elect to be an interest charge domestic international sales corporation (IC–DISC). Form 4876–A is used to make the election. The IRS uses the information to determine if the corporation qualifies to be an IC–DISC.

Current Actions: There are no changes being made to the form at this time.

Type of Review: Extension of a currently approved collection.

Affected Public: Business or other for-profit organizations.

Estimated Number of Responses: 1,000.

Estimated Time per Response: 6 hrs., 22 minutes.

Estimated Total Annual Burden Hours: 6,360.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 19, 2015.

Martha Brinson,

IRS Tax Analyst.

[FR Doc. 2015–22968 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Regulation Project

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning limitations on percentage depletion in the case of oil and gas wells.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Martha Brinson, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the regulation should be directed to Kerry Dennis, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet at *Kerry.Dennis@irs.gov.*

SUPPLEMENTARY INFORMATION:

Title: Limitations on Percentage Depletion in the Case of Oil and Gas Wells.

OMB Number: 1545–1251.

Regulation Project Number: TD 8437.

Abstract: This regulation concerns oil and gas property held by partnerships. Because the depletion allowance with respect to production from domestic oil and gas properties is computed by the partners and not by the partnership, section 1.613A–3(e)(6)(i) of the regulation requires each partner to separately keep records of the partner's share of the adjusted basis in each oil and gas property of the partnership.

Current Actions: There is no change to this existing regulation.

Type of Review: Extension of a currently approved collection.

Affected Public: Business or other for-profit organizations.

Estimated Number of Respondents: 1,500,000.

Estimated Time per Respondent: 2 minutes.

Estimated Total Annual Burden Hours: 49,950.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 19, 2015.

Martha Brinson,

IRS Tax Analyst.

[FR Doc. 2015–22965 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Form 13751

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning Form 13751, Waiver of Right to Consistent Agreement of Partnership Items and Partnership-Level Determinations as to Penalties, Additions to Tax, and Additional Amounts.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Martha Brinson, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or

copies of the form and instructions should be directed to Kerry Dennis at Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet at *Kerry.Dennis@irs.gov.*

SUPPLEMENTARY INFORMATION:

Title: Waiver of Right to Consistent Agreement of Partnership Items and Partnership-Level Determinations as to Penalties, Additions to Tax, and Additional Amounts.

OMB Number: 1545–1969.

Form Number: 13751.

Abstract: The information requested on Form 13751 will be used to determine the eligibility for participation in the settlement initiative of taxpayers related through TEFRA partnerships to ineligible applicants. Such determinations will involve partnership items and partnership-level determinations, as well as the calculation of tax liabilities resolved under this initiative, including penalties and interest.

Current Actions: There are no changes being made to the form at this time.

Type of Review: Extension of a currently approved collection.

Affected Public: Individuals or households, Business or other for-profit organizations, not-for-profit institutions.

Estimated Number of Respondents: 100.

Estimated Time per Respondent: 1 hour.

Estimated Total Annual Burden Hours: 100.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 19, 2015.

Martha Brinson,

IRS Tax Analyst.

[FR Doc. 2015–22967 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Revenue Procedure 2009–16

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning Revenue Procedure 2008–16, Section 168(k)(4) Election Procedures.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Christie Preston, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for copies of the revenue procedure should be directed to Sara Covington, at Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet, at *Sara.L.Covington@irs.gov.*

SUPPLEMENTARY INFORMATION:

Title: Section 168(k)(4) Election Procedures.

OMB Number: 1545–2133.

Revenue Procedure Number: Revenue Procedure 2009–16.

Abstract: This revenue procedure provides the time and manner for (1) corporations to make the election to apply section 168(k)(4) of the Code, (2) corporations to make the allocation of the bonus depreciation amount resulting from the section 168(k)(4) election, (3) corporate partners who make the section 168(k)(4) election to notify partnerships, and (3) U.S. automobile manufacturing partnerships (such as, Chrysler) to make the election to apply section 3081(b) of the Act.

Current Actions: Extension of a previously approved collection.

Affected Public: Businesses and for-profit institutions.

Estimated Number of Respondents: 5,400.

Estimated Time per Respondent: 30 minutes (varies .25 to 1 hr.).

Estimated Total Annual Burden Hours: 2,700.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 20, 2015.

Sara Covington,

IRS Tax Analyst.

[FR Doc. 2015–22963 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Revenue Procedure 2015–36

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning master and prototype and volume submitter plans.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Martha Brinson, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the revenue procedure should be directed to Kerry Dennis, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the Internet at *Kerry.Dennis@irs.gov.*

SUPPLEMENTARY INFORMATION:

Title: Master and Prototype and Volume Submitter Plans.

OMB Number: 1545–1674.

Revenue Procedure Number: Revenue Procedure 2015–36 (modifies Rev. Proc. 2011–49).

Abstract: The master and prototype and volume submitter revenue procedure sets forth the procedures for sponsors of master and prototype and volume submitter pension, profit-sharing and annuity plans to request an opinion letter or an advisory letter from the Internal Revenue Service that the form of a master or prototype plan or volume submitter plan meets the requirements of section 401(a) of the Internal Revenue Code. The information requested is in addition to the information required to be submitted with Forms 4461 (*Application for Approval of Master or Prototype Defined Contribution Plan*), 4461–A (*Application for Approval of Master or Prototype Defined Benefit Plan*) and 4461–B (*Application for Approval of Master or Prototype or Plan (Mass Submitter Adopting Sponsor)*). This information is needed in order to enable the Employee Plans function of the Service's Tax Exempt and Government Entities Division to issue an opinion letter or an advisory letter.

Current Actions: There are no changes being made to the revenue procedure at this time.

Type of Review: Extension of a currently approved collection.

Affected Public: Individuals or households, business or other for-profit organizations, not-for-profit institutions, farms, and state, local or tribal governments.

Estimated Number of Responses: 340,765.

Estimated Time per Response: 2 hour, 54 minutes.

Estimated Total Annual Burden Hours: 988,290.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 19, 2015.

Martha Brinson,

IRS Tax Analyst.

[FR Doc. 2015–22971 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Form 5495

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning Form 5495, Request for Discharge From Personal Liability Under Internal Revenue Code section 2204 or 6905.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Christie Preston, Internal Revenue Service, room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the form and instructions should be directed to Sara Covington, at Internal Revenue Service, room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet at *Sara.L.Covington@irs.gov.*

SUPPLEMENTARY INFORMATION: *Title:* Request for Discharge From Personal Liability Under Internal Revenue Code Section 2204 or 6905.

OMB Number: 1545–0432.

Form Number: Form 5495.

Abstract: Form 5495 provides guidance under sections 2204 and 6905 for executors of estates and fiduciaries of decedent's trusts. The form, filed after regular filing of an Estate, Gift, or Income tax return for a decedent, is used by the executor or fiduciary to request discharge from personal liability for any deficiency for the tax and periods shown on the form.

Current Actions: There is no change in the paperwork burden previously approved by OMB. This form is being submitted for renewal purposes only.

Type of Review: Extension of a currently approved collection.

Affected Public: Individuals or Households.

Estimated Number of Respondents: 25,000.

Estimated Time per Respondent: 12 hours 16 minutes.

Estimated Total Annual Burden Hours: 306,500.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number.

Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request For Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 20, 2015.

Sara Covington,

IRS Tax Analyst.

[FR Doc. 2015–22964 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

Proposed Collection; Comment Request for Notice 2009–89 (as Modified by 2012–54) and Form 8936

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice and request for comments.

SUMMARY: The Department of the Treasury, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995, Public Law 104–13 (44 U.S.C. 3506(c)(2)(A)). Currently, the IRS is soliciting comments concerning qualified plug-in electric vehicle credit.

DATES: Written comments should be received on or before November 13, 2015 to be assured of consideration.

ADDRESSES: Direct all written comments to Martha Brinson, Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224.

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the form and instructions should be directed to Kerry Dennis, at Internal Revenue Service, Room 6129, 1111 Constitution Avenue NW., Washington, DC 20224, or through the internet at *Kerry.Dennis@irs.gov* .

SUPPLEMENTARY INFORMATION:

Title: Qualified Plug-in Electric Vehicle Credit (Notice 2009–89, as modified by Notice 2012–54).

OMB Number: 1545–2137.

Form Number: 8936.

Abstract: Notice 2009–54 sets forth interim guidance, pending the issuance of regulations, relating to the qualified plug-in electric drive motor vehicle credit under section 30D of the Internal Revenue Code, as in effect for vehicles acquired after December 31, 2009. Notice 2012–54 modifies Notice 2009–89, by providing a new address to which a vehicle manufacturer (or, in the case of a foreign vehicle manufacturer, its domestic distributor) must send vehicle certifications and quarterly reports under Notice 2009–89.

Form 8936, is used for tax years beginning after 2008, to figure the credit for qualified plug-in electric drive motor vehicles placed in service during your tax year. The credit attributable to depreciable property (vehicles used for business or investment purposes) is treated as a general business credit. Any credit not attributable to depreciable property is treated as a personal credit.

Current Actions: There is no change in the paperwork burden previously approved by OMB.

Type of Review: Extension of a currently approved collection.

Affected Public: Individual, Businesses and other for-profit organizations.

Notice 2012–54

Estimated Number of Respondents: 12.

Estimated Time per Respondent: 24 hours.

Estimated Total Annual Burden Hours: 280.

Form 8936

Estimated Number of Respondents: 50,000.

Estimated Time per Respondent: 5 hours, 21 minutes.

Estimated Total Annual Burden Hours: 267,500.

The following paragraph applies to all of the collections of information covered by this notice:

An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the collection of information displays a valid OMB control number. Books or records relating to a collection of information must be retained as long as their contents may become material in the administration of any internal revenue law. Generally, tax returns and tax return information are confidential, as required by 26 U.S.C. 6103.

Request for Comments: Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval. All comments will become a matter of public record. Comments are invited on: (a) Whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology; and (e) estimates of capital or start-up costs and costs of operation, maintenance, and purchase of services to provide information.

Approved: August 19, 2015.

Martha Brinson,

IRS Tax Analyst.

[FR Doc. 2015–22969 Filed 9–11–15; 8:45 am]

BILLING CODE 4830–01–P

DEPARTMENT OF VETERANS AFFAIRS

Advisory Committee on Former Prisoners of War; Notice of Meeting

The Department of Veterans Affairs (VA) gives notice under the Federal Advisory Committee Act, 5 U.S.C. App. 2, that the Advisory Committee on Former Prisoners of War (FPOW) will meet on October 5–7, 2015. The first two meetings will be held on October 5–6 from 9:00 a.m. to 4:00 p.m. at the Audie Murphy VA Medical Center, 7400

Merton Minter Blvd., San Antonio, TX. The third meeting will be held on October 7 from 9:00 a.m. to 12:00 p.m. at the Courtyard Marriott, 8585 Marriott Dr., San Antonio, TX. The meetings are open to the public.

The purpose of the Committee is to advise the Secretary of VA on the administration of benefits under title 38, United States Code, for Veterans who are FPOWs. The Committee also makes recommendations on the needs of FPOW Veterans for compensation, health care, and rehabilitation.

The Committee will hear from its Chairman and will receive briefings by representatives from the Veterans Benefits Administration and the Veterans Health Administration. On October 6, at 3:30 p.m., the Committee will host an open public forum and FPOW panel to gain information from FPOWs about their experiences, issues, and recommendations for health benefits and claims processing. Participation is limited to FPOWs. On October 7, the Committee will begin drafting their 2016 recommendations and decide the location of their next meeting in the spring.

FPOWs who wish to speak at the public forum are invited to submit a 1–2 page summary of their comments at the end of the meeting for inclusion in the official meeting record. Members of the public may also submit written statements for the Committee's review to Mr. Eric Robinson, Designated Federal Officer, Advisory Committee on Former Prisoners of War, (and Program Analyst, Compensation Service), Department of Veterans Affairs, 810 Vermont Avenue NW., Washington, DC 20420 (212), or by email at *eric.robinson3@va.gov.* Any member of the public seeking additional information should contact Mr. Robinson by email or call (202) 443–6016.

Dated: September 9, 2015.

Jelessa Burney,

Federal Advisory Committee Management Officer.

[FR Doc. 2015–23023 Filed 9–11–15; 8:45 am]

BILLING CODE P

DEPARTMENT OF VETERANS AFFAIRS

[OMB Control No. 2900–0764]

Agency Information Collection (Survey of Health Care Experiences Dental Patient Satisfaction Survey) Activities Under OMB Review

AGENCY: Veterans Health Administration, Department of Veterans Affairs.

ACTION: Notice.

SUMMARY: In compliance with the Paperwork Reduction Act (PRA) of 1995 (44 U.S.C. 3501–3521), this notice announces that the Veterans Health Administration (VHA), Department of Veterans Affairs, will submit the collection of information abstracted below to the Office of Management and Budget (OMB) for review and comment. The PRA submission describes the nature of the information collection and its expected cost and burden and includes the actual data collection instrument.

DATES: Written comments and recommendations on the proposed collection of information should be received on or before October 14, 2015.

ADDRESSES: Submit written comments on the collection of information through *www.Regulations.gov,* or to Office of Information and Regulatory Affairs, Office of Management and Budget, Attn: VA Desk Officer; 725 17th St. NW., Washington, DC 20503 or sent through electronic mail to *oira_submission@omb.eop.gov.* Please refer to "OMB Control No. 2900–0764 (SURVEY OF HEALTHCARE EXPERIENCES DENTAL PATIENT SATISFACTION SURVEY) in any correspondence. During the comment period, comments may be viewed online through the FDMS.

FOR FURTHER INFORMATION CONTACT: Crystal Rennie, Enterprise Records Service (005R1B), Department of Veterans Affairs, 810 Vermont Avenue NW., Washington, DC 20420, (202) 632–7492 or email *crystal.rennie@va.gov.* Please refer to "OMB Control No. 2900–0764 (Survey of Health Care Experiences Dental Patient Satisfaction Survey) in any correspondence.

SUPPLEMENTARY INFORMATION: Under the PRA of 1995 (Public Law 104–13; 44 U.S.C. 3501–3521), Federal agencies must obtain approval from the Office of Management and Budget (OMB) for each collection of information they conduct or sponsor. This request for comment is being made pursuant to Section 3506(c)(2)(A) of the PRA.

With respect to the following collection of information, VHA invites comments on: (1) Whether the proposed collection of information is necessary for the proper performance of VHA's functions, including whether the information will have practical utility; (2) the accuracy of VHA's estimate of the burden of the proposed collection of information; (3) ways to enhance the quality, utility, and clarity of the information to be collected; and (4) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or the use of other forms of information technology.

SUPPLEMENTARY INFORMATION:

Titles:

1. Survey of Health Care Experiences Dental Patient Satisfaction Survey.

2. *OMB Control Number:* 2900–0764.

Type of Review: Extension of a currently approved collection.

Abstracts:

The mission of the Veterans Health Administration (VHA) is to provide high quality medical and dental care to eligible veterans. Executive Order 12862, dated September 11, 1993, calls for the establishment and implementation of customer service standards, and for agencies to "survey customers to determine the kind and quality of services they want and their level of satisfaction with current services". At present, VA does not specifically evaluate patient satisfaction for over 400,000 veterans receiving dental services each year.

The Dental Patient satisfaction survey is comprised primarily of questions taken from two validated and extensively tested surveys. The first survey is the VA Nation-wide Customer Satisfaction Survey: Survey of Health Experience of Patients (SHEP); this has OMB approval under clearance number 2900–0712. The second survey, Dental Consumer Assessment of Healthcare Provider and Systems (DCAHPS), was developed by the Agency for Healthcare Research and Quality (AHRQ). The psychometric properties of this survey are well documented and the survey has been used extensively in measuring patient satisfaction for TRICARE dental services.

Affected Public: Individuals or households.

Estimated Annual Burden:

a. Survey of Health Care Experiences Dental Patient Satisfaction Survey, VA Form 10–10070—9,146 hours.

Estimated Average Burden per Respondent:

a. Survey of Health Care Experiences Dental Patient Satisfaction Survey, VA Form 10–10070—15 minutes.

Frequency of Response: Annually.

Estimated Annual Responses:

a. Survey of Health Care Experiences Dental Patient Satisfaction Survey, VA Form 10–10070—36,585.

By direction of the Secretary.

Kathleen M. Manwell,

Program Analyst, VA Privacy Service, Office of Privacy and Records Management, Department of Veterans Affairs.

[FR Doc. 2015–23025 Filed 9–11–15; 8:45 am]

BILLING CODE 8320–01–P

FEDERAL REGISTER

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Part II

Securities and Exchange Commission

17 CFR Part 240
Access to Data Obtained by Security-Based Swap Data Repositories and Exemption From Indemnification Requirement; Proposed Rule

SECURITIES AND EXCHANGE COMMISSION

17 CFR Part 240

[Release No. 34–75845; File No. S7–15–15]

RIN 3235–AL74

Access to Data Obtained by Security-Based Swap Data Repositories and Exemption From Indemnification Requirement

AGENCY: Securities and Exchange Commission.

ACTION: Proposed rule.

SUMMARY: Pursuant to section 763(i) of Title VII ("Title VII") of the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 ("Dodd-Frank Act"), the Securities and Exchange Commission ("Commission") is proposing amendments to rule 13n–4 under the Securities Exchange Act of 1934 ("Exchange Act") related to regulatory access to security-based swap data held by security-based swap data repositories. The proposed rule amendments would implement the conditional Exchange Act requirement that security-based swap data repositories make data available to certain regulators and other authorities, and would set forth a conditional exemption from the statutory indemnification requirement associated with that regulatory access provision.

DATES: Submit comments on or before October 29, 2015.

ADDRESSES: Comments may be submitted by any of the following methods:

Electronic Comments

- Use the Commission's Internet comment form (*http://www.sec.gov/rules/proposed.shtml*); or
- Send an email to *rule-comments@sec.gov*. Please include File Number S7–15–15 on the subject line; or
- Use the Federal eRulemaking Portal (*http://www.regulations.gov*). Follow the instructions for submitting comments.

Paper Comments

- Send paper comments to Secretary, Securities and Exchange Commission, 100 F Street NE., Washington, DC 20549–1090.

All submissions should refer to File Number S7–15–15. This file number should be included on the subject line if email is used. To help us process and review your comments more efficiently, please use only one method. The Commission will post all comments on the Commission's Internet Web site (*http://www.sec.gov/rules/proposed.shtml*). Comments are also available for Web site viewing and printing in the Commission's Public Reference Room, 100 F Street NE., Washington, DC 20549 on official business days between the hours of 10:00 a.m. and 3:00 p.m. All comments received will be posted without change; the Commission does not edit personal identifying information from submissions. You should submit only information that you wish to make available publicly.

Studies, memoranda, or other substantive items may be added by the Commission or staff to the comment file during this rulemaking. A notification of the inclusion in the comment file of any such materials will be made available on the SEC's Web site. To ensure direct electronic receipt of such notifications, sign up through the "Stay Connected" option at *www.sec.gov* to receive notifications by email.

FOR FURTHER INFORMATION CONTACT: Carol McGee, Assistant Director, or Joshua Kans, Senior Special Counsel, at (202) 551–5870; Division of Trading and Markets, Securities and Exchange Commission, 100 F Street NE., Washington, DC 20549–7010.

SUPPLEMENTARY INFORMATION: The Commission is proposing to add paragraphs (b)(9) and (b)(10) to Exchange Act rule 13n–4 to implement the statutory requirement that security-based swap data repositories conditionally provide data to certain regulators and other authorities. The Commission also is proposing to add paragraph (d) to rule 13n–4 to provide a conditional exemption from the associated statutory indemnification requirement.

I. Background

A. Statutory Requirements for Access to Security-Based Swap Data Repository Information

Title VII of the Dodd-Frank Act amended the Exchange Act to provide a comprehensive regulatory framework for security-based swaps, including the regulation of security-based swap data repositories.[1]

Those amendments, among other things, require that security-based swap data repositories make data available to certain regulators and other entities. In particular, the amendments conditionally require that security-based swap data repositories "on a confidential basis pursuant to section 24, upon request, and after notifying the Commission of the request, make available all data obtained by the security-based swap data repository, including individual counterparty trade and position data."[2] The repositories must make that data available to: "each appropriate prudential regulator";[3] the Financial Stability Oversight Council ("FSOC"); the Commodity Futures Trading Commission ("CFTC"); the Department of Justice; and "any other person that the Commission determines to be appropriate," including foreign financial supervisors (including foreign futures authorities), foreign central banks and foreign ministries.[4]

This access to data is conditional, however. In part, before a repository shares such data, the repository "shall receive a written agreement from each entity stating that the entity shall abide by the confidentiality requirements described in section 24 relating to the information on security-based swap transactions that is provided."[5] Moreover, before such data is shared, "each entity shall agree to indemnify the security-based swap data repository and the Commission for any expenses arising from litigation relating to the information provided under section 24."[6]

B. Prior Proposals and Comments Received

1. 2010 proposal

In 2010, the Commission proposed several rules to implement statutory provisions related to the registration process, duties and core principles applicable to security-based swap data repositories.[7] That proposal, among other things, encompassed rules that

[1] Public Law 111–203, section 761(a) (adding Exchange Act section 3(a)(75) (defining "security-based swap data repository")) and section 763(i) (adding Exchange Act section 13(n) (establishing a regulatory regime for security-based swap data repositories)).

References in this release to the terms "data repository," "trade repository," "repository" or "SDR" generally address security-based swap data repositories unless stated otherwise.

[2] Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G). The confidentiality requirements addressed by Exchange Act section 24, 15 U.S.C. 78x, are addressed below. *See* note 84, *infra*.

[3] As discussed below, the term "prudential regulator" encompasses the Board of Governors of the Federal Reserve System and certain other regulators, with regard to certain categories of regulated entities. *See* note 44, *infra*.

[4] Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G).

[5] Exchange Act section 13(n)(5)(H)(i), 15 U.S.C. 78m(n)(5)(H)(i).

[6] Exchange Act section 13(n)(5)(H)(ii), 15 U.S.C. 78m(n)(5)(H)(ii).

[7] *See* Security-Based Swap Data Repository Registration, Duties, and Core Principles, Exchange Act Release No. 63347 (Nov. 19, 2010), 75 FR 77306 (Dec. 10, 2010), *corrected at* 75 FR 79320 (Dec. 20, 2010) *and* 76 FR 2287 (Jan. 13, 2011) ("SDR Proposing Release").

incorporated the statutory language that set forth the data access provisions.[8]

In proposing those rules, the Commission recognized that "regulators may be legally prohibited or otherwise restricted from agreeing to indemnify third parties, including SDRs as well as the Commission," and that the "indemnification provision could chill requests for access to data obtained by SDRs, thereby hindering the ability of others to fulfill their regulatory mandates and responsibilities." [9] The Commission added that it expected that a repository "would not go beyond the minimum requirements of the statute so as not to preclude [recipient entities described by the statute] from obtaining the data maintained by an SDR." [10] The Commission further noted that the Commission itself had the authority to share nonpublic information with, among others, certain domestic and foreign regulatory authorities.[11]

In response, four commenters addressed the data access provisions.[12] Those commenters generally supported providing relevant authorities with access to security-based swap data maintained by repositories when the access is within the scope of those authorities' mandates, but expressed particular concerns relating to the indemnification requirement and to the scope of authorities' access to data. Two commenters concurred that relevant authorities likely would be unable to agree to indemnify data repositories or the Commission.[13] One commenter expressed the concern that the statutory requirement is vague and could result in a data repository providing access to persons without proper authority.[14] Another commenter recommended that the Commission adopt rules to help streamline the indemnification requirement for an "efficient exchange of information." [15]

2. 2013 Cross-Border Proposal

a. Proposed Exemption to Indemnification Requirement

In 2013, the Commission proposed a number of rules related to the cross-border application of the Title VII security-based swap requirements. At that time, recognizing the significance of commenter concerns and understanding that certain authorities may be unable to agree to indemnify a data repository and the Commission, the Commission preliminarily concluded that the indemnification requirement could frustrate the purposes of the statutory requirement that repositories make available data to relevant authorities. The Commission further took the view that the indemnification requirement should not be applied rigidly so as to frustrate the statutory purposes of data repositories, and hinder relevant authorities' ability to fulfill their regulatory mandates and legal responsibilities.[16]

To address these concerns, the Commission proposed an exemption to provide that a data repository "is not required" to comply with the indemnification requirement, conditioned on: (1) An entity requesting the information "to fulfill a regulatory mandate and/or legal responsibility"; (2) the request pertaining "to a person or financial product subject to the jurisdiction, supervision or oversight of the entity"; and (3) the entity having entered into a supervisory and enforcement memorandum of understanding ("MOU") or other arrangement addressing the confidentiality of the information provided and any other matter as determined by the Commission.[17] The Commission took the preliminary view that the proposed exemption was consistent with commenters' views, including one commenter's suggestion that the indemnification requirement not apply when relevant authorities carry out their responsibilities in accordance with international agreements and while maintaining the

[8] *See* SDR Proposing Release, 75 FR 77368 (paragraphs (b)(9) and (b)(10) of proposed Exchange Act rule 13n-4 incorporated relevant language of Exchange Act sections 13(n)(5)(G) and (H)).

[9] 75 FR 77318–19.

[10] 75 FR 77319.

[11] *Id.*

[12] Cleary Gottlieb comment (Sept. 20, 2011) at 31–32 (comment was provided in response to a joint SEC–CFTC roundtable regarding the cross-border application of Title VII, and can be found at *http://www.sec.gov/comments/4-636/4-636.shtml*), DTCC comment (Nov. 15, 2010) at 3, ESMA comment (Jan. 17, 2011) at 2 and Managed Funds Association comment (Jan. 24, 2011) at 3.

[13] Prior to the proposed rules, one of those commenters described the indemnification requirement as contravening the purpose of data repositories and jeopardizing market stability by diminishing regulators' ability to carry out oversight functions. *See* DTCC comment (Nov. 15, 2010) at 3. This comment and other comments that addressed data repository issues in response to a general request for comments regarding the implementation of Title VII are located on the Commission's Web site at *http://www.sec.gov/comments/df-title-vii/swap-data-repositories/swap-data-repositories.shtml.*

Subsequently, in response to the proposed rules, that commenter further: (1) Stated that the indemnification requirement should not apply where relevant authorities carry out their regulatory responsibilities in accordance with international agreements and while maintaining the confidentiality of data provided to them; (2) suggested that the Commission provide model indemnification language; and (3) urged that "any indemnity should be limited in scope to minimize the potential reduction in value of registered SDRs to the regulatory community." *See* DTCC comment (Jan. 24, 2011) at 12. These and other comments addressing the proposed implementation of the data access provisions (as well as other aspects of the Commission's 2010 proposal regarding security-based swap data repository registration, duties and core principles) are located on the Commission's Web site at *http://www.sec.gov/comments/s7-35-10/s73510.shtml.*

Another commenter stated that because indemnification would not be feasible, "it would be problematic for [the Commission and the CFTC] to require non-U.S. SDRs to register with the Commissions," and that the indemnification requirement could impede effective regulatory coordination. *See* Cleary Gottlieb comment (Sept. 20, 2011) at 31–32.

That commenter further stated that when a non-U.S. data repository registers with the Commission "but is also subject to regulatory oversight by an appropriate non-U.S. regulator," the SEC should adopt the CFTC's interpretation "that the non-U.S. regulator is not as a result subject to Dodd-Frank's notice and indemnification provisions." *See id.* The Commission since then has issued final rules and interpretations regarding the cross-border application of the registration requirement for security-based swap data repositories, which exempts certain non-U.S. data repositories subject to regulation abroad from having to comply with requirements otherwise applicable to repositories. *See* Exchange Act Release No. 74246 (Feb. 11, 2015), 80 FR 14438, 14450–51, 14516–17, 14556 (Mar. 19, 2015) ("SDR Adopting Release") (generally stating that a non-U.S. person that performs the functions of a security-based swap data repository within the United States is required to register with the Commission absent an exemption, and adopting Exchange Act rule 13n–12 to provide an exemption from data repository requirements for certain non-U.S. persons when regulators with supervisory authority over those non-U.S. persons have entered into a memorandum of understanding ("MOU") or other arrangement with the Commission regarding the confidentiality of data collected and maintained by such non-U.S. person, access by the Commission to such data, and any other matters determined by the Commission). Also, under the preliminary interpretation discussed below, the conditions to the Exchange Act data access requirements would not restrict access when a repository registered with the Commission also is registered or licensed with a foreign authority that obtains the data pursuant to foreign law. *See* part IV.A, *infra.*

[14] That commenter particularly expressed concern regarding the possibility of "unfettered access" to security-based swap information by regulators, including foreign financial supervisors, foreign central banks and foreign ministries, "beyond their regulatory authority and mandate." *See* Managed Funds Association comment (Jan. 24, 2011) at 3. That comment further recommended that the Commission take an approach similar to that taken by rules proposed by the CFTC, requiring any regulator requesting access to such data to certify the statutory authority for the request and detail the basis for the request. *See id.* at 3–4. The CFTC subsequently adopted that certification requirement as a final rule, but did not adopt the proposed requirement that the regulator also detail the basis for the request. *See* note 31, *infra*, and accompanying text.

[15] That commenter also reiterated the notion that relevant authorities must ensure the confidentiality of security-based swap data provided to them, and that the indemnification requirement "undermines the key principle of trust according to which exchange of information [among relevant authorities] should occur." *See* ESMA comment (Jan. 17, 2011) at 2.

[16] *See* Exchange Act Release No. 69490 (May 1, 2013), 78 FR 30968, 31048–49 (May 23, 2013) ("Cross-Border Proposing Release").

[17] *See id.* at 31209 (paragraph (d) of proposed Exchange Act rule 13n–4).

confidentiality of data provided to them.[18]

The Commission further stated that the exemption's proposed condition that the request be for the purpose of fulfilling a relevant authority's regulatory mandate or legal responsibility was aligned with statutory requirements to protect the security-based swap information maintained by a repository, including proprietary and highly sensitive data, from unauthorized disclosure, misappropriation or misuse.[19] The Commission also expressed the preliminary view that the proposed condition that the Commission enter into an MOU or other arrangement with a relevant authority represented an effective way to streamline the indemnification requirement for an "efficient exchange of information" to help protect the confidentiality of information and further the purposes of the Dodd-Frank Act.[20]

b. Additional guidance

In the Cross-Border Proposing Release, the Commission also addressed the application of the statutory requirement that repositories notify the Commission regarding data requests. The Commission stated its preliminarily belief that repositories could satisfy that requirement by providing the Commission with notice of an initial request by a relevant authority, and maintaining records of the initial request and all subsequent requests.[21] The Commission further expressed preliminary views regarding the process for determining which additional authorities may obtain information from data repositories pursuant to these data access provisions.[22]

c. Comments

In response to this proposal, the Commission received one comment that addressed the data access provisions, including the indemnification requirement. That commenter stated that the proposal "did not erase the need for a legislative solution to clarify the scope and applicability" of the indemnification requirement.[23] The commenter further recommended that the Commission incorporate, as part of the exemption, a "safe harbor provision from liability for information shared pursuant to global information sharing agreements."[24]

The commenter also objected to the prospect that repositories would be required to notify the Commission of an initial information request, stating that such a requirement could lead authorities to hesitate to make requests if that would trigger notice, "particularly if such request is pursuant to an investigation." The commenter instead recommended that the Commission consider the notification requirement to be satisfied if the request is made "pursuant to an established information sharing agreement."[25]

3. Final Rules Reserving Action on the Data Access Provisions

In February 2015, the Commission adopted a number of final rules governing the registration process, duties and core principles applicable to security-based swap data repositories.[26] Those final rules, however, neither addressed the statutory data access requirements applicable to data repositories, nor provided an exception to the indemnification requirement. The Commission instead stated that final resolution of the issue would benefit from further consideration and public comment.[27]

C. Treatment of These Issues in the Swaps Context

The Dodd-Frank Act also revised the Commodity Exchange Act ("CEA") to impose comparable data access requirements—including confidentiality and indemnification conditions—upon swap data repositories that are subject to CFTC jurisdiction.[28]

1. Certification of Scope of Jurisdiction

To implement those requirements, the CFTC adopted rules that in part identify the domestic[29] and foreign regulators[30] to which a swap data repository must make swap data available. The rules provide that when those regulators seek access to data maintained by a swap data repository, they must file a request with the swap data repository and certify that they are acting within the scope of their jurisdiction.[31]

2. Scope of Confidentiality and Indemnification Requirements

The CFTC implementing rules generally require domestic and foreign regulators to execute confidentiality and indemnification agreements with the swap data repository prior to receipt of any requested swap data.[32] The CFTC,

[18] *See id.* at 31049 (addressing DTCC comment from Jan. 24, 2011). The Commission also stated that the proposal was consistent with commenter suggestions that the exemption be "location agnostic" (by treating relevant domestic and foreign authorities similarly), and that the exemption was intended to help preserve the "spirit of cooperation and coordination" between regulators around the world. *See id.*

[19] *See id.* at 31049–50.

[20] *See id.* at 31050. The Commission moreover expressed the preliminary view that, in determining whether to enter into such an MOU or other arrangement, the Commission would consider, among other things, whether: (1) "The relevant authority needs security-based swap information from an SDR to fulfill its regulatory mandate or legal responsibilities; (2) the relevant authority agrees to protect the confidentiality of the security-based swap information provided to it; (3) the relevant authority agrees to provide the Commission with reciprocal assistance in securities matters within the Commission's jurisdiction; and (4) a supervisory and enforcement MOU or other arrangement would be in the public interest." *See id.* at 31049–50.

[21] *See id.* at 31046–47.

[22] *See id.* at 31047–48 (indicating that the Commission would make such determinations by order, and that the Commission would consider a variety of factors, including whether there is a supervisory and enforcement MOU between the Commission and the relevant authority, and whether the relevant authority has a legitimate need for the information).

[23] *See* DTCC cross-border comment (Aug. 21, 2013) at 6–7 (expressing concern that the indemnification provision would continue to limit data sharing across jurisdictions, leading foreign regulators to seek to establish "national" repositories that would fragment data among jurisdictions). That comment and other comments responding to the cross-border proposal are located on the Commission's Web site at: *http://www.sec.gov/comments/s7-02-13/s70213.shtml.*

[24] *See* DTCC cross-border comment at 8.

[25] *See id.* at 7.

[26] *See* SDR Adopting Release.

[27] *See id.*, 80 FR 14487–88 (further noting that repositories will have to comply with all statutory requirements, including the indemnification requirement, when the current exemptive relief from requirements applicable to repositories expires). As a result, in adopting those final rules the Commission reserved paragraphs (b)(9) and (b)(10) of Exchange Act rule 13n–4 (which as proposed would have addressed the data access obligations of registered security-based swap data repositories), and did not adopt the indemnification exemption proposed as paragraph (d) of rule 13n–4.

[28] *See* CEA sections 21(c)(7), (d), 7 U.S.C. 24a(c)(7), (d).

[29] The CFTC has defined "Appropriate Domestic Regulator" to mean: (i) The SEC; (ii) each prudential regulator "with respect to requests related to any of such regulator's statutory authorities, without limitation to the activities listed for each regulator" in the statutory definition; (iii) the Financial Stability Oversight Council; (iv) the Department of Justice; (v) any Federal Reserve Bank; (vi) the Office of Financial Research; and (vii) any other person the CFTC deems appropriate. *See* 17 CFR 49.17(b)(1).

[30] The CFTC has defined "Appropriate Foreign Regulator" to mean foreign regulators "with an existing memorandum of understanding or other similar type of information sharing arrangement" executed with the CFTC, and/or foreign regulators "without an MOU as determined on a case-by-case basis" by the CFTC. *See* 17 CFR 49.17(b)(2).

[31] *See* 17 CFR 49.17(d)(1). In this regard, the CFTC did not adopt proposed requirements to require regulators to set forth the basis for their requests in sufficient detail, and to require a swap data repository to provide access only if it is satisfied that the regulator is acting within the scope of its authority. *See* 76 FR 54538, 54553 (Sept. 1, 2011).

[32] *See* 17 CFR 49.17(d)(6), 49.18(b).

however, also recognized that it might be difficult for certain regulators to implement those confidentiality and indemnification requirements.[33] Accordingly, the CFTC provided that a domestic regulator with regulatory jurisdiction over a swap data repository registered with it pursuant to separate statutory authority may access such data without the need to enter into confidentiality or indemnification agreements if: (i) The domestic regulator executes an MOU or similar information sharing arrangement with the CFTC; and (ii) the CFTC designates the domestic regulator to receive direct electronic access.[34]

The CFTC implementing rules further provided that a foreign regulator with supervisory responsibility over a swap data repository registered with the foreign regulator pursuant to foreign law and/or regulation would not need to enter into such confidentiality or indemnification agreements.[35] In addition, the CFTC noted that the confidentiality and indemnification requirements would not apply when the CFTC itself shares information in its possession with foreign authorities.[36]

The CFTC subsequently issued an interpretative statement that the indemnification and confidentiality provisions under the CEA generally apply only to such data reported pursuant to the CEA and CFTC regulations, and that those confidentiality and indemnification provisions "should not operate to inhibit or prevent foreign regulatory authorities from accessing data in which they have an independent regulatory interest (even if that data also has been reported pursuant to the CEA and [CFTC] regulations)." [37] The CFTC further stated that a registered swap data repository would not be subject to the indemnification and confidentiality provisions under the CEA if the swap data repository is "registered, recognized or otherwise authorized in a foreign jurisdiction's regulatory regime," when the data sought to be accessed by the foreign regulatory authority has been reported to the swap data repository "pursuant to the foreign jurisdiction's regulatory regime." [38]

D. The Current Proposal

The Commission today is proposing rules related to the data access obligation applicable to security-based swap data repositories, including rules to provide a conditional exemption from the indemnification requirement. This new proposal builds upon the earlier proposals, but with certain changes.

Among other aspects, as discussed below, the proposal would provide for the statutory confidentiality agreement requirement to be satisfied via the use of MOUs or other agreements between the Commission and the entity accessing data from a security-based swap data repository. The proposal also encompasses an indemnification exemption that would be effective when the relevant conditions are met, in contrast to the earlier proposed approach of conditionally allowing a data repository to elect whether to waive the indemnification requirement.

Taken as a whole, the proposal would provide that when the conditions to the data access provisions are satisfied—including as applicable the conditions to the indemnification exemption—a repository would be required to provide security-based swap data to relevant authorities.

II. Proposed Data Access Rules

The Commission is proposing rules, to implement the data access provisions of Exchange Act sections 13(n)(5)(G) and (H),[39] that address commenter concerns and reflect the Commission's further consideration of the issues. Under the proposal:

- Security-based swap data repositories generally would be required, on a confidential basis after notifying the Commission, to make available security-based swap data, including individual counterparty trade and position data, to certain entities that are identified in the proposed rules and any other persons that are determined by the Commission to be appropriate.[40]
- The data access requirement would be subject to a confidentiality provision that conditions the data access requirement on there being an agreement between the Commission and the entity (in the form of an MOU or otherwise) that addresses the confidentiality of the information received.[41]
- In addition, as discussed below, there would be a conditional exemption to the statutory provision that conditions the data access on the recipient of the data agreeing to indemnify the repository and the Commission for expenses arising from litigation related to the information provided.[42]

A. Data Access Requirement

1. Application to Prudential Regulators and Federal Reserve Banks

The Exchange Act specifically states that a repository is conditionally obligated to make information available to, among others, "each appropriate prudential regulator." [43] The proposed rules would specifically identify, as being eligible to access data, each of the entities encompassed within the statutory "prudential regulator" definition: The Board of Governors of the Federal Reserve System ("Board"), the Office of the Comptroller of the Currency, the Federal Deposit Insurance Corporation ("FDIC"), the Farm Credit Administration, and the Federal Housing Finance Agency.[44]

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[33] *See* 76 FR 54554.

[34] *See* 17 CFR 49.17(d)(2), 49.18(c); 76 FR 54554 (also referencing a separate statutory provision, CEA section 21(c)(4)(A), 7 U.S.C. 24a(c)(4)(A), that requires swap data repositories to provide "direct electronic access" to the CFTC and its designees).

There are differences between the Commission's proposed approach, discussed below, and the approach the CFTC has taken in adopting rules to implement the data access requirement under the CEA. In part, while the CFTC rule requires that entities accessing swap data certify that they are acting within the scope of their jurisdiction, the Commission's proposal instead anticipates considering an entity's interest in the security-based swap information when determining whether to determine that entity may access security-based swap information. *See* part II.A.3.a, *infra*. Also, the Commission's proposed exemption from the indemnification requirement is conditioned in part on an entity requesting security-based swap information in connection with a regulatory mandate, or legal responsibility or authority. *See* part III.B.1.a, *infra*.

[35] *See* 17 CFR 49.17(d)(3), 49.18(c); 76 FR 54555 n.166 (adding that the CFTC does not interpret the notification and indemnification provisions to apply "in circumstances in which an Appropriate Foreign Regulator possesses independent sovereign legal authority to obtain access to the information and data held and maintained by an SDR").

[36] *See* 76 FR 54554.

[37] *See* Swap Data Repositories: Interpretative Statement Regarding the Confidentiality and Indemnification Provisions of the Commodity Exchange Act, 77 FR 65177, 65180–81 (Oct. 25, 2012).

[38] *See id.* The CFTC added that this principle applies even if the applicable data also is reported pursuant to CFTC rules, and that foreign and domestic regulatory authorities also may receive data from the CFTC (rather than the swap data repository) without execution of a confidentiality and indemnification agreement. *See id.* at 65181.

[39] 15 U.S.C. 78m(n)(5)(G) and (H).

[40] *See* proposed Exchange Act rule 13n–4(b)(9).

[41] *See* proposed Exchange Act rule 13n–4(b)(10).

[42] *See* proposed Exchange Act rule 13n–4(b)(ii).

[43] *See* Exchange Act section 13(n)(5)(G)(i), 15 U.S.C. 78m(n)(5)(G)(i).

[44] *See* proposed Exchange Act rule 13n–4(b)(9)(i)–(v).

Exchange Act section 3(a)(74), 15 U.S.C. 78c(a)(74), defines "prudential regulator" by reference to the CEA. The CEA, in turn, defines "prudential regulator" to encompass: (a) The Board, (b) the Office of the Comptroller of the Currency, (c) the FDIC, (d) the Farm Credit Administration or (e) the Federal Housing Finance Agency—in each case with respect to swap dealers, major swap participants, security-based swap dealers or major security-based swap participants (cumulatively, "dealers" or "major participants") that fall within the regulator's authority. *See* CEA section 1a(39); 7 U.S.C. 1a(39).

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Under this approach of specifically identifying each of those regulators, rather than generally referring to "appropriate prudential regulators," the ability of those regulators to access security-based swap data would not vary depending on whether entities regulated by the regulators are acting as security-based swap dealers, as major security-based swap participants, or in some other capacity.[45] For similar reasons, under this approach those regulators' access also would not vary depending on whether the regulator acts in a "prudential" capacity in connection with the information.[46]

The proposed rules also would include "any Federal Reserve Bank" among the entities conditionally eligible to access security-based swap data from repositories,[47] in accordance with the Exchange Act provision that extends data access to "any other person that the Commission determines to be appropriate."[48] Consistent with the standards the Commission expects to consider in connection with determining other entities to be authorized to access such data—including consideration of a relevant authority's interest in accessing security-based swap data based on its regulatory mandate, or legal responsibility or authority[49]—the Commission preliminarily believes that it is appropriate for the Federal Reserve Banks to be able to access such data. The Commission particularly understands that the Federal Reserve Banks occupy important oversight roles under delegated authority from the Board, including supervision of banks that are under the Board's authority, and gathering and analyzing information to inform the Federal Open Market Committee regarding financial conditions.[50] We further understand that the Federal Reserve Banks, as well as the Board, would use data from security-based swap data repositories to fulfill statutory responsibilities related to prudential supervision and financial stability.[51] The Commission accordingly believes preliminarily that the Federal Reserve Banks' access to security-based swap data held by repositories would appropriately fall within their regulatory mandate and legal responsibility or authority, and that the Federal Reserve Banks should conditionally have access to the security-based swap data.[52]

A Federal Reserve Bank's ability to access such data would be subject to conditions related to confidentiality and indemnification (as would the ability of any other entity that is identified by statute or determined by the Commission to access such data).[53]

2. FSOC, CFTC, Department of Justice and Office of Financial Research

The Exchange Act also states that FSOC, CFTC, and the Department of Justice may access security-based swap data.[54] The proposed rules accordingly would identify those entities as being conditionally authorized to access such data.[55]

The proposed rules further would make the Office of Financial Research ("OFR") conditionally eligible to access such data,[56] in accordance with the Exchange Act provision that that extends data access to "any other person

For example, the definition provides that the Board is a prudential regulator with regard to, among others, certain dealers and major participants that are: State-chartered banks and agencies, foreign banks that do not operate insured branches, or members of bank holding companies. Also, for example, the definition provides that the Office of the Comptroller of the Currency is a prudential regulator with regard to, among others, certain dealers or major participants that are national banks, federally chartered branches or agencies of foreign banks or federal saving associations.

[45] This approach particularly addresses the fact that the statutory "prudential regulator" definition noted above specifically refers to those regulators in connection with dealers and major participants that fall within their authority. In the Commission's preliminary view the application of the data access provision should not vary depending on whether an entity regulated by the regulator is acting as a dealer or major participant, or in some other capacity. Such a reading would not further the purposes of Title VII, and the Dodd-Frank Act more generally, including facilitating regulator access to security-based swap information to help address the risks associated with those instruments. Accordingly, the proposed rule does not limit those regulators' access to security-based swap information based on the capacity in which a regulated entity is acting.

[46] Those regulators' ability to access security-based swap data accordingly would not be limited to situations in which they act in the capacity of a prudential supervisor. Thus, for example, the FDIC would conditionally be authorized to access security-based swap data from a repository in connection with all of its statutory capacities, including its prudential supervisory capacity as well as other capacities such as the FDIC's resolution authority pursuant to the Federal Deposit Insurance Act and the Orderly Liquidation Authority provisions of Title II of the Dodd-Frank Act.

[47] *See* proposed Exchange Act rule 13n–4(b)(9)(i).

[48] *See* Exchange Act section 13(n)(5)(G)(v), 15 U.S.C. 78m(n)(5)(G)(v). The CFTC has identified the Federal Reserve Banks as being "appropriate domestic regulators" that may access swap data from swap data repositories. *See* note 29 *supra*.

[49] *See* part II.A.3, *infra*.

[50] Section 11(k) of the Federal Reserve Act grants the Board authority "to delegate, by published order or rule . . . any of its functions, other than those relating to rulemaking or pertaining to monetary and credit policies to . . . members or employees of the Board, or Federal Reserve banks." 12 U.S.C. 248(k). The Federal Reserve Banks carry out the Board's activities including the supervision, examination and regulation of financial institutions as directed by the Board and under its supervision. *See* the Board's Rules of Organization, sec. 3(j) FRRS 8–008 (providing that the Director of the Board's Division of Banking Supervision and Regulation "coordinates the System's supervision of banks and bank holding companies and oversees and evaluates the Reserve Banks' examination procedures"). The Board further has delegated extensive authority to the Reserve Banks with respect to numerous supervisory matters. *See* 12 CFR 265.11 (functions delegated by the Board to the Federal Reserve Banks).

[51] We understand that the Board and the Federal Reserve Banks jointly would use the data in support of the prudential supervision of institutions under the Board's jurisdiction, such as state member banks, bank holding companies, and Edge Act corporations. *See, e.g.*, section 9 of the Federal Reserve Act, 12 U.S.C. 321–338a (supervision of state member banks); the Bank Holding Company Act, 12 U.S.C. 1841–1852 (supervision of bank holding companies); the Edge Act, 12 U.S.C. 610 *et seq.* (supervision of Edge Act corporations). We also understand that the Board and the Federal Reserve Banks would use the data in support of the implementation of monetary policy, such as through market surveillance and research. *See, e.g.*, section 12A of the Federal Reserve Act, 12 U.S.C. 263 (establishing the Federal Open Market Committee); and section 2A of the Federal Reserve Act, 12 U.S.C. 225a (setting monetary policy objectives). In addition, we understand that the Board and the Federal Reserve Banks would use the data in fulfilling the Board's responsibilities with respect to assessing, monitoring and mitigating systemic risk, such as supervision of systemically important institutions. *See, e.g.*, section 113 of the Dodd-Frank Act, 12 U.S.C. 5323 (SIFIs); and section 807 of the Dodd-Frank Act, 12 U.S.C. 5466 (designated FMUs).

[52] The Federal Reserve Banks' access to this information, like the access of the entities directly identified by the statute, would be subject to conditions related to confidentiality and indemnification as discussed below, including conditions to limit an authority's access to data by linking the scope of the exemption from the indemnification requirement to information that is related to persons or activities within an entity's regulatory mandate or its legal responsibility or authority, as specified in an MOU between the Commission and the entity. *See* parts II.C and III.C, *infra*.

In proposing to permit the Federal Reserve Banks to access security-based swap information pursuant to the data access provisions, the Commission preliminarily believes that the Federal Reserve Banks' access should not be limited to information regarding security-based swap transactions entered into by banks supervised by the Board, but should be available more generally with regard to security-based swap transaction data. This is consistent with the fact that Title VII does not limit the Board's access to data in such a way. This view also reflects the breadth of the Federal Reserve Banks' responsibilities regarding prudential supervision and financial stability, as addressed above.

[53] In this regard, the Commission notes that personnel of the Board and the Reserve Banks already are subject to a number of confidentiality requirements. *See* 18 U.S.C. 1905 (imposing criminal sanctions on U.S. government personnel who disclose non-public information except as provided by law), 18 U.S.C. 641 (imposing criminal sanctions on the unauthorized transfer of records), 5 CFR 2635.703 (Office of Government Ethics regulations prohibiting unauthorized disclosure of nonpublic information); *see also* Federal Reserve Bank Code of Conduct section 3.2 (requiring Reserve Bank employees to maintain the confidentiality of nonpublic information).

[54] *See* Exchange Act sections 13(n)(5)(G)(ii)–(iv), 15 U.S.C. 78m(n)(5)(G)(ii)–(iv).

[55] *See* proposed Exchange Act rule 13n–4(b)(9)(vi)–(viii).

[56] *See* proposed Exchange Act rule 13n–4(b)(9)(ix), (x).

that the Commission determines to be appropriate."

The Commission preliminarily believes that such access by the OFR is appropriate in light of the OFR's regulatory mandate and legal responsibility and authority.[57] The OFR was established by Title I of the Dodd-Frank Act to support FSOC and FSOC's member agencies by identifying, monitoring and assessing potential threats to financial stability thorough the collection and analysis of financial data gathered from across the public and private sectors.[58] In connection with this statutory mandate to monitor and assess potential threats to financial stability, the OFR's access to security-based swap transaction data may be expected to help assist it in examining the manner in which derivatives exposures and counterparty risks flow through the financial system, and in otherwise assessing those risks. The Commission accordingly believes preliminarily that the OFR's access to security-based swap data held by repositories would appropriately fall within its regulatory mandate and legal responsibility and authority, and that the OFR should conditionally have access to the security-based swap data.[59]

As with the other entities that may access data pursuant to the data access provision, the OFR's ability to access such data would be subject to conditions related to confidentiality and indemnification.[60]

3. Future Commission Determination of Additional Entities

The proposal also would require that repositories provide data to any other person that the Commission determines to be appropriate. The Commission anticipates that entities that may seek such access would likely include foreign financial supervisors (including foreign futures authorities), foreign central banks and foreign ministries.[61] One or more self-regulatory organizations also potentially may seek such access. The proposal further would provide that the Commission will make such determinations through the issuance of Commission orders, and that such determinations may be conditional or unconditional.[62] A relevant authority would be able to request that the Commission make such a determination.

a. Determination Factors and Conditions

The Commission continues to expect that it would consider a variety of factors in connection with making such a determination, and that it may impose associated conditions in connection with the determination. The Commission expects to consider the factors discussed below, as well as any other factors the Commission determines to be relevant.[63]

In part, the Commission expects to consider whether there is an MOU or other arrangement[64] between the Commission and the relevant authority that is designed to protect the confidentiality of the security-based swap data provided to the authority.[65] The Commission also expects to consider whether information accessed by the applicable authority would be subject to robust confidentiality safeguards. The Commission believes that these factors are important given the proprietary and highly sensitive nature of the data maintained by the repository.[66]

In making a determination the Commission also may consider the relevant authority's interest in access to security-based swap data based on the relevant authority's regulatory mandate, or legal responsibility or authority. Limiting the amount of information accessed by an authority in this manner may help minimize the risk of unauthorized disclosure, misappropriation, or misuse of security-based swap data because each relevant authority will only have access to information within its regulatory mandate, or legal responsibility or authority.

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[57] See proposed Exchange Act rule 13n–4(b)(9)(ix). We note that the CFTC has identified the OFR as being an "appropriate domestic regulator" that may access swap data from swap data repositories. *See* note 29, *supra*.

[58] *See* Dodd-Frank Act section 153(a) (identifying the purpose of the OFR as: (1) Collecting data on behalf of FSOC and providing such data to FSOC and its member agencies; (2) standardizing the types and formats of data reported and collected; (3) performing applied research and essential long-term research; (4) developing tools for risk measurement and monitoring; (5) performing other related services; (6) making the results of the activities of the Office available to financial regulatory agencies; and (7) assisting those member agencies in determining the types and formats of data authorized by the Dodd-Frank Act to be collected by the member agencies); Dodd-Frank Act section 154(c) (requiring that OFR's Research and Analysis Center, on behalf of FSOC, develop and maintain independent analytical capabilities and computing resources to: (A) Develop and maintain metrics and reporting systems for risks to U.S. financial stability; (B) monitor, investigate, and report on changes in systemwide risk levels and patterns to FSOC and Congress; (C) conduct, coordinate, and sponsor research to support and improve regulation of financial entities and markets; (D) evaluate and report on stress tests or other stability-related evaluations of financial entities overseen by FSOC member agencies; (E) maintain expertise in such areas as may be necessary to support specific requests for advice and assistance from financial regulators; (F) investigate disruptions and failures in the financial markets, report findings and make recommendations to FSOC based on those findings; (G) conduct studies and provide advice on the impact of policies related to systemic risk; and (H) promote best practices for financial risk management).

The OFR is also required to report annually to Congress its analysis of any threats to the financial stability of the United States. *See* Dodd-Frank Act section 154(d).

[59] As discussed below, the conditions to the proposed indemnification exemption would limit an entity's access to data by linking the scope of the exemption to information that related to persons or activities within an entity's regulatory mandate or legal responsibility or authority, as specified in an MOU between the Commission and the entity. *See* part III.C, *infra*.

[60] As U.S. government personnel, OFR personnel are subject to the same general confidentiality requirements that are addressed above in the context of the Board and the Federal Reserve Banks. *See* note 53, *supra*. In addition, the OFR is required to keep data collected and maintained by the OFR data center secure and protected against unauthorized disclosure. *See* Dodd-Frank Act section 154(b)(3); *see also* 12 CFR 1600.1 (ethical conduct standards applicable to OFR employees, including post-employment restrictions linked to access to confidential information); 31 CFR 0.206 (Treasury Department prohibition on employees disclosing official information without proper authority).

[61] *See* proposed Exchange Act rule 13n–4(b)(9)(x).

[62] *See id.* In those respects, the proposed rule would implement the corresponding statutory language, which provides the Commission with the authority to allow data access to "any other person that the Commission determines to be appropriate." *See* Exchange Act section 13(n)(5)(G)(v), 15 U.S.C. 78m(n)(5)(G)(v).

[63] The factors discussed below that may be expected to be relevant to a Commission's determination that a person is eligible to access security-based swap information pursuant the statutory data access provisions—including factors related to the presence of a confidentiality MOU and related to a person's regulatory mandate, or legal responsibility or authority—parallel certain of the conditions to the exemption from the indemnification requirement. *See* parts III.B, C, *infra*.

[64] The Cross-Border Proposing Release specifically referred to a "supervisory and enforcement MOU or other arrangement" in this context. *See* Cross-Border Proposing Release, 78 FR 31047. The Commission is revising its proposed guidance to refer to MOUs and other arrangements generally—rather than "supervisory and enforcement" MOUs and arrangements—to allow the parties more flexibility in arriving at such confidentiality arrangements.

[65] Such an MOU or other arrangement may also satisfy the statutory requirement that a security-based swap data repository obtain a confidentiality agreement from the authority. *See* part II.B.1, *infra* (proposed Exchange Act rule 13n–4(b)(10)(i) would permit an agreement between the Commission and a relevant authority to satisfy the statutory condition that the repository obtain a confidentiality agreement from the authority).

Moreover, this MOU or other arrangement further may satisfy the proposed indemnification exemption's condition that there be an arrangement between the Commission and an entity regarding the confidentiality of the information provided. *See* part III.C, *infra*. To the extent that a relevant authority's needs access to additional information, the relevant authority may request that the Commission consider revising its determination order, and MOU or other arrangement, as applicable.

[66] *See* Exchange Act section 13(n)(5)(H)(i).

Consistent with this factor, the Commission preliminarily expects that such determination orders typically would incorporate conditions that specify the scope of a relevant authority's access to data, and that limit this access in a manner that reflects the relevant authority's regulatory mandates or legal responsibility or authority.[67] Depending on the nature of the relevant authority's interest in the data, such conditions potentially could address factors such as the domicile of the counterparties to the security-based swap, and the domicile of the underlying reference entity.[68] Focusing access to data in this way should help address one commenter's concerns regarding "unfettered access" to such proprietary data.[69]

The Commission further anticipates taking into account any other factors that are appropriate to the determination, including whether such a determination would be in the public interest. This consideration likely would include whether the relevant authority agrees to provide the Commission and other U.S. authorities with reciprocal assistance in matters within their jurisdiction.

b. Additional Matters Related to the Determinations

The Commission contemplates taking various approaches in deciding whether to impose additional conditions in connection with its consideration of requests for determination orders. For example, the Commission may issue a determination order that is for a limited time. The Commission further may revoke a determination at any time. For example, the Commission may revoke a determination or request additional information from a relevant authority to support the continuation of the determination if for example a relevant authority fails to comply with the MOU, such as by failing to keep confidential security-based swap data provided to it by a repository. Even absent such a revocation, moreover, an authority's access to data pursuant to these provisions also would cease upon the termination of the MOU or other arrangement used to satisfy the confidentiality condition, or, as applicable, the indemnification exemption.[70]

The Commission preliminarily believes that the determination process described above represents a reasonable approach toward providing appropriate access to relevant authorities. Moreover, the Commission preliminarily believes that this process—particularly the link between access and the authority's interest in the information—appropriately builds upon existing voluntary frameworks, in accordance with one commenter's suggestion that the applicable framework incorporate other cooperative efforts with regard to access to information.[71]

The Commission expects that repositories will provide relevant authorities with access to security-based swap data in accordance with the determination orders, and the Commission generally does not expect to be involved in reviewing, signing-off on or otherwise approving relevant authorities' requests for security-based swap data from repositories that are made in accordance with a determination order. Moreover, the Commission continues preliminarily to believe that it is not necessary to prescribe by rule specific processes to govern a repository's treatment of requests for access.[72]

Finally, the Commission notes that it may elect to apply these determination factors and consider applying protections similar to those in the data access provisions of Exchange Act sections 13(n)(5)(G) and (H) when designating authorities to receive direct access under section 13(n)(5)(D). Section 13(n)(5)(D) states that a repository must provide direct electronic access to the Commission "or any designee of the Commission, including another registered entity." [73] In practice, the Commission expects that security-based swap data repositories may satisfy their obligation to make available data pursuant to sections 13(n)(5)(G) and (H) by providing electronic access to appropriate authorities. To the extent a repository were to satisfy those requirements by some method other than electronic access, however, the Commission separately may consider whether to also designate particular authorities as being eligible for electronic access to the repository pursuant to section 13(n)(5)(D). In making such assessments under section 13(n)(5)(D), the Commission preliminarily believes that it may consider factors similar to the above determination factors, including the presence of confidentiality safeguards, and the authority's interest in the information based on its regulatory mandate or legal responsibility or authority.

4. Notification Requirement

The proposal would implement the statutory notification requirement—which states that a repository must notify the Commission when an entity requests that the repository make

[67] To appropriately limit a relevant authority's access to only security-based swap data that is consistent with the MOU between the Commission and the relevant authority, a repository may, for example, need to customize permissioning parameters to reflect each relevant authority's electronic access to security-based swap data. *See generally* note 103, *infra* (discussing access criteria currently used by DTCC in connection with current voluntary disclosure practices).

[68] *See* note 105, *infra*, and accompanying text (discussing application of those factors in the context of the indemnification exemption).

[69] *See* note 14, *supra* (comment voicing concerns about "unfettered access" to security-based swap information by regulators, including foreign financial supervisors, foreign central banks and foreign ministries, beyond their regulatory authority and mandate).

As discussed below, moreover, the availability of the proposed indemnification exemption would similarly be conditioned to reflect the recipient's regulatory mandates or legal responsibility or authority. *See* part III.C, *infra*. Accordingly, based on the expectation that persons who seek access pursuant to these provisions would rely on the indemnification exemption, there would be comparable limitations to access applicable to persons directly identified by Exchange Act sections 15(n)(5)(i) through (iv) (the "prudential regulators," FSOC, CFTC and Department of Justice) or added by the proposed rules (the Federal Reserve Banks and the OFR).

[70] *See* parts II.B and III.B, C, *supra*.

[71] *See* DTCC comment (June 3, 2011) at 6–7 ("It is critical that the United States, the European Union and the other major global markets align their regulatory regimes to limit opportunities for market distorting arbitrage. The creation of a global credit default swap repository would not have occurred without the global regulatory cooperation achieved through the OTC Derivatives Regulators' Forum ('ODRF') and the OTC Derivatives Regulators Supervisors Group ('ODSG'). It is important that the global SDR framework incorporate their efforts, particularly the ODRF's guidelines on regulatory access to information stored in trade repositories for over-the-counter derivatives."); DTCC comment (Jan. 24, 2011) at 3 ("DTCC relies upon the direction provided by the OTC Derivatives Regulators' Forum ('ODRF'), whose membership includes the SEC and the Commodity Futures Trading Commission ('CFTC'). DTCC's Trade Information Warehouse (the 'Warehouse' or 'TIW') has followed the ODRF's guidance, recognizing that broad agreement among global regulators is difficult to achieve. DTCC is committed to complying with the policies adopted by the regulators and working with the Commission in this regard.").

In this regard, DTCC further has stated that it routinely provides U.S. regulators with credit default swap data related to overseas transactions entered into by non-U.S. persons on U.S. reference entities, and that it provides European regulators with data related to transactions in the U.S. by U.S. persons on European reference entities. *See* DTCC comment (Jan. 24, 2011) at 12; *see also* DTCC comment (June 3, 2011) at 7–8.

[72] *See* Cross-Border Proposing Release, 78 FR 31047–48. One commenter suggested that the Commission adopt an approach proposed by the CFTC, whereby a regulator requesting access to data first file a request for access and certify the statutory authority for the request and detail the basis for the request. *See* Managed Funds Association comment (Jan. 24, 2011) at 3–4. In contrast to that proposal, however, the final CFTC rules do not require relevant authorities to detail the basis for their requests, and do not require a swap data repository to provide access only if it is satisfied that the regulator is acting within the scope of its authority. *See* note 31, *supra*.

[73] 15 U.S.C. 78m(n)(5)(D).

available security-based swap data [74]—by requiring the repository to inform the Commission upon its receipt of the first request for data from a particular entity (which may include any request that the entity be provided ongoing online or electronic access to the data).[75] A repository must keep such notifications and any related requests confidential.[76]

The repository further would have to maintain records of all information related to the initial and all subsequent requests for data access requests from that entity, including records of all instances of online or electronic access, and records of all data provided in connection with such requests or access.[77] For these purposes, we believe that "all information related to" such requests would likely include, among other things: The identity of the requestor or person accessing the data; the date, time and substance of the request or access; and copies of all data reports or other aggregations of data provided in connection with the request or access.

In the Commission's preliminary view, the proposed notification requirement is designed to account for the way in which we believe entities are likely to access such data from repositories, by distinguishing steps that an entity takes to arrange access from subsequent electronic instructions and other means by which the recipient obtains data. By making relevant data available to the Commission in this manner, the proposed approach would place the Commission on notice that a recipient has the ability to access security-based swap data, and place the Commission in a position to examine such access as appropriate, while avoiding the inefficiencies that would accompany an approach whereby a repository must direct to the Commission information regarding each instance of access by each recipient. Moreover, the proposed approach would be consistent with the manner in which the Commission examines the records of regulated entities under the Commission's authority.

The Commission recognizes that one commenter opposed any requirement that the Commission receive notice of a recipient's initial request, on the grounds that such notice may cause other authorities to hesitate to make such requests.[78] While the Commission appreciates the commenter's concerns, the Commission preliminarily believes that it is necessary for the Commission to be informed of the initial request from a particular entity so that the Commission may assess whether the initial conditions to data access (*i.e.*, MOUs or other arrangements as needed to satisfy the confidentiality condition and the indemnification exemption) [79] have been met at the time the repository first is requested to provide the entity with information pursuant to the data access provisions, and, more generally, to facilitate the Commission's ongoing assessment of the repository's compliance with the data access provisions. The Commission also believes that commenter concerns that other regulators may be reluctant to place the Commission on notice of such initial requests are mitigated by the Commission's long history of cooperation with other authorities in supervisory and enforcement matters.[80]

5. Limitation to "Security-Based Swap Data"

Repositories that obtain security-based swap data may also obtain data regarding other types of financial instruments, such as swaps under the CFTC's jurisdiction. We do not read the data access provisions of Exchange Act sections 13(n)(5)(G) and (H)—which were added by Subtitle B of Title VII (which focused on the regulatory treatment of security-based swaps) [81] to the Exchange Act (which generally addresses the regulation of securities such as security-based swaps)—to require a repository to make available data that does not involve security-based swaps. The statutory confidentiality condition to the data access requirement further suggests that the data access provisions are intended to apply only to security-based swap data.[82] Accordingly, the proposed rules specifically address access to "security-based swap data" obtained by a security-based swap data repository.[83]

B. Confidentiality Condition

The Exchange Act provides that, prior to providing data, a repository "shall receive a written agreement from each entity stating that the entity shall abide by the confidentiality requirements described in section 24 relating to the information on security-based swap transactions that is provided." [84]

[74] *See* Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G). As discussed below, *see* part IV, *infra*, the notification requirement does not apply to circumstances in which disclosures are made outside of the requirements of Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G), particularly when a dually regulated data repository makes disclosure pursuant to foreign law, or when the Commission provides security-based swap data to an entity.

[75] *See* proposed Exchange Act rule 13n–4(e). The rule does not require the repository to proactively inform the Commission of subsequent requests.

[76] Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G), and proposed rule 13n–4(b)(9) both require that a repository must make data available "on a confidential basis." Failure by a repository to treat such notifications and requests as confidential could have adverse effects on the underlying basis for the requests. If, for example, a regulatory use of the data is improperly disclosed, such disclosure could signal a pending investigation or enforcement action, which could have detrimental effects.

[77] *See* proposed Exchange Act rule 13n–4(e).

We note that Exchange Act rule 13n–7(b)(1) requires security-based swap data repositories to maintain copies of "all documents and policies and procedures required by the Act and the rules and regulations thereunder, correspondence, memoranda, papers, books, notices, accounts and other such records as shall be made or received by it in the course of its business as such." *See also* SDR Adopting Release, 80 FR 14501 ("This rule includes all electronic documents and correspondence, such as data dictionaries, emails and instant messages, which should be furnished in their original electronic format."). Proposed Exchange Act rule 13n–4(e) identifies specific types of records that must be maintained in the specific context of access request to repositories.

[78] *See* DTCC comment (Aug. 13, 2013) ("DTCC discourages the Commission from requiring a notification requirement upon initial request as suggested by the Cross-Border Proposal. Authorities will likely be hesitant to make such request to an SDR if it triggers a notice to another authority, particularly if such request is pursuant to an investigation. DTCC proposes that the Commission consider notification to be deemed satisfied if the request is made by an entity to the SDR pursuant to an established information sharing arrangement[.]").

[79] *See* parts II.B and III.B, *infra*.

[80] The Commission also recognizes that the same commenter stated that "regulators want direct electronic access to data in SDRs where that data is needed to fulfill regulatory responsibilities" rather than access "by request, with notice to another regulatory authority." *See* DTCC comment (Jan. 24, 2011) at 11–12. Data repositories in fact can provide direct electronic access to relevant authorities under the proposed interpretation. The proposed requirement that the repository inform the Commission when the relevant authority first requests access to security-based swap data maintained by the repository, and to retain records of subsequent access, is designed to facilitate such direct access.

[81] *See* Dodd-Frank Act section 763(i) (addressing "public reporting and repositories for security-based swaps," including the addition of section 13(n), 15 U.S.C. 78m(n), to the Exchange Act to address security-based swap data repositories); *see generally* Subtitle B to Title VII of the Dodd-Frank Act, section 761 *et seq.* (addressing "Regulation of Security-Based Swap Markets").

[82] In particular, the confidentiality condition to the data access provisions specifically requires that the recipient entity abide by confidentiality requirements for "the information on security-based swap transactions that is provided," suggesting that the Exchange Act data access provisions are intended solely to address security-based swap data. *See* Exchange Act section 13(n)(5)(H)(i), 15 U.S.C. 78m(n)(5)(H)(i).

Moreover, this approach is consistent with the CFTC's comparable rules, which apply only to swap data. *See* 17 CFR 49.17(d) and 49.18 (discussing regulators' access to swap data under the CEA).

[83] *See* proposed Exchange Act rule 13n–4(b)(9).

[84] *See* Exchange Act section 13(n)(5)(H)(i), 15 U.S.C. 78m(n)(5)(H)(i).

Exchange Act section 24, 15 U.S.C. 78x, generally addresses disclosures of information by the Commission and its personnel. In relevant part it provides that the Commission may, "in its discretion and upon a showing that such

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The proposed rule implementing this condition would require that, before a repository provides information pursuant to the data access provisions, "there shall be in effect an arrangement between the Commission and the entity (in the form of a memorandum of understanding or otherwise) to address the confidentiality of the security-based swap information made available to the entity." [85] The proposed rule further would provide that this arrangement would be deemed to satisfy the statutory requirement that the repository receive a written confidentiality agreement from the entity.[86]

This proposed approach to implementing the confidentiality condition, in other words, would use an arrangement between the Commission and a regulator or other recipient entity to satisfy the statutory confidentiality condition. The approach would not necessitate the use of confidentiality agreements entered into by repositories.[87]

In the Commission's preliminary view, this approach reflects an appropriate way to satisfy the interests associated with the confidentiality condition, while facilitating the statutory data access provision's goal of promoting the flow of information to authorities. The approach further would build upon the Commission's experience in negotiating MOUs with other regulators in connection with enforcement and supervision, particularly the Commission's experience in connection with the development of provisions related to maintaining the confidentiality of information.

As a result, the approach would potentially obviate the need for each individual repository to negotiate and enter into dozens of confidentiality agreements. By building upon the Commission's experience and expertise in this area, moreover, the Commission expects that this approach also would help avoid the possibility of uneven and potentially inconsistent application of confidentiality protections across data repositories and recipient entities.

In proposing this approach, the Commission also is mindful that the statutory provision specifically references the "confidentiality requirements described in section 24" of the Exchange Act. In the Commission's preliminary view this statutory language articulates a standard which requires that there be adequate confidentiality assurances. Thus, the Commission preliminarily believes that the proposed provision, under which the Commission would negotiate and enter into agreements providing such confidentiality assurances, appropriately implements the statutory reference to section 24.

C. Request for Comment

The Commission requests comment regarding all aspects of these proposed rules regarding access to security-based swap data from repositories. Among other things, commenters particularly are invited to address the proposal that the confidentiality agreement requirement would be satisfied by an MOU or other agreement between the Commission and another entity. Commenters also are invited to address: The proposed limitation of the data access requirement to security-based swap data; the proposed provisions related to access by prudential regulators, the Federal Reserve Banks and the OFR; the criteria that the Commission should consider in evaluating whether to determine to permit additional entities to access data from repositories; whether the orders that make such determinations generally should encompass conditions that limit a relevant authority's access to information to reflect its regulatory mandate or legal responsibility or authority; whether the Commission should prescribe specific processes to govern requests for such access; and whether the Commission should prescribe a process to govern a repository's treatment of requests for access.

In addition, commenters are invited to address the proposed rules implementing the notification requirement, including the proposed provisions regarding the maintenance of information related to data requests. In this regard, is there an alternative to requiring repositories to maintain copies of all data they provide in connection with the data access provisions that would still permit the Commission to assess the repository's ongoing compliance with those provisions? For example, are alternative approaches available such that the Commission should not require repositories to maintain actual copies of all reports or other aggregations of data provided pursuant to the data access provisions, such as if the repository instead implements policies and procedures sufficient to demonstrate a process for creating records that reflect the data provided, and the repository produces promptly copies of such records upon request by a representative of the Commission? [88] Would such an alternative approach reduce the burdens on repositories while still permitting the Commission to assess ongoing compliance?

Commenters further are invited to address whether the Commission should determine that other domestic authorities, such as one or more self-regulatory organizations, should be eligible to access security-based swap data pursuant to these provisions. If so, should the access of such self-regulatory organizations be limited in any particular respects?

information is needed," provide all records and other information "to such persons, both domestic and foreign, as the Commission by rule deems appropriate if the person receiving such records or information provides such assurances of confidentiality as the Commission deems appropriate." *See* Exchange Act section 24(c), 15 U.S.C. 78x(c); *see also* Exchange Act rule 24c–1(b) (providing that the Commission may, upon "such assurances of confidentiality as the Commission deems appropriate," provide non-public information to persons such as domestic and foreign governments or their political subdivisions, authorities, agencies or instrumentalities, self-regulatory organizations and foreign financial authorities).

[85] *See* proposed Exchange Act rule13n-4(b)(10).

[86] *See* Exchange Act section 13(n)(5)(H)(1). As discussed below, *see* part IV, *infra*, the confidentiality condition does not apply to circumstances in which disclosures are made outside of the requirements of Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G), particularly when a dually regulated data repository makes disclosure pursuant to foreign law, or when the Commission provides security-based swap data to an entity.

[87] In this regard, the Commission notes that the statute does not require that the security-based swap data repository "agree" with the entity, "enter into" an agreement, or otherwise be a party to the confidentiality agreement. The statute merely states that the repository "receive" such an agreement. *See* Exchange Act section 13(n)(5)(H)(i), 15 U.S.C. 78m(n)(5)(H)(i). Accordingly, we believe that, at a minimum, the statutory language is ambiguous as to whether the data repository must itself be a party to the confidentiality agreement. In light of this ambiguity, we have preliminarily determined to read the statute to permit the Commission to enter into confidentiality agreements with the entity, with the repository receiving the benefits of the agreement. Accordingly, the Commission believes that it is appropriate to view a security-based swap data repository as having received a confidentiality agreement when the entity enters into a confidentiality agreement with the Commission and that agreement runs to the benefit of the repository.

[88] For example, in adopting Exchange Act rule 17a–4(b)(13) to provide that broker-dealers must preserve certain written policies and procedures in connection with creditworthiness assessments, the Commission stated that although the rule does not require that a broker-dealer maintain a record of each such creditworthiness determination, a broker-dealer would need to be able to support each such determination, and that the broker-dealer may do so by either maintaining documentation of those determinations or by being in a position to "replicate the original credit risk determination using the same process, information, and inputs employed to make the original determination." *See* Exchange Act Release No. 71194 (Dec. 27, 2013), 79 FR 1522, 1528–29, 1550 (Jan. 8, 2014).

III. Proposed Exemption From the Indemnification Requirement

A. Proposed Exemption

The Exchange Act also conditions the data access requirement on each recipient entity agreeing "to indemnify the security-based swap data repository and the Commission for any expenses arising from litigation relating to information provided under section 24." [89]

Pursuant to the Commission's authority under Exchange Act section 36,[90] the Commission is proposing a conditional exemption from that statutory indemnification requirement. This proposed exemption would be effective whenever the applicable conditions are met, in contrast with the earlier proposal, which would have conditionally exempted regulators and other authorities from the indemnification requirement only at the election of the data repository.[91]

This proposed exemption reflects the Commission's preliminary concern that requiring authorities to agree to provide indemnification could lead to negative consequences in practice. The Commission continues to understand that certain authorities may be legally prohibited or otherwise limited from agreeing to indemnify data repositories or the Commission for expenses arising in connection with the information received from a repository.[92]

As a result, application of the indemnification requirement may chill some requests by regulators or other authorities for access to security-based swap data, which would hinder those authorities' ability to address their own regulatory mandate or legal responsibility or authority.[93] The resulting lack of access also may impair coordination among regulators with regard to the oversight of market participants that engage in security-based swap transactions across national boundaries. For example, European Union ("EU") law provides that the ability of certain non-EU regulators to access data from EU repositories is conditioned on there being an international agreement that ensures that EU authorities have "immediate and continuous access to all of the information needed for the exercise of their duties." [94] As a result, application of the indemnification requirement without an exemption being available potentially could preclude EU authorities from accessing data from U.S. security-based swap data repositories. Under such circumstances, it is possible that EU authorities may be unwilling to permit the Commission and other U.S. regulators to access security-based swap data from EU repositories. The resulting concerns associated with a lack of regulatory access to security-based swap data are particularly significant given that data access allows relevant authorities to be in a better position to, among other things, monitor risk exposures of individual counterparties to swap and security-based swap transactions, monitor concentrations of risk exposures and evaluate risks to financial stability.[95]

Such a result associated with application of the indemnification requirement further may make substituted compliance unavailable in connection with security-based swap data reporting requirements, given that under rules adopted by the Commission the availability of substituted compliance for those requirements is predicated in part on the Commission's ability to directly access data in foreign repositories.[96]

The Commission recognizes that indemnification may help support confidentiality safeguards by making a recipient liable for expenses that a repository or the Commission incurs in connection with breaches of confidentiality. Nonetheless, the

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[89] Exchange Act section 13(n)(5)(H)(ii), 15 U.S.C. 78m(n)(5)(H)(ii). As discussed below, *see* part IV, *infra*, the statutory indemnification requirement would not always be triggered by the disclosure of security-based swap information.

In the event that the proposed exemption is unavailable, the Commission agrees with one commenter's view that "any indemnity should be limited in scope to minimize the potential reduction in value of registered SDRs to the regulatory community." *See* DTCC comment (Jan. 24, 2011) at 12. Consistent with that view, as stated in the Cross-Border Proposing Release, the Commission would not expect that an indemnification agreement would include a provision requiring a relevant authority to indemnify the repository from the repository's own wrongful or negligent acts. *See* Cross-Border Proposing Release, 78 FR 31051 n.829.

[90] 15 U.S.C. 78mm (providing the Commission with general exemptive authority . . . "to the extent that such exemption is necessary or appropriate in the public interest, and is consistent with the protection of investors").

[91] To implement this approach, the Commission proposes in relevant part that the indemnification requirement conditionally "shall not be applicable" with regard to the repository's disclosure of security-based swap information. *See* proposed Exchange Act rule 13n–4(d)(1). The earlier proposal would have conditionally provided that a registered security-based swap data repository "is not required to comply" with the indemnification requirement. *See* Cross-Border Proposing Release, 78 FR 31209 (paragraph (d) of proposed rule 13n–4).

[92] As stated in the Cross-Border Proposing Release, the Commission recognizes that certain domestic authorities, including some of those expressly identified in Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G), as a matter of law cannot provide an open-ended indemnification agreement. *See* Cross-Border Proposing Release, 78 FR 31048–49 (particularly noting that the Antideficiency Act prohibits certain U.S. federal agencies from obligating or expending federal funds in advance or in excess of an appropriation, apportionment, or certain administrative subdivisions of those funds, *e.g.*, through an unlimited or unfunded indemnification).

[93] *See* DTCC cross-border comment (Aug. 21, 2013) at 6 ("The continued presence of the Indemnification Provision (even as modified by the exemption in the Cross-Border Proposal) may pose problems for Commission-regulated, U.S.-based SDRs and their ability to share information with third-party regulatory authorities. As a result, foreign regulators may seek to establish their own 'national' repositories to ensure access to the information they need, fragmenting the data among jurisdictions. Similarly, non-U.S. trade repositories may find themselves subject to similar reciprocal impediments to sharing information with the Commission or other U.S. regulatory agencies absent a confidentiality and indemnification agreement."); *see also* DTCC comment (Nov. 15, 2010) at 3 ("DTCC remains concerned that regulators are not likely to grant SDRs indemnification in exchange for access to the information and, accordingly, regulators may actually receive less aggregated market data. Such an outcome would result in a reduction of information accessible to regulators on a timely basis both domestically and internationally, which contravenes the purpose of SDRs and jeopardizes market stability."); Cleary Gottlieb comment (Sept. 20, 2011) at 31 ("[T]he indemnification requirement could be a significant impediment to effective regulatory coordination, since non-US regulators may establish parallel requirements for U.S. regulators to access swap data reported in their jurisdictions."); ESMA comment (Jan. 17, 2011) at 2 ("We believe that ensuring confidentiality is essential for exchanging information among regulators and such indemnification agreement undermines the key principle of trust according to which exchange of information should occur.").

[94] *See* EU regulation 648/2012 ("EMIR"), art. 75(2).

[95] *See* Darrell Duffie, Ada Li, and Theo Lubke, Policy Perspectives of OTC Derivatives Market Infrastructure, Federal Reserve Bank of New York Staff Report No. 424, dated January 2010, as revised March 2010 (with data from repositories regulators can "explore the sizes and depths of the markets, as well as the nature of the products being traded. With this information, regulators are better able to identify and control risky market practices, and are better positioned to anticipate large market movements."); *see also* DTCC comment (June 3, 2011) at 5 (noting that a data repositories should be able to provide: (i) Enforcement authorities with necessary trading information; (ii) regulatory agencies with counterparty-specific information about systemic risk based on trading activity; (iii) aggregate trade information on market-wide activity and aggregate gross and net open interest for publication; and (iv) real-time reporting from [security-based swap execution facilities] and bilateral counterparties and related dissemination).

[96] *See* Regulation SBSR, rule 908(c)(2)(iii)(C), 17 CFR 242.908(c)(2)(iii)(C) (conditioning the availability of substituted compliance in part on the Commission having "direct electronic access to the security-based swap data held by a trade repository or foreign regulatory authority to which security-based swaps are reported pursuant to the rules of that foreign jurisdiction"); *see also* Exchange Act Release No. 74244 (Feb. 11, 2015), 80 FR 14564, 14661 (Mar.19, 2015) ("Regulation SBSR Adopting Release") ("granting substituted compliance without direct electronic access would not be consistent with the underlying premise of substituted compliance: That a comparable regulatory result is reached through compliance with foreign rules rather than with the corresponding U.S. rules.").

countervailing considerations noted above indicate that indemnification—of either the repository or the Commission—should not be required so long as appropriate confidentiality protections are provided in other ways.

For these reasons the Commission preliminarily believes that it is necessary and appropriate in the public interest, and consistent with the protection of investors, that the indemnification requirement be subject to an exemption that applies whenever the applicable conditions are satisfied.[97]

B. Confidentiality Arrangement Condition

The proposal in part would condition the indemnification exemption upon there being in effect one or more arrangements (in the form of an MOU or otherwise) between the Commission and the entity that addresses the confidentiality of the security-based swap information provided and other matters as determined by the Commission.[98] The Commission preliminarily believes that such an MOU or other arrangement would address similar confidentiality interests that appear to be reflected by the statutory indemnification requirement, particularly given that the disclosure of confidential information inconsistent with such arrangements can lead to the termination of the arrangement and the loss of data access. Just as an indemnification agreement may be expected to incentivize the confidential treatment of information, such a confidentiality arrangement would help strengthen the authority's incentive to maintain the confidentiality of information.

The Commission anticipates that in determining whether to enter into such an MOU or other arrangement, it would consider, among other things, whether: (a) Security-based swap information from a repository would help fulfill the relevant authority's regulatory mandate, or legal responsibility or authority; (b) the relevant authority provides such assurances of confidentiality as the Commission deems appropriate with respect to the security-based swap information provided to the authority; (c) the relevant authority is subject to statutory and/or regulatory confidentiality safeguards; (d) the relevant authority agrees to provide the Commission with reciprocal assistance in matters within the Commission's jurisdiction; and (e) an MOU or other arrangement would be in the public interest. These considerations are comparable to the criteria that the Commission anticipates considering as it determines whether an entity is eligible to access information pursuant to the data access provisions.[99] Accordingly, for regulators or other authorities whose access is subject to a determination order, the same confidentiality MOUs or other agreements that are needed to satisfy the indemnification exemption may also serve to satisfy those prerequisites to the determinations.[100]

C. Condition Regarding Regulatory Mandate or Legal Responsibility or Authority

The proposal further would condition the indemnification exemption on the requirement that the information relate to persons or activities within the recipient entity's regulatory mandate, or legal responsibility or authority.[101] This proposed condition should reduce the potential for disclosure of confidential information by limiting the quantity of information each recipient may access. This limitation on access also should help address commenter concerns regarding "unfettered access" to security-based swap data.[102] This approach of limiting the availability of data to reflect such considerations also has parallels to the approach that one commenter indicated that it follows on a voluntary basis for providing relevant authorities with access to certain credit default swap information.[103]

The proposal would implement this requirement by further conditioning the indemnification exemption by requiring that the MOU or other arrangement between the Commission and the entity accessing the data would specify the types of security-based swap information that would relate to the recipient entity's regulatory mandate, or legal responsibility or authority.[104] While the relevant factors for specifying which information is within an entity's regulatory mandate, or legal responsibility or authority for these purposes may vary depending on the relevant facts and circumstances, such factors potentially would include the location of a counterparty to the transaction and the location of the reference entity.[105] In this way, the MOU or other arrangement would help reduce uncertainty regarding how the associated condition to the indemnification exemption may apply

[97] The Commission is not incorporating a commenter's suggestion that there be "a safe harbor provision from liability for information shared pursuant to global information sharing agreements into the Indemnification Exemption for SDRs operating pursuant to information sharing arrangements, as defined in the Indemnification Exemption, or comparable to those published by the OTC Derivatives Regulators Forum ("ODRF") or CPSS–IOSCO." *See* DTCC cross-border comment (Aug. 21, 2013) at 7; *see also* DTCC comment (Jan. 24, 2011) at 3 (urging the Commission to aim for regulatory comity as reflected in ODRF and CPSS–IOSCO standards); DTCC comment (June 3, 2011) at 6–7 (urging that the global framework incorporate efforts of the ODRF and the OTC Derivatives Regulators Supervisors Group).

To the extent that the commenter suggests that there be a safe harbor from the indemnification requirement, the Commission preliminarily believes that this proposed exemption, which is more narrowly tailored than the commenter's suggestion, would sufficiently address a repository's need for certainty. The Commission further notes that a repository's statutory duty to maintain the privacy of the information received is separate and distinct from its statutorily mandated duty to provide security-based swap data to relevant authorities when specific conditions are satisfied, and that the privacy of security-based swap data provided to relevant authorities was addressed by Congress through the confidentiality agreement requirement in Exchange Act section 13(n)(5)(H), 15 U.S.C. 78m(n)(5)(H).

[98] *See* proposed Exchange Act rule 13n–4(d)(2)(ii).

[99] *See* notes 64 through 69, *supra*, and accompanying text.

[100] Those entities that are expressly identified in the statute or the implementing rules (and thus are not subject to the determination process) also would need to enter into a separate MOU or other agreement to satisfy the confidentiality agreement condition.

[101] *See* proposed Exchange Act rule 13n–4(d)(1).

[102] *See* note 14, *supra*.

[103] *See* note 71, *supra* (DTCC statement that it routinely provides U.S. regulators with data related to overseas credit default swap transactions entered into by non-U.S. persons on U.S. reference entities, and that it provides European regulators with data related to credit default swap transactions in the U.S. by U.S. persons on European reference entities).

[104] *See* proposed Exchange Act rule 13n–4(d)(2)(ii).

[105] As an example, in the event of a request for access by a foreign authority that is responsible for security-based swap market surveillance and enforcement—and subject to negotiation of such an MOU or other arrangement between the Commission and that authority—criteria indicative of data regarding a transaction being within the authority's regulatory mandate or legal responsibility or authority may include: (i) One or more of the counterparties to the transaction being domiciled or having a principal place of business in the foreign jurisdiction (including branches of entities that are domiciled or that have a principal place of business in that jurisdiction); (ii) one or more of the counterparties being a subsidiary of a person domiciled or having a principal place of business in the foreign jurisdiction; (iii) one or more of the counterparties being a fund or other collective investment vehicle with an adviser that is domiciled or that have a principal place of business in the foreign jurisdiction; (iv) one or more of the counterparties being registered with the authority as a dealer or in some other capacity; or (v) the reference entity for the security-based swap being domiciled or having a principal place of business in the foreign jurisdiction.

As another example, in the case of a foreign authority that is responsible for prudential regulation, criteria indicative of data regarding a transaction being within the entity's regulatory mandate or legal responsibility or authority may include one or more of the counterparties to the transaction being part of a consolidated organization that is supervised by the prudential authority, including all affiliates within that consolidated organization.

to particular types of information requests, and would provide direction to repositories regarding which disclosures would be covered by the indemnification exemption.[106]

D. Request for Comment

The Commission requests comment on all aspects of the proposed exemption to the statutory indemnification requirement. Commenters particularly are invited to address whether the exemption's proposed scope would adequately address the concerns associated with implementing the indemnification requirement. Among other things, commenters are invited to address whether alternative approaches or other considerations more effectively reflect the access and confidentiality interests associated with the Dodd-Frank Act? Also, should additional conditions be incorporated into the exemption?

Commenters further are invited to address whether the proposal appropriately would make use of an MOU or other arrangement to provide sufficient guidance to a repository regarding an entity's regulatory mandate, or legal responsibility or authority in connection with a request for security-based swap data. In this respect, would the proposed approach provide a repository with an adequate degree of guidance regarding which disclosures of information may or may not be subject to protection? Are there particular criteria that would be useful for incorporating into the MOU or other arrangement to help delimit which information would fall within an entity's regulatory mandate, or legal responsibility or authority?

IV. Applicability of Exchange Act Data Access and Indemnification Provisions

The Exchange Act provisions addressed above—sections 13(n)(5)(G) and (H) [107]—establish one means by which certain regulators and other authorities may access security-based swap data from repositories. It is important to recognize, however, that those provisions do not exclusively govern the means by which such regulators or other authorities might access security-based swap data.

In particular, in the circumstances discussed below, regulators and other authorities in certain circumstances may access security-based swap data via authority that is independent of the above provisions. In those circumstances, the Commission preliminarily believes that the conditions associated with those data access provisions—particularly the provisions regarding indemnification, notification and confidentiality agreements—should not govern access arising from such independent authority.

A. Data Access Authorized by Foreign Law

The Commission continues to believe preliminarily, as discussed in the Cross-Border Proposing Release, that "the Indemnification Requirement does not apply when an SDR is registered with the Commission and is also registered or licensed with a foreign authority and that authority is obtaining security-based swap information directly from the SDR pursuant to that foreign authority's regulatory regime." [108] In those circumstances, the dually registered data repository would be subject to a data access obligation that is independent of the Exchange Act data access obligation, and the notification, confidentiality and indemnification conditions to the Exchange Act data access provision would not apply.

B. Receipt of Information Directly From the Commission

The Exchange Act also provides that relevant authorities may obtain security-based swap data from the Commission, rather than directly from data repositories.[109]

First, Exchange Act section 21(a)(2) [110] states that, upon request of a foreign securities authority, the Commission may provide assistance in connection with an investigation the foreign securities authority is conducting to determine whether any person has violated, is violating or is about to violate any laws or rules relating to securities matters that the requesting authority administers or enforces.[111] That section further provides that, as part of this assistance, the Commission in its discretion may conduct an investigation to collect information and evidence pertinent to the foreign securities authority's request for assistance.[112]

In addition, the Commission may share "nonpublic information in its possession" with, among others, any "federal, state, local, or foreign government, or any political subdivision, authority, agency or instrumentality of such government . . . [or] a foreign financial regulatory authority." [113] This authority is subject to the recipient providing "such assurances of confidentiality as the Commission deems appropriate." [114]

In the Commission's view, and consistent with Commission practice for many years, these sections provide the Commission with separate, additional authority to assist domestic and foreign authorities in certain circumstances, such as, for example, by providing security-based swap data directly to the authority. At those times, the authority would receive information not from the data repository, but instead from the Commission.

C. Request for Comment

The Commission requests comment on these preliminary interpretations regarding the scope of the data access requirement and conditions set forth in Exchange Act sections 13(n)(5)(G) and (H).

V. Paperwork Reduction Act

Certain provisions of the proposed rules contain "collection of information" requirements within the meaning of the Paperwork Reduction Act of 1995 ("PRA").[115] The SEC has submitted them to the Office of Management and Budget ("OMB") for review in accordance with 44 U.S.C. 3507 and 5 CFR 1320.11. The title of the new collection of information is "Security-Based Swap Data Repository Data Access Requirements." An agency may not conduct or sponsor, and a

[106] The Commission anticipates that data repositories would be able to rely on the guidance provided by such arrangements when assessing whether particular information would be subject to the indemnification exemption, thus permitting an authority to access that information without an indemnification agreement.

[107] 15 U.S.C. 78m(n)(5)(G) and (H).

[108] *See* Cross-Border Proposing Release, 78 FR 31049 n.807.

[109] *See* Cross-Border Proposing Release, 78 FR 31045.

[110] 15 U.S.C. 78u(a)(2).

[111] Exchange Act section 3(a)(50), 15 U.S.C. 78c(a)(50), broadly defines "foreign securities authority" to include "any foreign government, or any governmental body or regulatory organization empowered by a foreign government to administer or enforce its laws as they relate to securities matters."

[112] Exchange Act section 21(a)(2), 15 U.S.C. 78u(a)(2), also states that the Commission may provide such assistance without regard to whether the facts stated in the request also would constitute a violation of U.S. law.

That section further states that when the Commission decides whether to provide such assistance to a foreign securities authority, the Commission shall consider whether the requesting authority has agreed to provide reciprocal assistance in securities matters to the United States, and whether compliance with the request would prejudice the public interest of the United States.

[113] *See* Exchange Act rule 24c–1(c) (implementing Exchange Act section 24(c), 15 U.S.C. 78x(c), which states that the Commission may, "in its discretion and upon a showing that such information is needed," provide records and other information "to such persons, both domestic and foreign, as the Commission by rule deems appropriate," subject to assurances of confidentiality).

[114] *See id.*

[115] 44 U.S.C. 3501 *et seq.*

person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. OMB has not yet assigned a control number to the new collection of information.

A. Summary of Collection of Information

The proposal would require security-based swap data repositories to make security-based swap data available to other parties, including certain government bodies. This data access obligation would be conditioned on confidentiality and indemnification requirements, and the indemnification requirement itself would be subject to a conditional exemption. The proposal further would require such repositories to create and maintain information regarding such data access.

B. Proposed Use of Information

The data access requirement and associated conditions would provide the regulators and other authorities that receive the relevant security-based swap data with tools to assist with the oversight of the security-based swap market and of dealers and other participants in the market, and to assist with the monitoring of risks associated with that market.

C. Respondents

The data access requirement will apply to every person required to be registered with the Commission as a security-based swap data repository—that is every U.S. person performing the functions of a security-based swap data repository, and to every non-U.S. person performing the functions of a security-based swap data repository within the United States absent an exemption.[116] Commission staff is aware of seven persons that have, to date, filed applications for registration with the CFTC as swap data repositories, three of which have withdrawn their applications and four of which are provisionally registered with the CFTC. It is reasonable to estimate that a similar number of persons provisionally registered with the CFTC may seek to register with the Commission as security-based swap data repositories. Therefore, the Commission estimates, for PRA purposes, that ten persons might register with the Commission as security-based swap data repositories.[117]

The conditions to data access under these proposed rules further will affect all persons that may seek access to security-based swap data pursuant to these provisions. As discussed below, these may include up to 30 domestic entities.

D. Total Annual Reporting and Recordkeeping Burden

1. Data Access Generally

The data access provisions may implicate various types of PRA burdens and costs: (i) Burdens and costs that regulators and other authorities incur in connection with negotiating MOUs or other arrangements with the Commission in connection with the data access provisions; (ii) burdens and costs that certain authorities that have not been determined by statute or Commission rule may incur in connection with requesting that the Commission grant them access to repository data;[118] (iii) burdens and costs associated with information technology systems that repositories develop in connection with providing data to regulators and other authorities; and (iv) burdens and costs associated with the requirement that repositories notify the Commission of requests for access to security-based swap data, including associated recordkeeping requirements.

a. MOUs

As discussed above, entities that access security-based swap data pursuant to these data access provisions would be required to enter into MOUs or other arrangements with the Commission to address the confidentiality condition and the indemnification exemption. In some cases, those entities also would enter into MOUs or other arrangements in connection with the Commission's determination of the entity as authorized to access such data (to the extent that the entity's access is already determined by statute or by the proposed rules). For purposes of the PRA requirements, the Commission estimates that up to 30 domestic entities potentially might enter into such MOUs or other arrangements, reflecting the nine entities specifically identified by statute or the proposed rules, and up to 21 additional domestic governmental entities or self-regulatory organizations that may seek access to such data. Based on the Commission's experience in negotiating similar MOUs that address regulatory cooperation, including confidentiality issues associated with regulatory cooperation, the Commission preliminarily believes that each regulator on average would expend 500 hours in negotiating such MOUs.[119]

b. Requests for Access

Separately, certain entities that are not identified by statute and/or the proposed rules may request that the Commission determine that they may access such security-based swap data. For those entities, in light of the relevant information that the Commission preliminarily would consider in connection with such determinations (apart from the MOU issues addressed above)—including information regarding how the entity would be expected to use the information, information regarding the entity's regulatory mandate or legal responsibility or authority, and information regarding reciprocal access—the Commission preliminarily estimates that each such entity would expend 40 hours in connection with such request. As noted above, the Commission estimates that 21 domestic entities not encompassed in the proposed rule may seek access to the data. Accordingly, to the extent that 21 domestic entities were to request access (apart from the nine entities identified by statute or the proposed rule), the Commission estimates a total burden of 840 hours for these entities to prepare and submit requests for access.

c. Systems Costs

The Commission previously addressed the PRA costs associated with the Exchange Act's data access

[116] As discussed above, *see* note 13, *supra*, the Commission has determined that a non-U.S. person that performs the functions of a security-based swap data repository within the United States is required to register with the Commission absent an exemption. The Commission also has adopted Exchange Act rule 13n–12 to provide an exemption from data repository requirements for certain non-U.S. persons.

[117] The Commission used the same estimate when adopting final rules to implement statutory provisions related to the registration process, duties and core principles applicable to security-based swap data repositories. *See* SDR Adopting Release, 80 FR 14521.

[118] These include MOUs and other arrangements in connection with: The determination of additional entities that may access security-based swap data (*see* part II.A.3, *supra*), the confidentiality condition (*see* part II.B.1, *supra*) and the indemnification exemption (*see* parts III.B.2, 3, *supra*).

[119] It may be expected that the initial MOU or other arrangement that is entered into between the Commission and another regulator may take up to 1,000 hours for that regulator to negotiate. In practice, however, subsequent MOUs and other arrangements involving other recipient entities would be expected to require significantly less time on average, by making use of using the prior MOUs as a basis for negotiation. Based on these principles, the Commission preliminarily estimates that the average amount of time that domestic and foreign recipients of data would incur in connection with negotiating these arrangements would be 500 hours.

To the extent that each of those 30 domestic entities were to seek to access data pursuant to these provisions, and each of the applicable MOUs or other arrangements were to take 500 hours on average, the total burden would amount to 15,000 hours.

requirement in 2010, when the Commission initially proposed rules to implement those data access requirements in conjunction with other rules to implement the duties applicable to security-based swap data repositories. At that time, based on discussions with market participants, the Commission estimated that a series of proposed rules to implement duties applicable to security-based swap data repositories—including the proposed data access rules as well as other rules regarding repository duties (*e.g.*, proposed rules requiring repositories to accept and maintain data received from third parties, to calculate and maintain position information, and to provide direct electronic access to the Commission and its designees)—together would result in an average one-time start-up burden per repository of 42,000 hours and $10 million in information technology costs for establishing systems compliant with all of those requirements. The Commission further estimated the average per-repository ongoing annual costs of such systems to be 25,200 hours and $6 million.[120]

The Commission incorporated those same burden estimates earlier this year, when the Commission adopted final rules to implement the duties applicable to security-based swap data repositories, apart from the data access requirement.[121]

Subject to the connectivity issues addressed below, the Commission believes that the burden estimates associated with the 2010 proposed repository rules encompassed the costs and burdens associated with the proposed data access requirements in conjunction with other system-related requirements applicable to security-based swap dealers. To comply with those other system-related requirements—including in particular requirements that repositories provide direct electronic access to the Commission and its designees—we preliminarily believe that it is reasonable to expect that repositories may use the same systems as they would also use to comply with the data access requirements at issue here, particularly given that both types of access requirements would require repositories to provide security-based swap information to particular recipients subject to certain parameters.[122] As a result, subject to per-recipient connectivity burdens addressed below, the Commission preliminarily believes that would be no additional burdens associated with information technology costs to implement the data access requirements of the proposed rule.

The Commission also recognizes, however, that once the relevant systems have been set up, repositories may be expected to incur addition incremental burdens and costs associated with setting up access to security-based swap data consistent with the recipient's regulatory mandate or legal responsibility or authority.[123] The Commission preliminarily believes that, for any particular recipient, security-based swap data repositories on average would incur a burden of 26 hours.[124] As discussed below, based on the estimate that approximately 300 relevant authorities may make requests for data from security-based swap data repositories,[125] the Commission preliminarily estimates that each repository would incur a one-time burden of 7,800 hours in connection with providing that connectivity.[126]

[120] *See* SDR Proposing Release, 75 FR 77348–49. The Commission previously estimated, for PRA purposes, that ten persons may register with the Commission as security-based swap data repositories. *See* SDR Adopting Release, 80 FR 14521, 14523. Based on the estimate of ten respondents, the Commission estimated total one-time costs of 420,000 hours and $10 million, and total annual ongoing systems costs of 252,000 and $60 million. *See* SDR Proposing Release, 75 FR 77349.

[121] *See* SDR Adopting Release, 80 FR 14523. The Commission submitted the PRA burden associated with that release to OMB for approval, and the OMB has approved that collection of information.

[122] The Commission also anticipates that repositories would use the same systems in connection with the Exchange Act data access requirements as they use in connection with the corresponding requirements under the CEA.

[123] In addressing those burdens, the Commission expects that the MOUs or other arrangements that are used to satisfy the conditions of the indemnification exemption will set forth objective criteria that delimit the scope of a recipient's ability to access security-based swap data pursuant to the indemnification exemption. The Commission further expects that repositories would use those criteria to program their data systems to reflect the scope of the recipient's access to repository data. Absent such objective and programmable criteria, repositories would be expected to incur greater burdens to assess whether an authority's request satisfies the relevant conditions, particularly with regard to whether particular information relates to persons or activities within the entity's regulatory mandate or legal responsibility or authority.

[124] This estimate is based on the view that for each recipient requesting data, a repository would incur a 25 hour burden associated with programming or otherwise inputting the relevant parameters, encompassing 20 hours of programmer analyst time and five hours of senior programmer time. The estimate also encompasses one hour of attorney time in connection with each such recipient.

[125] *See* part VI.C.3.ii, *infra*.

[126] Across an estimated ten repositories, accordingly, the Commission estimates that repositories cumulatively would incur a one-time burden of 78,000 hours in connection with providing such connectivity.

d. Providing Notification of Requests, and Associated Records Requirements

Under the proposed rules, repositories would be required to inform the Commission when they receive the first request for security-based swap data from a particular entity.[127] As discussed below, based on the estimate that approximately 300 relevant authorities may make requests for data from security-based swap data repositories, the Commission estimates that each repository would provide the Commission with actual notice approximately 300 times.[128] Moreover, based on the estimate that ten persons may register with the Commission as security-based swap data repository, the Commission estimates that repositories in the aggregate would provide the Commission with actual notice a total of 3,000 times. The Commission preliminarily estimates that each such notice would take no more than one-half hour to make on average, leading to a cumulative estimate of 1,500 hours associated with the notice requirement.

The proposed rule further requires that repositories must maintain records of all information related to the initial and all subsequent requests for data access, including records of all instances of online or electronic access, and records of all data provided in connection with such access.[129] The Commission estimates that there cumulatively may be 360,000 subsequent data requests or access per year across all security-based swap data repositories, for which repositories must maintain records as required by the proposed rule.[130] Based on its experience with recordkeeping costs associated with security-based swaps generally, the Commission preliminarily estimates that for each repository this requirement would create an initial burden of roughly 360 hours, and an annualized burden of roughly 280 hours and $40,000 in information technology costs.[131]

2. Confidentiality Condition

The Commission preliminarily does not believe that the confidentiality provision of the proposal would be

[127] *See* proposed Exchange Act rule 13n–4(e) (further requiring the repository to maintain records of the initial and all subsequent requests).

[128] *See* part VI.C.3.a.ii, *infra*.

[129] *See* proposed Exchange Act rule 13n–4(e).

[130] *See* part VI.C.3.a.ii, *infra*.

[131] Across an estimated ten repositories, accordingly, the Commission preliminarily estimates that repositories cumulatively will incur an initial burden of roughly 3,600 hours in information technology costs, and an annualized burden of roughly 2,800 hours and $400,000 in information technology costs.

associated with collections of information that would result in a reporting or recordkeeping burden for security-based swap data repositories. This is because, under the proposal, the confidentiality condition would be satisfied by an MOU or other arrangement between the Commission and the recipient entity (*i.e.*, another regulatory authority) addressing confidentiality. We preliminarily expect that in practice that the condition will be addressed by MOUs or other arrangements entered into by the Commission, and that repositories accordingly would not be involved in the drafting or negotiation of confidentiality agreements.

As discussed above, moreover, the confidentiality provision would be expected to impose burdens on authorities that seek to access data pursuant to these provisions, as a result of the need to negotiate confidentiality MOUs or other arrangements.[132]

E. Collection of Information Is Mandatory

The conditional data access requirements of Exchange Act sections 13(n)(5)(G) and (H) and the underlying rules are mandatory for all security-based swap data repositories. The confidentiality condition is mandatory for all entities that seek access to data under those requirements. Also, the conditions to the indemnification exemption are mandatory to entities that seek to rely on the exemption, which the Commission believes will be all entities that seek data pursuant to these requirements.

F. Confidentiality

The Commission will make public requests for a determination that an authority is appropriate to conditionally access security-based swap data, as well as Commission determinations issued in response to such requests. The Commission preliminarily expects that it will make publicly available the MOUs or other arrangements with the Commission used to satisfy the confidentiality and indemnification conditions.

Initial notices of requests for access provided to the Commission by repositories will be kept confidential, subject to the provisions of applicable law. To the extent that the Commission obtains subsequent requests for access that would be required to be maintained by the repositories, the Commission also will keep those records confidential, subject to the provisions of applicable law.

[132] *See* part V.D.1.a, *supra*.

G. Request for Comment

We request comment on our approach and the accuracy of the current estimates. Pursuant to 44 U.S.C. 3506(c)(2)(A), the Commission solicits comments to: (1) Evaluate whether the collection of information is necessary for the proper performance of the functions of the agency, including whether the information will have practical utility; (2) evaluate the accuracy of the Commission's estimate of burden of the collection of information; (3) determine whether there are ways to enhance the quality, utility and clarity of the information to be collected; and (4) evaluate whether there are ways to minimize the burden of the collection of information on those who are required to respond, including through the use of automated collection techniques or other forms of information technology.

In this regard, the Commission particularly requests comment regarding the systems-related costs associated with these data access requirements. Among other things, commenters are invited to address the burdens associated with establishing and programming systems to provide regulators and other authorities with connectivity to repository data systems, including whether such costs would be incremental to the systems-related costs associated with the existing rule requiring that repositories provide direct electronic access to the Commission and its designees, and whether such systems-related costs would encompass capacity-related elements linked to the total number of regulators and other authorities that access repositories pursuant to these data access provisions. Commenters also are invited to address the estimated burdens associated with the requirement that repositories maintain records in connection with the notification requirement.

The Commission further requests comment regarding the burdens associated with the negotiation of MOUs or other arrangements between the Commission and other authorities, including the average time required for those regulators to negotiate such MOUs or other arrangements, and whether those other authorities may incur costs to retain outside counsel in connection with such negotiations.

Persons submitting comments on the collection of information requirements should direct the comments to the Office of Management and Budget, Attention: Desk Officer for the Securities and Exchange Commission, Office of Information and Regulatory Affairs, Washington, DC 20503, and send a copy to Secretary, Securities and Exchange Commission, 100 F Street NE., Washington, DC 20549–1090, with reference to File No. S7–_____. Requests for materials submitted to OMB by the Commission with regard to these collections of information should be in writing, refer to File No. S7–_____, and be submitted to the Securities and Exchange Commission, Office of FOIA Services, 100 F Street NE., Washington, DC 20549–2736. OMB is required to make a decision concerning the collection of information between 30 and 60 days after publication of this release. Consequently, a comment to OMB is assured of having its full effect if OMB receives it within 30 days of publication.

VI. Economic Analysis

As discussed above, the Commission is proposing rules to implement data access requirements for relevant authorities other than the Commission that the Dodd-Frank Act imposes on security-based swap repositories, and to provide an exemption from the associated indemnification requirement. To carry out their regulatory mandate, or legal responsibility or authority, certain relevant entities other than the Commission may periodically need access to security-based swap data collected and maintained by SEC-registered security-based swap data repositories, and the proposed rules are intended to facilitate such access.

The Commission is sensitive to the economic effects of its rules, including the costs and benefits and the effects of its rules on efficiency, competition, and capital formation. Section 3(f) [133] of the Exchange Act requires the Commission, whenever it engages in rulemaking pursuant to the Exchange Act, to consider or determine whether an action is necessary or appropriate in the public interest, and to consider, in addition to the protection of investors, whether the action would promote efficiency, competition, and capital formation. In addition, section 23(a)(2) [134] of the Exchange Act requires the Commission, when promulgating rules under the Exchange Act, to consider the impact such rules would have on competition. Exchange Act section 23(a)(2) also provides that the Commission shall not adopt any rule which would impose a burden on competition that is not necessary or appropriate in furtherance of the purposes of the Exchange Act.

[133] 15 U.S.C. 78c(f).

[134] 15 U.S.C. 78w(a)(2).

A. Economic Considerations

1. Title VII Transparency Framework

The security-based swap market prior to the passage of the Dodd-Frank Act has been described as being opaque, in part because transaction-level data were not widely available to market participants or to regulators.[135] To increase the transparency of the over-the-counter derivatives market to both market participants and regulatory authorities, Title VII requires the Commission to undertake a number of rulemakings, including rules the Commission adopted earlier this year to address the registration process, duties and core principles applicable to security-based swap data repositories,[136] and to address regulatory reporting and public dissemination of security-based swap information.[137] Among other matters, those rules address market transparency by requiring security-based swap data repositories, absent an exemption, to collect and maintain accurate security-based swap transaction data, and address regulatory transparency by requiring security-based swap data repositories to provide the Commission with direct electronic access to such data.[138]

Consistent with the goal of increasing transparency to regulators, the data access provisions at issue here set forth a framework for security-based swap data repositories to provide access to security-based swap data to relevant authorities other than the Commission. The proposed rules would implement that framework for repositories to provide data access to other relevant entities in order to fulfill their regulatory mandate, or legal responsibility or authority.

2. Transparency in the Market for Security-Based Swaps

The proposed data access rules and indemnification exemption, in conjunction with the transparency-related requirements generally applicable to security-based swap data repositories, are designed to, among other things, make available to the Commission and other relevant authorities data that will provide a broad view of the security-based swap market and help monitor for pockets of risk and potential market abuses that might not otherwise be observed by those authorities.[139] Unlike most other securities transactions, security-based swaps involve ongoing financial obligations between counterparties during the life of transactions that typically span several years. Counterparties to a security-based swap rely on each other's creditworthiness and bear this credit risk and market risk until the security-based swap terminates or expires. This can lead to market instability when a large market participant, such as a security-based swap dealer, major security-based swap market participant, or central counterparty ("CCP") becomes financially distressed. The default of a large market participant could introduce the potential for sequential counterparty failure; the resulting uncertainty could reduce the willingness of market participants to extend credit, and substantially reduce liquidity and valuations for particular types of financial instruments.[140]

A broad view of the security-based swap market, including information regarding aggregate market exposures to particular reference entities (or securities), positions taken by individual entities or groups, and data elements necessary to determine the market value of the transaction, may be expected to provide the Commission and other relevant authorities with a better understanding of the actual and potential risks in the market and promote better risk monitoring efforts. The information provided by security-based swap data repositories also may be expected to help the Commission and other relevant authorities investigate market manipulation, fraud and other market abuses.

3. Global Nature of the Security-Based Swap Market

As highlighted in more detail in the Economic Baseline below, the security-based swap market is a global market. Based on market data in the Depository Trust and Clearing Corporation's Trade Information Warehouse ("DTCC–TIW"), the Commission estimates that only 12 percent of the global transaction volume that involves either a U.S.-domiciled counterparty or a U.S-domiciled reference entity (as measured by gross notional) between 2008 and 2014 was between two U.S.-domiciled counterparties, compared to 48 percent entered into between one U.S.-domiciled counterparty and a foreign-domiciled counterparty and 40 percent entered into between two foreign-domiciled counterparties.[141]

In light of the security-based swap market's global nature there is the possibility that regulatory data may be fragmented across jurisdictions, particularly because a large fraction of transaction volume includes at least one counterparty that is not a U.S. person[142] and the applicable U.S. regulatory reporting rules depend on the U.S. person status of the counterparties.[143] As discussed further below,

[135] With respect to one type of security-based swap, credit default swaps ("CDSs"), the Government Accountability Office found that "comprehensive and consistent data on the overall market have not been readily available," "authoritative information about the actual size of the [CDS] market is generally not available" and regulators currently are unable "to monitor activities across the market." Government Accountability Office, GAO–09–397T, *Systemic Risk: Regulatory Oversight and Recent Initiatives to Address Risk Posed by Credit Default Swaps*, at 2, 5, 27, (2009) *available at: http://www.gao.gov/new.items/d09397t.pdf; see also* Robert E. Litan, *The Derivatives Dealers' Club and Derivatives Market Reform: A Guide for Policy Makers, Citizens and Other Interested Parties*, Brookings Institution (Apr. 7, 2010), *http://www.brookings.edu/~/media/research/files/papers/2010/4/07%20derivatives%20litan/0407_derivatives_litan.pdf;* Michael Mackenzie, *Era of an Opaque Swaps Market Ends*, Financial Times, June 25, 2010, *available at: http://www.ft.com/intl/cms/s/0/f49f635c-8081-11df-be5a-00144feabdc0.html#axzz3HLUjYNI7.*

[136] *See* SDR Adopting Release, note 13, *supra.*

[137] *See* Regulation SBSR Adopting Release.

[138] *See* Exchange Act rule 13n–5 (requiring repositories to comply with data collection and data maintenance standards related to transaction and position data); Exchange Act rule 13n–4(b)(5) (requiring repositories to provide direct electronic access to the Commission and its designees).

[139] *See, e.g.*, Exchange Act section 13(n)(5)(D), 15 U.S.C. 78m(n)(5)(D), and rule 13n–4(b)(5) (requiring SDRs to provide direct electronic access to the Commission). *See also* 156 Cong. Rec. S5920 (daily ed. July 15, 2010) (statement of Sen. Lincoln) ("These new 'data repositories' will be required to register with the CFTC and the SEC and be subject to the statutory duties and core principles which will assist the CFTC and the SEC in their oversight and market regulation responsibilities.").

[140] *See, e.g.*, Markus K. Brunnermeier and Lasse Heje Pedersen, *Market Liquidity and Funding Liquidity*, 22 Review of Financial Studies 2201 (2009); Denis Gromb and Dimitri Vayanos, *A Model of Financial Market Liquidity Based on Intermediary Capital*, 8 Journal of the European Economic Association 456 (2010).

[141] The data the Commission receives from the DTCC–TIW does not include transactions between two non-U.S. domiciled counterparties that reference a non-U.S. entity or security. This is approximately 19 percent of global transaction volume. *See* note 152, *infra*. Therefore, factoring in these transactions, approximately 10 percent of global transaction volume involves two U.S.-domiciled counterparties, 39 percent involve one U.S.-domiciled counterparty and one foreign counterparty, and 51 percent are between two foreign-domiciled counterparties.

[142] This statement is based on staff analysis of voluntary CDS transaction data reported to the DTCC–TIW, which includes self-reported counterparty domicile. *See* note 161, *infra*. The Commission notes that the DTCC–TIW entity domicile may not be completely consistent with the Commission's definition of "U.S. person" in all cases but preliminarily believes that these two characteristics have a high correlation.

[143] *See* Regulation SBSR rule 908(a) (generally requiring regulatory reporting and public dissemination when at least one direct or indirect counterparty is a U.S. person). Note that current voluntary reporting considers the self-reported domicile of the counterparty but the recently adopted SBSR rules consider the counterparty's status as a U.S. person.

fragmentation of data can increase the difficulty in consolidating and interpreting security-based swap market data from repositories, potentially reducing the general economic benefits derived from transparency of the security-based swap market to regulators. Absent a framework for the cross-border sharing of data reported pursuant to regulatory requirements in various jurisdictions, the relevant authorities responsible for monitoring the security-based swap market may not be able to access data consistent with their regulatory mandate, or legal responsibility or authority.

4. Economic Purposes of the Rulemaking

The proposed data access requirements and indemnification exemption are designed to increase the quality and quantity of transaction and position information available to relevant authorities about the security-based swap market while helping to maintain the confidentiality of that information. The increased availability of security-based swap information may be expected to help relevant authorities act in accordance with their regulatory mandate, or legal responsibility or authority, and to respond to market developments.

Moreover, by facilitating access to security-based swap data for relevant authorities, including non-U.S. authorities designated by the Commission, the Commission anticipates an increased likelihood that the Commission itself will have commensurate access to security-based swap data stored in trade repositories located in foreign jurisdictions.[144] This may be particularly important in identifying transactions in which the Commission has a regulatory interest (*e.g.*, transactions involving a U.S. reference entity or security) but may not have been reported to a registered security-based swap data repository due to the transactions occurring outside of the U.S. between two non-U.S. persons.[145] This should assist the Commission in fulfilling its regulatory mandate and legal responsibility and authority, including by facilitating the Commission's ability to detect and investigate market manipulation, fraud and other market abuses, by providing the Commission with greater access to security-based swap information than that provided under the current voluntary reporting regime.[146]

Such data access may be especially critical during times of market turmoil, by giving the Commission and other relevant authorities information to examine risk exposures incurred by individual entities or in connection with particular reference entities. Increasing the available data about the security-based swap market should further give the Commission and other relevant authorities better insight into how regulations are affecting or may affect the market, which may allow the Commission and other regulators to better craft regulations to achieve desired goals, and therefore increase regulatory effectiveness.

B. Baseline

To assess the economic impact of the proposed data access rules and indemnification exemption, the Commission is using as a baseline the security-based swap market as it exists today, including applicable rules that have already been adopted and excluding rules that have been proposed but not yet finalized. Thus we include in the baseline the rules that the Commission adopted earlier this year to govern the registration process, duties and core principles applicable to security-based swap data repositories, and to govern regulatory reporting and public dissemination of security-based swap transactions.

Because those rules were adopted only recently, there are not yet any registered swap data repositories, and the Commission does not yet have access to regulatory reporting data. Hence, our characterization of the economic baseline, including the quantity and quality of security-based swap data available to the Commission and other relevant authorities and the extent to which data are fragmented, considers the anticipated effects of the final SDR rules and Regulation SBSR. The Commission acknowledges limitations in the degree to which it can quantitatively characterize the current state of the security-based swap market. As described in more detail below, because the available data on security-based swap transactions do not cover the entire market, the Commission has developed an understanding of market activity using a sample that includes only certain portions of the market.

1. Regulatory Transparency in the Security-Based Swap Market

There currently is no robust, widely accessible source of information about individual security-based swap transactions. In 2006, a group of major dealers expressed their commitment in support of DTCC's initiative to create a central trade industry warehouse for credit derivatives.[147] Moreover, in 2009, the leaders of the G20—whose members include the United States, 18 other countries, and the European Union—called for global improvements in the functioning, transparency, and regulatory oversight of over-the-counter ("OTC") derivatives markets and agreed, among other things, that OTC derivatives contracts should be reported to trade repositories.[148] A single repository, the DTCC–TIW, makes the data reported to it under the voluntary reporting regime available to the Commission and other relevant authorities in accordance with the agreement between DTCC–TIW and the OTC Derivatives Regulatory Forum ("ODRF"), of which the Commission is a member.[149] Although many jurisdictions have implemented rules concerning reporting of security-based swaps to trade repositories,[150] the Commission understands that many market participants continue to report voluntarily to the DTCC–TIW.

The data that the Commission receives from DTCC–TIW do not encompass CDS transactions that both: (i) Do not involve any U.S. counterparty, and (ii) are not based on a U.S. reference entity.[151] Based on a comparison of

[144] As discussed above, for example, EU law conditions the ability of non-EU authorities to access data from EU repositories on EU authorities having "immediate and continuous" access to the information they need. *See* note 94, *supra*, and accompanying text.

Also, as discussed above, the Commission anticipates considering whether or not the relevant authority requesting access agrees to provide the Commission and other U.S. authorities with reciprocal assistance in matters within their jurisdiction when making a determination as to whether the requesting authority shall be granted access to security-based swap data held in registered SDRs. *See* part II.A.3(a) *supra*.

[145] For example, it is possible to replicate the economic exposure of either a long or short position in a debt security that trades in U.S. markets by trading in U.S. treasury securities and credit default swaps that reference the debt security. Transactions between two non-U.S. persons on a U.S. reference entity supervised by the Commission or novations between two non-U.S. persons that reduce exposure to a U.S. registrant may provide information to the Commission about the market's views concerning the financial stability or creditworthiness of the registered entity.

[146] *See* part VI.B, *supra*, for a description of the data the Commission receives from DTCC–TIW under the current voluntary reporting regime.

[147] *See* Letter to Timothy Geithner, President, Federal Reserve Bank of New York, Mar. 10, 2006, available at: *http://www.newyorkfed.org/newsevents/news/markets/2006/industryletter2.pdf.*

[148] *See* G20 Leaders Statement from the 2009 Pittsburgh Summit, available at: *http://www.g20.utoronto.ca/2009/2009communique0925.html.*

[149] *See* note 71, *supra*.

[150] *See* Eighth Progress Report on Implementation of OTC Derivatives Market Reforms (Nov. 2014), *available at: http://www.financialstabilityboard.org/wp-content/uploads/r_141107.pdf.*

[151] The Commission notes that the identification of entity domicile in the voluntary data reported to

weekly transaction volume publicly disseminated by DTCC–TIW with data provided to the Commission under the voluntary arrangement, we estimate that the transaction data provided to the Commission covers approximately 77 percent of the global single-name credit default swap market.[152]

While DTCC–TIW generally provides detailed data on positions and transactions to regulators that are members of the ODRF, DTCC–TIW makes only summary information available to the public.[153]

2. Current Security-Based Swap Market

The Commission's analysis of the current state of the security-based swap market is based on data obtained from DTCC–TIW, particularly data regarding the activity of market participants for single-name credit-default swaps from 2008 to 2014. While other repositories also may collect data on transactions in total return swaps on equity and debt, the Commission does not currently have access to such data for those products (or for other products that are security-based swaps). Although the definition of "security-based swap" is not limited to single-name credit-default swaps, the Commission believes that the single-name credit default swap data are sufficiently representative of the security-based swap market and therefore can directly inform the analysis of the state of the current security-based swap market.[154] The Commission believes that DTCC–TIW's data for single-name credit default swaps appear reasonably comprehensive because they include data on almost all single-name credit default swap transactions and market participants trading in single-name credit default swaps.[155]

Based on this information, our analysis below indicates that the current security-based swap market: (i) Is global in scope, and (ii) is concentrated among a small number of dealing entities. Although under the voluntary reporting regime discussed above there was a single repository, as various jurisdictions have implemented mandatory reporting rules in their jurisdictions the number of trade repositories holding security-based swap data has grown.[156]

a. Security-Based Swap Market Participants

A key characteristic of security-based swap activity is that it is concentrated among a relatively small number of entities that engage in dealing activities.[157] Based on the Commission's analysis of DTCC–TIW data, there were 1,879 entities engaged directly in trading credit default swaps between November 2006 and December 2014.[158] Table 1 below highlights that of these entities, there were 17, or approximately 0.9 percent, that were ISDA-recognized dealers.[159] ISDA-recognized dealers executed the vast majority of transactions (82.6 percent) measured by the number of counterparties (each transaction has two counterparties or transaction sides). Many of these dealers are regulated by entities other than, or in addition to, the Commission. In addition, thousands of other market participants appear as counterparties to security-based swap transactions, including, but not limited to, investment companies, pension funds, private (hedge) funds, sovereign entities, and non-financial companies.

DTCC–TIW may not be consistent with the Commission's definition of "U.S. person" in all cases.

[152] In 2014, DTCC–TIW reported on its Web site new trades in single-name CDSs with gross notional of $15.4 trillion. During the same period, data provided to the Commission by DTCC–TIW, which include only transactions with a U.S. counterparty or transactions written on a U.S. reference entity or security, included new trades with gross notional equaling $12.4 trillion, or 81% of the total reported by DTCC–TIW.

[153] The DTCC–TIW publishes weekly transaction and position reports for single-name credit default swaps. In addition, ICE Clear Credit provides aggregated volumes of clearing activity, and large multilateral organizations periodically further report measures of market activity. For example, the Bank for International Settlements ("BIS") reports gross notional outstanding for single-name credit default swaps and equity forwards and swaps semiannually.

[154] According to data published by BIS, the global notional amount outstanding in equity forwards and swaps as of December 2014 was $2.50 trillion. The notional amount outstanding was approximately $9.04 trillion for single-name CDSs, approximately $6.75 trillion for multi-name index CDSs, and approximately $0.61 trillion for multi-name, non-index CDSs. *See* Bank of International Settlement, BIS Quarterly Review, Statistical Annex, Table 19 (June 2015), *available at: http://www.bis.org/publ/qtrpdf/r_qt1506.htm.* For purposes of this analysis, the Commission assumes that multi-name index CDSs are not narrow-based security index CDSs, and therefore do not fall within the definition of security-based swap. *See* Exchange Act section 3(a)(68)(A), 15 U.S.C. 78c(a)(68)(A); *see also* Further Definition of "Swap," "Security-Based Swap," and "Security-Based Swap Agreement"; Mixed Swaps; Security-Based Swap Agreement Recordkeeping, Exchange Act Release No. 67453 (July 18, 2012), 77 FR 48207 (Aug. 13, 2012). The Commission also assumes that instruments reported as equity forwards and swaps include instruments such as total return swaps on individual equities that fall with the definition of security-based swap. Based on these assumptions, single-name CDS appear to constitute roughly 80 percent of the security-based swap market. Although the BIS data reflects the global OTC derivatives market, and not only the U.S. market, the Commission is not aware of any reason to believe that these ratios differ significantly in the U.S. market.

[155] *See* ISDA, CDS Marketplace, Exposures & Activity, *available at: http://www.isdacdsmarketplace.com/exposures_and_activity* ("DTCC Deriv/SERV's Trade Information Warehouse is the only comprehensive trade repository and post-trade processing infrastructure for OTC credit derivatives in the world. Its Deriv/SERV matching and confirmation service electronically matches and confirms more than 98% of credit default swaps transactions globally.").

[156] *See,* for example, the list of trade repositories registered by ESMA, *available at: http://www.esma.europa.eu/content/List-registered-Trade-Repositories.* As of May 28, 2015, there were six repositories registered by ESMA, all of which are authorized to receive data on credit derivatives.

[157] *See* Exchange Act Release No.72472 (Jun. 25, 2014), 79 FR 47278, 47293 (Aug. 12, 2014) ("Cross-Border Definitions Adopting Release"). All data in this section cites updated data from that release and its accompanying discussion.

[158] These 1,879 transacting agents represent over 10,000 accounts representing principal risk holders. *See* Cross-Border Definitions Adopting Release, 79 FR 47293–94 (discussing the number of transacting agents and accounts of principal risk holders).

As noted above, the data provided to the Commission by the DTCC–TIW only includes transactions that either include at least one U.S.-domiciled counterparty or reference a U.S. entity or security. Therefore, any entity that is not domiciled in the U.S., never trades with a U.S.-domiciled entity and never buys or sells protection on a U.S. reference entity or security would not be included in this analysis.

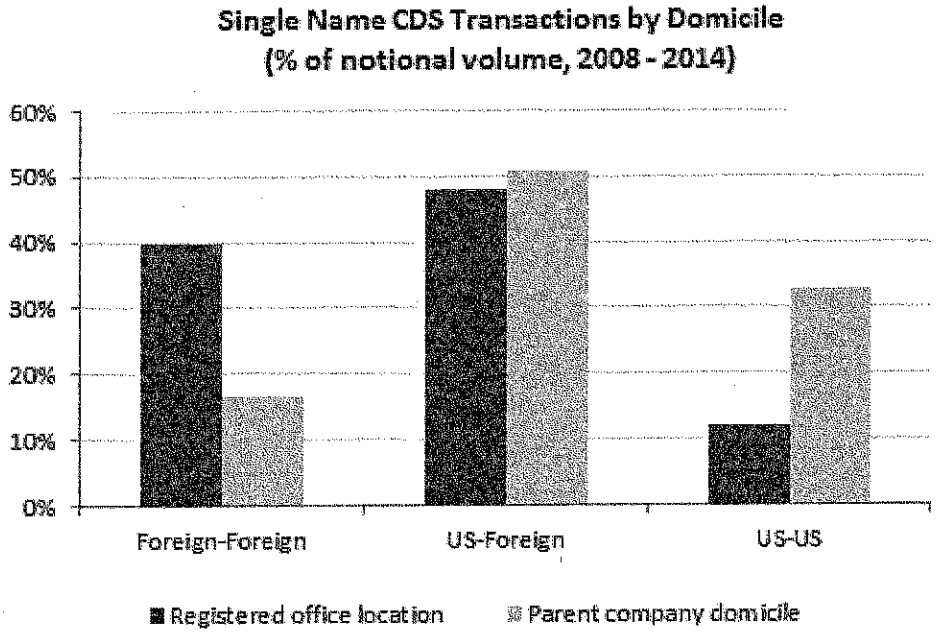
[159] For the purpose of this analysis, the ISDA-recognized dealers are those identified by ISDA as a recognized dealer in any year during the relevant period. Dealers are only included in the ISDA-recognized dealer category during the calendar year in which they are so identified. The complete list of ISDA recognized dealers is: JP Morgan Chase NA (and Bear Stearns), Morgan Stanley, Bank of America NA (and Merrill Lynch), Goldman Sachs, Deutsche Bank AG, Barclays Capital, Citigroup, UBS, Credit Suisse AG, RBS Group, BNP Paribas, HSBC Bank, Lehman Brothers, Société Générale, Credit Agricole, Wells Fargo, and Nomura. *See* ISDA, Operations Benchmarking Surveys, *available at: http://www2.isda.org/functional-areas/research/surveys/operations-benchmarking-surveys.*

TABLE 1—THE NUMBER OF TRANSACTING AGENTS IN THE SINGLE-NAME CDS MARKET BY COUNTERPARTY TYPE AND THE FRACTION OF TOTAL TRADING ACTIVITY, FROM NOVEMBER 2006 THROUGH DECEMBER 2014, REPRESENTED BY EACH COUNTERPARTY TYPE

Transacting agents	Number	Percent	Transaction share (percent)
Investment Advisers	1,419	75.5	10.9
SEC registered	*572*	*30.4*	*6.9*
Banks	260	13.8	5.0
Pension Funds	29	1.5	0.1
Insurance Companies	38	2.0	0.3
ISDA-Recognized Dealers[160]	17	0.9	82.6
Other	116	6.2	1.2
Total	1,879	100	100

Although the security-based swap market is global in nature, approximately 60 percent of the transaction volume in the 2008–2014 period included at least one U.S.-domiciled entity (see Figure 1). Moreover, 48 percent of the single-name CDS transactions reflected in DTCC–TIW data that include at least one U.S.-domiciled counterparty or a U.S. reference entity or security were between U.S.-domiciled entities and foreign-domiciled counterparties.

Figure 1: The fraction of notional volume in North American corporate single-name CDSs between (1) two U.S.-domiciled accounts, (2) one U.S.-domiciled account and one non-U.S.-domiciled account, and (3) two non-U.S.-domiciled accounts, computed from January 2008 through December 2014.



The fraction of new accounts with transaction activity that are domiciled in the U.S. fell through the 2008–2014 period. Figure 2 below is a chart of: (1) The percentage of new accounts with a domicile in the United States,[161] (2) the

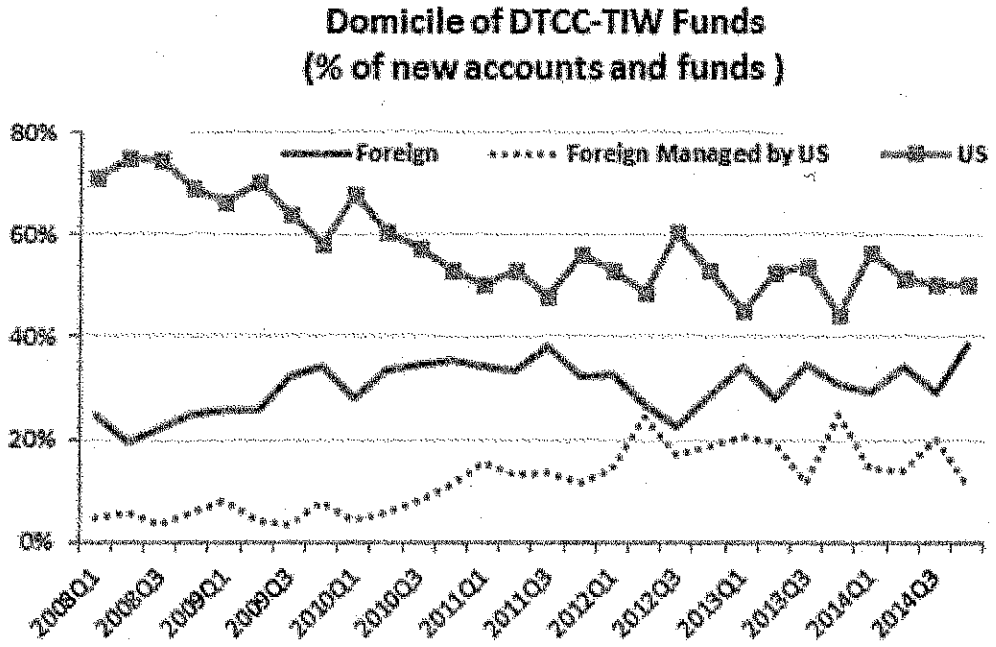
[160] For the purpose of this analysis, the ISDA-recognized dealers are those identified by ISDA as belonging to the G14 or G16 dealer group during the period: JP Morgan Chase NA (and Bear Stearns), Morgan Stanley, Bank of America NA (and Merrill Lynch), Goldman Sachs, Deutsche Bank AG, Barclays Capital, Citigroup, UBS, Credit Suisse AG, RBS Group, BNP Paribas, HSBC Bank, Lehman Brothers, Société Générale, Credit Agricole, Wells Fargo and Nomura. *See, e.g., http://www.isda.org/c_and_a/pdf/ISDA-Operations-Survey-2010.pdf.*

[161] The domicile classifications in DTCC–TIW are based on the market participants' own reporting and have not been verified by Commission staff. Prior to enactment of the Dodd-Frank Act, account holders did not formally report their domicile to DTCC–TIW because there was no systematic requirement to do so. After enactment of the Dodd-Frank Act, the DTCC–TIW has collected the registered office location of the account. This information is self-reported on a voluntary basis. It is possible that some market participants may misclassify their domicile status because the databases in DTCC–TIW do not assign a unique legal entity identifier to each separate entity. It is also possible that the domicile classifications may not correspond precisely to the definition of "U.S.

percentage of new accounts with a domicile outside the United States, and (3) the percentage of new accounts that are domiciled outside the United States but managed by a U.S. entity, foreign accounts that include new accounts of a foreign branch of a U.S. bank, and new accounts of a foreign subsidiary of a U.S. entity. Over time, a greater share of accounts entering the DTCC–TIW data either have had a foreign domicile or have had a foreign domicile while being managed by a U.S. person. The increase in foreign accounts may reflect an increase in participation by foreign accountholders, and the increase in foreign accounts managed by U.S. persons may reflect the flexibility with which market participants can restructure their market participation in response to regulatory intervention, competitive pressures and other factors. There are, however, alternative explanations for the shifts in new account domicile in Figure 2. Changes in the domicile of new accounts through time may reflect improvements in reporting by market participants to DTCC–TIW. Additionally, because the data include only accounts that are domiciled in the United States, transact with U.S.-domiciled counterparties or transact in single-name CDSs with U.S. reference entities or securities, changes in the domicile of new accounts may reflect increased transaction activity between U.S. and non-U.S. counterparties.

We note that cross-border rules related to regulatory reporting and public dissemination of security-based swap transactions depend on, among other things, the U.S. person status of the counterparties.[162] The analyses behind Figures 1 and 2 show that the security-based swap market is global, with an increasing share of the market characterized by cross-border trade.

Figure 2: The percentage of (1) new accounts with a domicile in the United States (referred to below as "US"), (2) new accounts with a domicile outside the United States (referred to below as "Foreign"), and (3) new accounts outside the United States, but managed by a U.S. entity, new accounts of a foreign branch of a U.S. bank, and new accounts of a foreign subsidiary of a U.S. entity (collectively referred to below as "Foreign Managed by US").[163] Unique, new accounts are aggregated each quarter and shares are computed on a quarterly basis, from January 2008 through December 2014.



b. Security-Based Swap Data Repositories

No security-based swap data repositories are currently registered with the Commission. The Commission is aware of one entity in the market (*i.e.*, the DTCC–TIW) that has been accepting voluntary reports of single-name and index credit default swap transactions. In 2014, DTCC–TIW received approximately 4 million records of single-name credit default swap transactions, of which approximately 868,000 were price-forming transactions.[164]

person" under the rules defined in Exchange Act rule 3a71–3(a)(4), 17 CFR 240.3a71–3(a)(4). Notwithstanding these limitations, the Commission believes that the cross-border and foreign activity demonstrates the nature of the single-name CDS market.

[162] *See* note 143, *supra*.

[163] Following publication of the Warehouse Trust Guidance on CDS data access, TIW surveyed market participants, asking for the physical address associated with each of their accounts (*i.e.*, where the account is organized as a legal entity). This is designated the registered office location by TIW. When an account does not report a registered office location, we have assumed that the settlement country reported by the investment adviser or parent entity to the fund or account is the place of domicile. This treatment assumes that the registered office location reflects the place of domicile for the fund or account.

[164] Price-forming credit default swap transactions include all new transactions, assignments, modifications to increase the notional amounts of previously executed transactions and terminations

Continued

The CFTC has provisionally registered four swap data repositories.[165] These swap data repositories are: BSDR LLC, Chicago Mercantile Exchange Inc., DTCC Data Repository LLC, and ICE Trade Vault, LLC. The Commission believes that these entities will likely register with the Commission as security-based swap data repositories and that other persons may seek to register with both the CFTC and the Commission as swap data repositories and security-based swap data repositories, respectively.[166]

Efforts to regulate the swap and security-based swap markets are underway not only in the United States, but also abroad. Consistent with the call of the G20 leaders for global improvements in the functioning, transparency and regulatory oversight of OTC derivatives markets,[167] substantial progress has been made in establishing the trade repository infrastructure to support the reporting of OTC derivatives transactions.[168] Currently, multiple trade repositories operate, or are undergoing approval processes to do so, in a number of different jurisdictions.[169] Combined with the fact that the requirements for trade reporting differ across jurisdictions, the result is that security-based swap data is fragmented across many locations, stored in a variety of formats, and subject to many different rules for authorities' access. The data in these trade repositories accordingly will need to be aggregated in various ways if authorities are to obtain a comprehensive and accurate view of the global OTC derivatives markets.

C. Economic Costs and Benefits, Including Impact on Efficiency, Competition, and Capital Formation

As discussed above, the security-based swap market to date largely has developed as an opaque OTC market with limited dissemination of transaction-level price and volume information.[170] Accordingly, the Commission envisions that registered security-based swap data repositories, by storing the security-based swap transaction and position data required to be reported to them by market participants, will become an essential part of the infrastructure of the market in part by providing the data to relevant authorities in accordance with their regulatory mandate, or legal responsibility or authority.

In proposing these rules to implement the Exchange Act data access requirement and to provide a conditional exemption from the indemnification requirement, the Commission has attempted to balance different goals. On the one hand, the Commission preliminarily believes that the proposed rules will facilitate the sharing of information held by repositories with relevant authorities, which should assist those authorities in acting in accordance with their regulatory mandate, or legal responsibility or authority. At the same time, although regulatory access raises important issues regarding the confidentiality of the information, the Commission preliminarily believes that the proposed rules should appropriately reduce the risk of breaching the confidentiality of the data by providing for a reasonable assurance that confidentiality will be maintained before access is granted.

Additionally, we note that the magnitude of the costs and benefits of the proposed rules depend in part on the type of access granted to relevant authorities. Ongoing, unrestricted direct electronic access by relevant authorities may be most beneficial in terms of facilitating efficient access to data necessary for those authorities to act in accordance with their regulatory mandate, or legal responsibility or authority, but at the cost of increasing the risk of improper disclosure of confidential information. Restricting each relevant authority's access to only that data consistent with that authority's regulatory mandate, or legal responsibility or authority reduces the quantity of data that could become subject to improper disclosure. On the other hand, restricting a relevant authority's access to data may make it more difficult for it to effectively act in accordance with its regulatory mandate or legal responsibility or authority.

The potential economic effects stemming from the proposed rules can be grouped into several categories. In this section, we first discuss the general costs and benefits of the proposed rules, including the benefits of reducing data fragmentation, data duplication and enhancing regulatory oversight, as well as the risks associated with potential breaches of data confidentiality. Next, we discuss the effects of the rules on efficiency, competition and capital formation. Finally, we discuss specific costs and benefits linked to the proposed rules.

1. General Costs and Benefits

As discussed above, the proposed rules would implement the statutory provisions that require a security-based swap data repository to disclose information to certain relevant authorities, conditional upon the authority agreeing to keep the information confidential and to indemnify the repository and the Commission for any expenses arising from litigation relating to the information provided. The proposal also would set forth a conditional exemption from the requirement that entities requesting data agree to provide indemnification. The exemption would be conditional on the requested information relating to a regulatory mandate and/or legal responsibility of the entity requesting the data, and on the entity entering into an MOU with the Commission addressing the confidentiality of the information provided and any other matters as determined by the Commission.

a. Anticipated Benefits

The proposed rules should facilitate access to security-based swap transaction and position data by entities that require such information to fulfill their regulatory mandate or legal responsibility or authority. Market participants accordingly should benefit from relevant domestic authorities other than the Commission having access to the data necessary to fulfill their responsibilities. In particular, such access could help promote stability in the security-based swap market particularly during periods of market turmoil,[171] and thus could indirectly contribute to improved stability in related financial markets, including equity and bond markets.[172]

of previously executed transactions. Transactions terminated or entered into in connection with a compression exercise, and expiration of contracts at maturity, are not considered price-forming and are therefore excluded, as are replacement trades and all bookkeeping-related trades.

[165] CFTC rule 49.3(b) provides for provisional registration of a swap data repository. 17 CFR 49.3(b).

[166] For the purpose of estimating PRA related costs, the number of swap data repositories is estimated to be as high as ten. *See* part V.C, supra.

[167] *See* note 148, *supra*, and accompanying text.

[168] *See* Eighth Progress Report on Implementation of OTC Derivatives Market Reforms (Nov. 2014), *available at: http://www.financialstabilityboard.org/wp-content/uploads/r_141107.pdf.*

[169] *Id.*

[170] *See* part VI.B.1, *supra* (addressing limited information currently available to market participants and regulators).

[171] SDR Adopting Release, 80 FR 14531 ("Enhanced transparency could produce additional market-wide benefits by promoting stability in the [security-based swap] market, particularly during periods of market turmoil, and it should indirectly contribute to improved stability in related financial markets, including equity and bond markets.").

[172] *See* Darrell Duffie, Ada Li, and Theo Lubke, *Policy Perspectives of OTC Derivatives Market Infrastructure,* Federal Reserve Bank of New York Staff Report No. 424 (Jan. 2010, as revised Mar.

Moreover, as noted in part II.A(3)(a), the Commission anticipates, when making a determination concerning a relevant authority's access to security-based swap data, considering whether the relevant authority agrees to provide the Commission and other U.S. authorities with reciprocal assistance in matters within their jurisdiction. Allowing access to security-based swap data held by registered security-based swap data repositories by non-U.S. authorities may be expected to help facilitate the Commission's own ability to access data held by repositories outside the United States.[173] Accordingly, to the extent the Commission obtains access, the proposed rules further may be expected to assist the Commission in fulfilling its regulatory responsibilities, including by detecting market manipulation, fraud and other market abuses by providing the Commission with greater access to global security-based swap information.[174]

The ability of other relevant authorities to access data held in trade repositories registered with the Commission, as well as the ability of the Commission to access data held in repositories registered with other regulators, may be especially crucial during times of market turmoil. Increased data sharing should provide the Commission and other relevant authorities more-complete information to monitor risk exposures taken by individual entities and exposures connected to particular reference entities, and should promote global stability through enhanced regulatory transparency. Security-based swap data repositories registered with the Commission are required to retain complete records of security-based swap transactions and maintain the integrity of those records.[175] Based on discussions with other regulators, the Commission believes repositories registered with other authorities are likely to have comparable requirements. As a result, rules to facilitate regulatory access to those records in line with the recipient authorities' regulatory mandate, or legal responsibility or authority are designed to help position the Commission and other authorities to: detect market manipulation, fraud and other market abuses; monitor the financial responsibility and soundness of market participants; perform market surveillance and macroprudential supervision; resolve issues and positions after an institution fails; monitor compliance with relevant regulatory requirements; and respond to market turmoil.[176]

Additionally, improving the availability of data regarding the security-based swap market should give the Commission and other relevant authorities improved insight into how regulations are affecting, or may affect, the market. This may be expected to help increase regulatory effectiveness by allowing the Commission and other regulators to better craft regulation to achieve desired goals.

In addition, the Commission believes that providing relevant foreign authorities with access to data maintained by repositories may help reduce costs to market participants by reducing the potential for duplicative security-based swap transaction reporting requirements in multiple jurisdictions.[177] The Commission anticipates that relevant foreign authorities will likely impose their own reporting requirements on market participants within their jurisdictions.[178] Given the global nature of the security-based swap market and the large number of cross-border transactions, the Commission recognizes that it is likely that such transactions may be subject to the reporting requirements of at least two jurisdictions.[179] However, the Commission preliminarily believes that if relevant authorities are able to access security-based swap data in trade repositories outside their jurisdiction, such as repositories registered with the Commission, as needed, then relevant authorities may be more inclined to permit market participants involved in such transactions to fulfill their reporting requirements by reporting the transactions to a single trade repository.[180] If market participants can report a transaction to a single trade repository rather than to separate trade repositories in each applicable

2010), note 95, *supra* ("Transparency can have a calming influence on trading patterns at the onset of a potential financial crisis, and thus act as a source of market stability to a wider range of markets, including those for equities and bonds.").

[173] *See* note 94, *supra*, and accompanying text.

[174] *See* SDR Adopting Release, 80 FR 14450 ("Requiring U.S. persons that perform the functions of an SDR to be operated in a manner consistent with the Title VII regulatory framework and subject to the Commission's oversight, among other things, helps ensure that relevant authorities are able to monitor the build-up and concentration of risk exposure in the [security-based swap] market, reduce operational risk in that market, and increase operational efficiency."); *id.* at 14529 ("In conjunction with Regulation SBSR, the SDR Rules should assist the Commission in fulfilling its regulatory mandates and legal responsibilities such as detecting market manipulation, fraud, and other market abuses by providing it with greater access to [security-based swap] information than that provided under the voluntary reporting regime."); *see also* DTCC comment (Nov. 15, 2010) at 1 ("A registered SDR should be able to provide (i) enforcement agents with necessary information on trading activity; (ii) regulatory agencies with counterparty-specific information about systemic risk based on trading activity; (iii) aggregate trade information for publication on market-wide activity; and (iv) a framework for real-time reporting from swap execution facilities and derivatives clearinghouses.").

[175] *See* SDR Adopting Release, 80 FR 14531 ("The SDR Requirements [Exchange Act section 13(n) and the rules and regulations thereunder], including requirements that SDRs register with the Commission, retain complete records of [security-based swap] transactions, maintain the integrity and confidentiality of those records, and disseminate appropriate information to the public are intended to help ensure that the data held by SDRs is reliable and that the SDRs provide information that contributes to the transparency of the [security-based swap] market while protecting the confidentiality of information provided by market participants."); *see also* Exchange Act section 13(n)(5)(C), 15 U.S.C. 78m(n)(5)(c) (requiring SDRs to maintain security-based swap data)); Exchange Act rules 13n–5(b)(3) and (4) (requiring SDRs to establish, maintain, and enforce policies and procedures reasonably designed to ensure that transaction data and positions are accurate and to maintain the transaction data and positions for specified periods of time).

[176] *See, e.g.*, SDR Proposing Release, 75 FR 77307, 77356, *corrected at* 76 FR 79320 (stating that the "data maintained by an SDR may also assist regulators in (i) preventing market manipulation, fraud, and other market abuses; (ii) performing market surveillance, prudential supervision, and macroprudential (systemic risk) supervision; and (iii) resolving issues and positions after an institution fails," and further stating that "increased transparency on where exposure to risk reside in financial markets . . . will allow regulators to monitor and act before the risks become systemically relevant. Therefore, SDRs will help achieve systemic risk monitoring."); Cross-Border Proposing Release, 78 FR 31186–31187 (discussing benefits of providing relevant foreign authorities with access to data maintained by SDRs).

[177] *Cf.* Cleary Gottlieb comment (Sept. 20, 2011) at 31 (the indemnification requirement "could be a significant impediment to effective regulatory coordination, since non-U.S. regulators may establish parallel requirements for U.S. regulators to access swap data reported in their jurisdictions.").

[178] For example, EU law requires that counterparties to derivatives contracts report the details of the contract to a trade repository, registered or recognized in accordance with EU law, no later than the working day following the conclusion, modification or termination of the contract. *See* EMIR art. 9; *see also* EC Delegated Regulation no. 148/2013 (regulatory technical standards implementing the reporting requirement).

[179] For example, as noted above, market data regarding single-name CDS transactions involving U.S.-domiciled counterparties and/or U.S.-domiciled reference entities indicates that 13 percent of such transactions involve two U.S.-domiciled counterparties, while 48 percent involve a U.S.-domiciled counterparty and a foreign-domiciled counterparty. *See* note 141, *supra*, and accompanying text.

[180] For example, EU law anticipates the possibility that market participants may be able to satisfy their EU reporting obligations by reporting to a trade repository established in a third country, so long as that repository has been recognized by the European Securities and Markets Authority. *See* EMIR art. 77; *see also* Regulation SBSR, rule 908(c) (providing that to the extent that the Commission has issued a substituted compliance order/determination, compliance with Title VII regulatory reporting and public dissemination requirements may be satisfied by compliance with the comparable rules of a foreign jurisdiction).

jurisdiction, their compliance costs may be reduced. Similarly, to the extent that security-based swap data repositories provide additional ancillary services,[181] if market participants choose to make use of such services, they would likely find such services that make use of all of their data held in a single trade repository more useful than services that are applied only to a portion of that market participant's transactions. Ancillary services applied to only a portion of a participant's transactions could result if data were divided across multiple repositories as a result of regulations requiring participants to report data to separate trade repositories in each applicable jurisdiction.

b. Anticipated Costs

The Commission believes that although there are benefits to security-based swap data repositories providing access to relevant authorities to data maintained by the repositories, such access will likely involve certain costs and potential risks. For example, the Commission expects that repositories will maintain data that are proprietary and highly sensitive[182] and that are subject to strict privacy requirements.[183] Extending access to such data to anyone, including relevant authorities, increases the risk that the confidentiality of the data maintained by repositories may not be preserved.[184] A relevant authority's inability to protect the confidentiality of data maintained by repositories could erode market participants' confidence in the integrity of the security-based swap market and increase the overall risks associated with trading.[185] As we discuss below, this may ultimately lead to reduced trading activity and liquidity in the market, hindering price discovery and impeding the capital formation process.[186]

To help mitigate these risks and potential costs to market participants, the Exchange Act and the proposed rules impose certain conditions on relevant authorities' access to data maintained by repositories.[187] In part, the Exchange Act and the proposed rules limit the authorities that may access data maintained by a security-based swap data repository to a specific list of domestic authorities and other persons, including foreign authorities, determined by the Commission to be appropriate,[188] and further require that a repository notify the Commission when the repository receives an authority's initial request for data maintained by the repository.[189] Restricting access to security-based swap data available to relevant authorities should reduce the risk of unauthorized disclosure, misappropriation or misuse of security-based swap data because each relevant authority will only have access to information within its regulatory mandate, or legal responsibility or authority.

The proposed rules further require that, before a repository shares security-based swap information with a relevant authority, there must be an arrangement (in the form of a MOU or otherwise) between the Commission and the relevant authority that addresses the confidentiality of the security-based swap information provided, and under which the relevant authority agrees to indemnify the Commission and the repository for any expenses arising from litigation relating to the information provided.[190] While the proposal also conditionally exempts the relevant authority requesting data from the indemnification requirement, it does so only if the requested information relates to a regulatory mandate or legal responsibility or authority of the entity requesting the data, and there is in effect an arrangement between the Commission and such relevant authority that addresses the confidentiality of the information provided.[191] The arrangement should further reduce the likelihood of confidential trade or position data being inadvertently made public.

Although the statutory indemnification requirement could provide a strong incentive for relevant authorities to take appropriate care in safeguarding data they might receive from a registered SDR, the Commission recognizes the significance of commenter concerns regarding the impact of requiring indemnification,[192] and understands that certain authorities may be unable to agree to indemnify a data repository and the Commission. Therefore, the Commission preliminarily believes that the indemnification requirement could frustrate the purposes of the statutory requirement that repositories make available data to relevant authorities. The Commission preliminarily believes that the proposed approach appropriately balances confidentiality concerns associated with regulatory access with the benefits accruing to security-based swap market participants from increased regulatory transparency.

2. Effects on Efficiency, Competition and Capital Formation

The rules described in this proposal are intended to facilitate access for relevant authorities to data stored in SEC-registered repositories and therefore affect such repositories, but do not directly affect security-based swap market participants. As discussed below, access by relevant authorities to security-based swap data could indirectly affect market participants through the benefits that accrue from the relevant authorities' improved ability to fulfill their regulatory mandate or legal responsibility or authority as well as the potential impact of disclosure of confidential data.

[181] According to one commenter, ancillary services "may include: asset servicing, confirmation, verification and affirmation facilities, collateral management, settlement, trade compression and netting services, valuation, pricing and reconciliation functionalities, position limits management, dispute resolution, counterparty identity verification and others." *See* MarkitSERV comment (Jan. 24, 2011) at 4 (comment in response to SDR Proposing Release).

[182] As the Commission noted in the SDR Proposing Release, such data could include information about a market participant's trades or its trading strategy; it may also include non-public personal information. SDR Proposing Release, 75 FR 77339.

[183] *See* Exchange Act section 13(n)(5)(F), 15 U.S.C. 78m(n)(5)(F) (requiring an SDR to maintain the privacy of security-based swap transaction information); Exchange Act rules 13n–4(b)(8) and 13n–9 (implementing Exchange Act section 13(n)(5)(F)).

[184] *See, e.g.*, ESMA comment (Jam. 17, 2011) at 2 (noting that relevant authorities must ensure the confidentiality of security-based swap data provided to them).

[185] For example, should it become generally known by market participants that a particular dealer had taken a large position in order to facilitate a trade by a customer and was likely to take offsetting positions to reduce its exposure, other market participants may take positions in advance of the dealer attempting to take its offsetting positions. This "front running" of the dealer's trades would likely raise its trading costs. Should the dealer believe that its market exposure may become public before it has the opportunity to hedge, the price quote offered to its customer to establish the original position would reflect the increased hedging cost.

[186] *See* SDR Proposing Release, 75 FR 77307 ("Failure to maintain privacy of [SDR data] could lead to market abuse and subsequent loss of liquidity.").

[187] Exchange Act section 13(n)(5)(G) and (H), 15 U.S.C. 78m(n)(5)(G) and (H); *see also* Exchange Act rules 13n–4(b)(9) (implementing Exchange Act sections 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G)) and (b)(10) (implementing Exchange Act section 13(n)(5)(H), 15 U.S.C. 78m(n)(5)(H)).

[188] As discussed above in part II.A.3(a), the Commission anticipates that such determinations may be conditioned, in part, by specifying the scope of a relevant authority's access to data, and may limit this access to reflect the relevant authority's regulatory mandate, or legal responsibility or authority.

[189] *See* Exchange Act section 13(n)(5)(G), 15 U.S.C. 78m(n)(5)(G); proposed Exchange Act rule 13n–4(b)(9).

[190] *See* Exchange Act section 13(n)(5)(H), 15 U.S.C. 78m(n)(5)(H); proposed Exchange Act rule 13n–4(b)(10).

[191] *See* proposed Exchange Act rule 13n–4(d).

[192] *See* note 13, *supra*.

However, because the Commission preliminarily believes that its rules will condition access to security-based swap data on the agreement of the relevant authorities to protect the confidentiality of the data, the Commission expects these rules to have little effect on the structure or operations of the security-based swap market. Therefore, the Commission preliminarily believes that effects of the proposed rules on efficiency, competition and capital formation will be small.[193] Nevertheless, there are some potential effects, particularly with respect to efficiency and capital formation, which flow from efficient collection and aggregation of security-based swap data. We describe these effects below.

In part VI.B of this release, the Commission describes the baseline used to evaluate the economic impact of the proposed rules, including the impact on efficiency, competition and capital formation. In particular, the Commission noted that the security-based swap data currently available from the DTCC–TIW is the result of a voluntary reporting system and access to that data is made consistent with guidelines published by the ODRF.

Under the voluntary reporting regime, CDS transaction data involving counterparties and reference entities from most jurisdictions is reported to a single entity, the DTCC–TIW. The DTCC–TIW, using the ODRF guidelines, then allows relevant authorities, including the Commission, to obtain data necessary to carry out their respective authorities and responsibilities with respect to OTC derivatives and the regulated entities that use derivatives.[194] As various regulators implement reporting rules within their jurisdictions, counterparties within those jurisdictions may or may not continue to report to the DTCC–TIW. As a result, the ability of the Commission and other relevant authorities to obtain the data required consistent with their regulatory mandate, or legal responsibility or authority, may require the ability to access data held in a trade repository outside of their own jurisdictions. That is, because the market is global and interconnected, effective regulatory monitoring of the security-based swap market may require regulators to have access to information on the global market, particularly during times of market turmoil. The proposed data access rule amendments and indemnification exemption should facilitate access of relevant authorities other than the Commission to security-based swap data held in repositories, and may indirectly facilitate Commission access to data held by trade repositories registered with regulators other than the Commission. To the extent that the proposed data access rules and indemnification exemption facilitate the ability of repositories to collect security-based swap information involving counterparties across multiple jurisdictions, there may be benefits in terms of efficient collection and aggregation of security-based swap data.

To the extent that the proposed data access provisions and the indemnification exemption increase the quantity of transaction and position information available to regulatory authorities about the security-based swap market, the ability of the Commission and other relevant authorities to respond in an appropriate and timely manner to market developments could enhance investor protection through improved detection, and facilitating the investigation of fraud and other market abuses. Moreover, as noted above, we do not anticipate that the proposed rules would directly affect market participants, such enhancements in investor protections may decrease the risks and indirect costs of trading and could therefore encourage greater participation in the security-based swap market for a wider range of entities seeking to engage in a broad range of hedging and trading activities.[195] While we believe that increased participation is a possible outcome of the Commission's transparency initiatives, including these proposed rules, relative to the level of participation in this market if these initiatives were not undertaken, we preliminarily believe that the benefits that flow from improved detection, facilitating the investigation of fraud and other market abuses, and more-efficient data aggregation are the more direct benefits of the rules.

In addition, the improvement in the quantity of data available to regulatory authorities, including the Commission, should improve their ability to monitor concentrations of risk exposures and evaluate risks to financial stability and could promote the overall stability in the capital markets.[196]

Aside from the effects that the proposed data access rules may have on regulatory oversight and market participation, we expect the proposed rules potentially to affect how SDRs are structured. In particular, the proposed data access rules and indemnification exemption could reduce the potential for SDRs to be established along purely jurisdictional lines, with multiple repositories established in different countries or jurisdictions. That is, effective data sharing may reduce the need for repositories to be established along jurisdictional lines, reducing the likelihood that a single security-based swap transaction must be reported to multiple swap-data repositories. As noted previously by the Commission, due to high fixed costs and increasing economies of scale, the total cost of providing trade repository services to the market for security-based swaps may be lower if the total number of repositories is not increased due to a regulatory environment that results in trade repositories being established along jurisdictional lines.[197] To the extent that the proposed rules result in fewer repositories that potentially compete across jurisdictional lines, cost savings realized by fewer repositories operating on a larger scale could result in reduced fees, with the subsequent cost to market participants to comply with reporting requirements being lower.[198]

Furthermore, multiple security-based swap data repositories with duplication of reporting requirements for cross-border transactions increase data fragmentation and data duplication, both of which increase the potential for difficulties in data aggregation. To the extent that the proposed data access rule amendments and indemnification exemption facilitate the establishment of SDRs that accept transactions from multiple jurisdictions, there may be

[193] *See* part VI.C.1b above for a discussion of the potential impact on capital formation of inadequate data confidentiality protections. The Commission preliminarily believes that the proposed approach balances the need for data confidentiality and the need for regulatory transparency.

[194] *See* note 149, *supra*.

[195] Indirect trading costs refer to costs other than direct transaction costs. Front running costs described above provide an example of indirect trading costs. In the context of investor protection, the risk of fraud represents a cost of trading in a market with few investor protections or safeguards.

[196] *See* note 95, *supra*.

[197] *See* SDR Adopting Release, 80 FR 14533 (discussion of high fixed costs and increasing economies of scale in the provision of security-based swap data repository services); *see also* SDR Adopting Release, 80 FR 14479 (discussion of rule 13n–4(c)(1)(i), which requires each SDR to ensure that any dues, fees or other charges that it imposes, and any discounts or rebates that it offers, are fair and reasonable and not unreasonably discriminatory; particularly noting that "[o]ne factor that the Commission has taken into consideration to evaluate the fairness and reasonableness of fees, particularly those of a monopolistic provider of a service, is the cost incurred to provide the service").

[198] Alternatively, fewer repositories could result in those few repositories having the ability to take advantage of the reduced level of competition to charge higher prices.

benefits in terms of efficient collection and aggregation of security-based swap data. As discussed above, to the extent that the indemnification exemption allows relevant authorities to have better access to the data necessary to form a more complete picture of the security-based swap market—including information regarding risk exposures and asset valuations—the exemption should help the Commission and other relevant authorities perform their oversight functions in a more effective manner.

However, while reducing the likelihood of having multiple SDRs established along jurisdictional lines would resolve many of the challenges involved in aggregating security-based swap data, there may be costs associated with having fewer repositories. In particular, the existence of multiple repositories may reduce operational risks, such as the risk that a catastrophic event or the failure of a repository leaves no registered repositories to which transactions can be reported, impeding the ability of the Commission and relevant authorities to obtain information about the security-based swap market.

Finally, as we noted above, a relevant authority's inability to protect the privacy of data maintained by repositories could erode market participants' confidence in the integrity of the security-based swap market. More specifically, confidentiality breaches, including the risk that trading strategies may no longer be anonymous due to a breach, may increase the overall risks associated with trading or decrease the profits realized by certain traders. Increased risks or decreased profits may reduce incentives to participate in the security-based swap markets, which may lead to reduced trading activity and liquidity in the market. Depending on the extent of confidentiality breaches, as well as the extent to which such breaches lead to market exits, disclosures of confidential information could hinder price discovery and impede the capital formation process.[199]

3. Additional Costs and Benefits of Specific Rules

Apart from the general costs and benefits associated with the structure of the Exchange Act data access provisions and proposed implementing rules, certain discrete aspects of the proposed rules and related interpretation raise additional issues related to economic costs and benefits.

a. Benefits

i. Determination of Recipient Authorities

The Commission is proposing an approach to determining whether an authority, other than those expressly identified in the Exchange Act and the implementing rules,[200] should be provided access to data maintained by SDRs. The Commission believes that this proposed approach has the benefit of appropriately limiting relevant authorities' access to data maintained by repositories to protect the confidentiality of the data.[201] The Commission expects that relevant authorities from a number of jurisdictions may seek to obtain a determination by the Commission that they may appropriately have access to repository data. Each of these jurisdictions may have a distinct approach to supervision, regulation or oversight of its financial markets or market participants and to the protection of proprietary and other confidential information. The Commission believes that the proposed factors—which among other things would consider whether an authority has an interest in access to security-based swap data based on the relevant authority's regulatory mandate or legal responsibility or authority, whether there is an MOU or other arrangement between the Commission and the relevant authority that addresses the confidentiality of the security-based swap data provided to the authority, and whether information accessed by the applicable authority would be subject to robust confidentiality safeguards[202]—appropriately condition an authority's ability to access data on the confidentiality protections the authority will afford that data. This focus further would be strengthened by the Commission's ability to revoke its determination where necessary, including, for example, if a relevant authority fails to keep such data confidential.[203] This approach should increase market participants' confidence that their confidential trade data will be protected, reducing perceived risks of transacting in security-based swaps.

The Commission also believes that its proposed approach in determining the appropriate relevant authorities would reduce the potential for fragmentation and duplication of security-based swap data among trade repositories by facilitating mutual access to the data. Narrower approaches such as allowing regulatory access to security-based swap data only to those entities specifically identified in the Exchange Act[204] may increase fragmentation and duplication, and hence increase the difficulty in consolidating and interpreting security-based swap market data from repositories, potentially reducing the general economic benefits discussed above.

Furthermore, the Commission believes that its proposed approach in conditioning access to security-based swap data held in SDRs by requiring there to be in effect an arrangement between the Commission and the authority in the form of a MOU would promote the intended benefits of access by relevant authorities to data maintained by SDRs. Under the proposed approach, rather than requiring regulatory authorities to negotiate confidentiality agreements with multiple SDRs, a single MOU between the Commission and the relevant authority can serve as the confidentiality agreement that will satisfy the requirement for a written agreement stating that the relevant authority will abide by the confidentiality requirements described in section 24 of the Exchange Act relating to the security-based swap data. The Commission routinely negotiates MOUs or other arrangements with relevant authorities to secure mutual assistance or for other purposes, and the Commission preliminarily believes that the proposed approach is generally consistent with this practice.

The Commission further preliminarily believes that negotiating a single such agreement with the Commission will be less costly for the authority requesting data than negotiating directly with each registered SDR and eliminate the need for each SDR to negotiate as many as 200 confidentiality agreements with requesting authorities. This approach would also avoid the difficulties that may be expected to accompany an approach that requires SDRs to enter into confidentiality agreements—particularly questions regarding the parameters of an adequate confidentiality agreement, and the presence of uneven and potentially inconsistent confidentiality protections across SDRs and recipient entities.

[199] *See* SDR Proposing Release, 75 FR 77307 ("Failure to maintain privacy of [SDR data] could lead to market abuse and subsequent loss of liquidity.").

[200] *See* part II.A for a discussion of specific authorities included in the implementing rules.

[201] *See* ESMA comment (Jan. 17, 2011) at 2 (noting that relevant authorities must ensure the confidentiality of security-based swap data provided to them).

[202] *See* part II.A.3.a, *supra*.

[203] *See* part II.A.4, *supra*.

[204] *See* Exchange Act section 3(a)(74), 15 U.S.C. 78c(a)(74).

ii. Notification Requirement

The Commission is proposing an approach by which SDRs may satisfy the notification requirement by notifying the Commission upon the initial request for security-based swap data by a relevant authority and maintaining records of the initial request and all subsequent requests.[205] The Commission estimates that approximately 300 relevant authorities may make requests for data from security-based swap data repositories.[206] Based on the Commission's experience in making requests for security-based swap data from trade repositories, the Commission estimates that each relevant authority will access security-based swap data held in SDRs using electronic access. Such access may be to satisfy a narrow request concerning a specific counterparty or reference entity or security, to create a summary statistic of trading activity or outstanding notional, or to satisfy a large request for detailed transaction and position data. Requests may occur as seldom as once per month if the relevant authority is downloading all data to which it has access in order to analyze it on its own systems, or may occur 100 or more times per month if multiple staff of the relevant authority are making specific electronic requests concerning particular counterparties or reference entities and associated positions or transactions. Therefore, under the Commission's proposed approach to notification requirement compliance, the Commission estimates based on staff experience that each repository would provide the Commission with actual notice as many as 300 times, and that repositories cumulatively would maintain records of as many as 360,000 subsequent data requests per year.[207] The proposed rule would be expected to permit repositories to respond to requests for data by relevant authorities more promptly and at lower cost than if notification was required for each request for data access, while helping to preserve the Commission's ability to monitor whether the repository provides data to each relevant entity consistent with the applicable conditions.

The Commission's proposed rule would also simplify relevant authorities' direct access to security-based swap data needed in connection with their regulatory mandate or legal responsibility or authority, because repositories would not be required to provide the Commission with actual notice of every request prior to providing access to the requesting relevant authority.

iii. Use of Confidentiality Agreements Between the Commission and Recipient Authorities

The proposed rules in part would condition regulatory access on there being an arrangement between the Commission and the recipient entity, in the form of an MOU or otherwise, addressing the confidentiality of the security-based swap information made available to the recipient. The proposed rules add that those arrangements shall be deemed to satisfy the statutory requirement for a written confidentiality agreement.[208]

As discussed above, the Commission preliminarily believes that this approach reflects an appropriate way to satisfy the interests associated with the confidentiality condition. The benefits associated with this approach include obviating the need for repositories to negotiate and enter into multiple confidentiality agreements, avoiding difficulties regarding the parameters of an adequate confidentiality agreement, and avoiding uneven and potentially inconsistent confidentiality protections. The proposed approach also would build upon the Commission's experience in negotiating such agreements.[209]

iv. Indemnification Exemption

The Commission also is proposing a conditional indemnification exemption, recognizing that application of the indemnification requirement could prevent some relevant domestic and foreign authorities from obtaining security-based swap information from repositories, because they cannot provide an indemnification agreement.[210] Effectively prohibiting some authorities other than the Commission from obtaining access to security-based swap data maintained by repositories potentially would greatly reduce the market transparency to regulators provided by Title VII.[211] Moreover, although relevant authorities could obtain security-based swap data from the Commission,[212] repositories are likely to have systems in place and expertise that allows them to provide such data to relevant authorities quickly, and economic incentives to minimize their own cost of providing data.

The Commission also preliminarily believes that the absence of an exemption to the indemnification requirement could increase the likelihood that foreign authorities would require duplicate reporting of cross-border transactions to repositories within the foreign jurisdiction. To the extent that relevant foreign authorities are effectively restricted in obtaining data maintained by SEC-registered repositories, the Commission's own ability to access security-based swap data may similarly be restricted.[213] More generally, the resulting restrictions on regulatory access may likely lead to duplication and fragmentation of security-based swap data among trade repositories in multiple jurisdictions, which may increase other costs that relevant authorities may incur, including, for example, the difficulty of aggregating data across multiple repositories.[214]

The Commission preliminarily believes that the proposed indemnification exemption further would be beneficial by mitigating the risks associated with permitting relevant

[205] *See* proposed Exchange Act rule 13n–4(e).

[206] *See* proposed Exchange Act rule 13n–4(b)(9)(i)–(v) for a list of prudential regulators that may request data maintained by SDRs from SDRs. The Exchange Act also states that FSOC, the CFTC, and the Department of Justice may access security-based swap data. *See* parts II.A.1, 2, *supra*. The Commission also expects that certain self-regulatory organizations and registered futures associations may request security-based swap data from repositories. Therefore, the Commission estimates that up to approximately 30 relevant authorities in the United States may seek to access security-based swap data from repositories. The Commission preliminarily believes that most requests will come from authorities in G20 countries, and estimates that each of the G20 countries will also have no more and likely fewer than 30 relevant authorities that may request data from SDRs. Certain authorities from outside the G20 also may request data. Accounting for all of those entities, the Commission estimates that there will likely be a total of no more than 300 relevant domestic and foreign authorities that may request security-based swap data from repositories.

[207] The annual estimate of 360,000 is calculated based on 300 recipient entities each making 100 requests per month cumulatively across all repositories. The estimate of 100 requests per authority is based on staff experience with similar data requests in other contexts.

[208] *See* proposed Exchange Act rule 13n–4(10)(i).

[209] *See* part II.B.1, *supra*.

[210] *See* part III.A, *supra*.

[211] *See* Proposing Release, 75 FR 77307 (describing expected benefits of SDRs, including the market transparency benefits of access by regulators); *id.* at 77356 ("The ability of the Commission and other regulators to monitor risk and detect fraudulent activity depends on having access to market data."); *see also* part VI.B.1 of this release discussing transparency in the security-based swap market.

[212] *See* part IV.B, *supra* (discussing information sharing under Exchange Act sections 21 and 24); *see also* Proposing Release, 75 FR 77319.

[213] *See* note 94, *supra*, and accompanying text.

[214] *See* Proposing Release, 75 FR 77358. The costs associated with aggregating the data of multiple repositories would likely be significantly higher under the circumstances described here, as different jurisdictions might impose different requirements regarding how data is to be reported and maintained.

authorities to obtain access to data maintained by repositories. The exemption would be available only for requests that are consistent with each requesting authority's regulatory mandate, or legal responsibility or authority. The Commission preliminarily believes that these conditions would significantly reduce the confidentiality concerns relating to relevant authorities' access to data maintained by repositories.[215] Limiting an authority's access to data to that relating to its mandate, or legal responsibility or authority would reduce the opportunity for improper disclosure of the data in part because such limits reduce the quantity of data that is subject to potential improper disclosure, and because an authority is likely to be familiar with the need to maintain the confidentiality of data that relates to its mandate or legal responsibility or authority. Further, the Commission will have an opportunity to evaluate the confidentiality protections provided by the relevant authority in the context of negotiations of an MOU or other arrangement.[216] Should the Commission believe the relevant authority has failed to comply with the confidentiality provisions of the MOU, it may terminate access by revoking a determination by the Commission that the relevant entity was appropriate, or by terminating the MOU or other arrangement used to satisfy the confidentiality condition, or, as applicable, the indemnification exemption.[217]

b. Costs

The Commission recognizes that the proposed approach to providing access to relevant authorities other than the Commission to security-based swap data held in repositories has the potential to involve certain costs and risks.

The relevant authorities requesting securities-based swap data would incur some costs in seeking a Commission order deeming the authority appropriate to receive security-based swap data. These costs would include the negotiation of an MOU to address the confidentiality of the security-based swap information it seeks to obtain and providing information to justify that the security-based swap data relates to the entity's regulatory mandate or legal responsibility or authority. As discussed above, the Commission estimates that up to 300 entities potentially might enter into such MOUs or other arrangements.[218] Based on the Commission staff's experience in negotiating MOUs that address regulatory cooperation, the Commission preliminarily estimates the cost to each relevant authority requesting data associated with negotiating such an arrangement of approximately $205,000 per entity for a total of $61,500,000.[219]

In addition, authorities that are not specified by the proposed rule may request that that the Commission determine them to be appropriate to receive access to such security-based swap data. Given the relevant information that the Commission preliminarily would consider in connection with such designations (apart from the MOU issues addressed above)—including information regarding how the authority would be expected to use the information, information regarding the authority's regulatory mandate or legal responsibility or authority, and information regarding reciprocal access—the Commission preliminarily estimates the cost associated with such a request to be approximately $15,200 per requesting entity for a total of $4,560,000.[220]

Security-based swap data repositories would incur some costs to verify that an entity requesting data entered into the requisite agreements concerning confidentiality with the Commission, and that the entity either has agreed to indemnify the Commission and the repository, or that the indemnification exemption applies. The Commission generally expects that such verification costs would be minimal because information regarding such Commission arrangements would generally be readily available.[221]

To the extent that the security-based swap data repository provides the requested data through direct electronic means, the repository may incur some cost in providing the requesting authority access to the system that provides such access and setting data permissions to allow access only to the information that relates to the authority's regulatory mandate, or legal responsibility or authority. The Commission preliminarily believes most of the costs associated with providing such access would be the fixed costs incurred in designing and building the systems to provide the direct electronic access required by the recently adopted SDR rules.[222] The Commission preliminarily believes the marginal cost of providing access to an additional relevant authority and setting the associated permissions is approximately $6,295.[223] Based on an estimated 300 entities requesting access to each of ten registered SDRs, we estimate the total cost of connecting entities to SDRs to be approximately $18,885,000.

The Commission further recognizes that the conditions in the proposed indemnification exemption would not necessarily provide repositories and the Commission with the same level of confidentiality-related protection that an indemnification agreement would provide (*i.e.*, coverage for any expenses

[215] *See, e.g.*, ESMA comment (Jan. 17, 2011) at 2 (noting that relevant authorities must ensure the confidentiality of security-based swap data provided to them).

[216] For the indemnification exemption to apply to the requests of a particular requesting authority, the authority would be required to enter into an MOU or other arrangement with the Commission, which would enable the Commission to determine, prior to operation of the indemnification exemption, that the authority has a regulatory mandate, or legal responsibility or authority to access data maintained by SDRs, that the authority agrees to protect the confidentiality of any security-based swap information provided to it and that the authority will provide reciprocal assistance in securities matters within the Commission's jurisdiction. *See* part III, *supra* (discussing the proposed indemnification exemption).

[217] *See* part II.A.3, *supra*.

[218] *See* part VI.C.3.a.ii, *supra*.

[219] These figures are based on 300 entities each requiring 500 personnel hours on average to negotiate an MOU. *See* part V.D.1.a, *supra*. The cost per entity is 400 hours × attorney at $380 per hour + 100 hours × deputy general counsel at $530 per hour = $205,000, or a total of $61,500,000. We use salary figures from SIFMA's Management & Professional Earnings in the Securities Industry 2013, modified by SEC staff to account for a 1800-hour year-week and multiplied by 5.35 to account for bonuses, firm size, employee benefits and overhead.

[220] These figures are based on roughly 300 entities (noting that certain entities designated by statute or rule would not need to prepare such requests) requiring 40 personnel hours to prepare a request for access. *See* part V.D.1.b, *supra*. The cost per entity is 40 hours × attorney at $380 per hour = $15,200, or a total of $4,560,000. We use salary figures from SIFMA's Management & Professional Earnings in the Securities Industry 2013, modified by SEC staff to account for a 1800-hour year-week and multiplied by 5.35 to account for bonuses, firm size, employee benefits and overhead.

[221] As a general matter, the Commission provides a list of MOUs and other arrangements on its public Web site, which are available at: *http://www.sec.gov/about/offices/oia/oia_cooparrangements.shtml*.

[222] *See* SDR Adopting Release, 80 FR 14523 (estimating the aggregate one-time systems costs for ten respondents to be 420,000 hours and $10 million, and estimating the aggregate ongoing systems costs as being 252,000 hours and $60 million); *see also* part IV.D.1.c, *supra*.

[223] This figure is based on the view that, for each recipient requesting data, a repository would incur an 25 hour burden associated with programming or otherwise inputting the relevant parameters, encompassing 20 hours of programmer analyst time and five hours of senior programmer time. The estimate also encompasses one hour of attorney time in connection with each such recipient. *See* part V.D.1.c, *supra*. The cost per entity is 20 hours × programmer analyst at $220 per hour + 5 hours × senior programmer at $303 per hour + 1 hour × attorney at $380 per hour = $6,295, We use salary figures from SIFMA's Management & Professional Earnings in the Securities Industry 2013, modified by SEC staff to account for a 1800-hour year-week and multiplied by 5.35 to account for bonuses, firm size, employee benefits and overhead.

arising from litigation relating to information provided to a relevant authority). The Commission preliminarily believes, however, that the conditions in the proposed indemnification exemption, related to the need for a confidentiality arrangement and requiring that the information provided relate to a regulatory mandate, or legal responsibility or authority of the recipient entity, would provide appropriate protection of the confidentiality of data maintained by SDRs, albeit one that is different from the protection provided by an indemnification agreement that addresses potential costs of litigation associated with the data provided to it by the SDR.

In addition, under the Commission's proposed notification compliance rule, SDRs would be required to notify the Commission of the initial request for data but would not have to inform the Commission of all relevant authorities' requests for data prior to a SDR fulfilling such requests. Based on the estimate that approximately 300 relevant authorities may make requests for data from security-based swap data repositories, the Commission estimates that a repository would provide the Commission with actual notice approximately 300 times.[224] Moreover, based on the estimate that ten persons may register with the Commission as SDRs,[225] this suggests that repositories in the aggregate would provide the Commission with actual notice up to a total of 3,000 times. The Commission preliminarily estimates that the total of providing such notice to be $57,000 per SDR for a total of $570,000.[226]

Pursuant to rule, SDRs would be required to maintain records of subsequent requests.[227] Not receiving actual notice of all requests may impact the Commission's ability to track such requests, but the Commission preliminarily believes that the benefits of receiving actual notice of each request would not justify the additional costs that repositories would incur in providing such notices and the potential delay in relevant authorities receiving data that they need to fulfill their regulatory mandate, or legal responsibility or authority. At the same time, providing notice of initial requests will help to preserve the Commission's ability to monitor whether the repository provides data to each relevant entity consistent with the applicable conditions. As discussed above, the Commission preliminarily estimates that the average initial paperwork burden associated with maintaining certain records related to data requests or access would be roughly 360 hours, and that the annualized burden would be roughly 280 hours and $120,000 for each repository.[228] Assuming a maximum of ten security-based swap data repositories, the estimated aggregate one-time dollar cost would be roughly $1 million,[229] and the estimated aggregate annualized dollar cost would be roughly $1.2 million.[230]

D. Alternatives

The Commission considered a number of alternative approaches to implementing the Exchange Act data access provisions, including the indemnification requirement, but, for the reasons discussed below, is not proposing them.

1. No Indemnification Exemption

The Commission considered not proposing any exemptive relief from the indemnification requirement. As discussed above, application of the indemnification requirement may prevent some relevant authorities from accessing security-based swap data directly from repositories registered with the Commission.[231] Although relevant authorities could obtain such data from the Commission,[232] that alternative would be expected to be associated with delays and higher costs, particularly during periods of market stress and particularly since repositories are likely to have expertise in providing such data to relevant authorities and economic incentives for doing so efficiently.[233]

To the extent that relevant foreign authorities are effectively restricted in obtaining data maintained by SEC-registered repositories, the Commission's own ability to access security-based swap data may similarly be restricted.[234] More generally, the resulting restrictions on regulatory access may likely lead to duplication and fragmentation of security-based swap data among trade repositories in multiple jurisdictions, which may increase other costs that relevant authorities may incur, including, for example, the difficulty of aggregating data across multiple repositories.[235]

2. Repository Option To Waive Indemnification

The Commission also considered whether to adopt the approach set forth in the Cross-Border Proposing Release, to allow the SDR the option to waive the indemnification requirement.[236] As discussed above, however, the Commission preliminarily believes that the proposed approach would more effectively address the relevant concerns associated with implementing the indemnification provision.[237] Also, requiring each repository to elect whether to waive the indemnification requirement for each requesting entity would likely impose additional costs on repositories and may result in inconsistent treatment of data requests across repositories.

3. Additional Conditions to Indemnification Requirement or Proposed Indemnification Exemption

The Commission also considered whether to prescribe additional conditions or limitations to the indemnification requirement or the proposed indemnification exemption. In part, the Commission considered one commenter's suggestion that the Commission provide model indemnification language in connection with the indemnification requirement,

[224] *See* part VI.C.3.ii, *supra*.

[225] *See* note 117, *supra*, and accompanying text

[226] These figures are based each of ten SDRs providing notice for each of 300 requesting entities. *See* part V.D.1.d, *supra*. The cost per SDR is 300 requesting entities × 0.5 hours × attorney at $380 per hour = $57,000, or a total of $570,000. We use salary figures from SIFMA's Management & Professional Earnings in the Securities Industry 2013, modified by SEC staff to account for a 1800-hour year-week and multiplied by 5.35 to account for bonuses, firm size, employee benefits and overhead.

[227] *See* part V.D.1.d, *supra*. As noted above, existing rules require SDRs to maintain copies of all documents they make or receive in their course of business, including electronic documents. *See* note 77, *supra*.

[228] *See* part V.D.1.d, *supra*.

[229] The Commission preliminarily anticipates that a repository would assign the associated responsibilities primarily to a compliance manager and a senior systems analyst. The total estimated dollar cost would be roughly $100,000 per repository, reflecting the cost of a compliance manager at $283 per hour for 300 hours, and a senior systems analyst at $260 per hour for 60 hours. Across the estimated ten repositories, this would amount to roughly $1 million.

[230] The Commission preliminarily anticipates that a repository would assign the associated responsibilities primarily to a compliance manager. The total estimated dollar cost would be roughly $120,000 per repository, reflecting $40,000 annualized information technology costs, as well as a compliance manager at $283 per hour for 280 hours. Across the estimated ten repositories, this would amount to roughly $1.2 million.

[231] *See, e.g.*, DTCC comment (Nov. 15, 2010) at 3 (discussing how the indemnification requirement would result in the reduction of information accessible to regulators on a timely basis and would greatly diminish regulators' ability to carry out oversight functions).

[232] *See* part IV.B, *supra*, discussing information sharing under Exchange Act sections 21 and 24; *see also* SDR Proposing Release, 75 FR 77319.

[233] *See* part VI.C.3.a.iv, *supra*.

[234] *See* note 94, *supra*, and accompanying text.

[235] *See* note 214, *supra*.

[236] *See* note 91, *supra*, and accompanying text.

[237] *See* part III.A, *supra*.

but concluded preliminarily that the benefits of such model language are largely mitigated by an indemnification exemption that would condition the indemnification exemption upon there being in effect one or more arrangements (in the form of an MOU or otherwise) between the Commission and the entity that addresses the confidentiality of the security-based swap information provided and other matters as determined by the Commission.[238]

4. Use of Confidentiality Arrangements Directly Between Repositories and Recipients

The Commission considered the alternative approach of permitting confidentiality agreement between SDRs and the recipient of the information to satisfy the confidentiality condition to the data access requirement. The Commission preliminarily believes, however, that the proposed approach, which would make use of confidentiality arrangements between the Commission and the recipients of the data, would avoid difficulties such as questions regarding the parameters of the confidentiality agreement, and the presence of uneven and inconsistent confidentiality protections.[239] This also would avoid the need for SDRs to potentially negotiate and enter into dozens of confidentiality agreements, instead such costs would be borne by the Commission.

6. Notice of Individual Requests for Data Access

Finally, the Commission considered requiring repositories to provide notice to the Commission of all requests for data prior to repositories fulfilling such requests, rather than the proposed approach of requiring such notice only of the first request from a particular recipient, with the repository maintaining records of all subsequent requests.[240] The Commission preliminarily believes that the benefits of receiving actual notice for each and every request would not justify the additional costs that would be imposed on repositories to provide such notice, and providing notice of subsequent requests may not be feasible if data is provided by direct electronic access.

E. Comments on the Economic Analysis

The Commission requests comment on all aspects of this economic analysis. Commenters particularly are requested to address whether there are other costs or benefits—not addressed above—that the Commission should take into account when adopting final rules. Commenters also are requested to address whether the Commission has appropriately weighed the costs and benefits of the potential alternative approaches addressed above, and whether there are other potential alternative approaches that the Commission should assess.

VII. Consideration of Impact on the Economy

For purposes of the Small Business Regulatory Enforcement Fairness Act of 1996 ("SBREFA")[241] the Commission must advise OMB whether the proposed regulation constitutes a "major" rule. Under SBREFA, a rule is considered "major" where, if adopted, it results or is likely to result in: (1) An annual effect on the economy of $100 million or more; (2) a major increase in costs or prices for consumers or individual industries; or (3) significant adverse effect on competition, investment or innovation.

The Commission requests comment on the potential impact of the proposed rules and amendments on the economy on an annual basis. Commenters are requested to provide empirical data and other factual support for their views to the extent possible.

VIII. Regulatory Flexibility Act Certification

Section 3(a) of the Regulatory Flexibility Act of 1980 ("RFA")[242] requires the Commission to undertake an initial regulatory flexibility analysis of the proposed rules on "small entities." Section 605(b) of the RFA[243] provides that this requirement shall not apply to any proposed rule or proposed rule amendment which, if adopted, would not have a significant economic impact on a substantial number of small entities. Pursuant to 5 U.S.C. 605(b), the Commission hereby certifies that the proposed rules would not, if adopted, have a significant economic impact on a substantial number of small entities. In developing these proposed rules, the Commission has considered their potential impact on small entities. For purposes of Commission rulemaking in connection with the RFA, a small entity includes: (1) When used with reference to an "issuer" or a "person," other than an investment company, an "issuer" or "person" that, on the last day of its most recent fiscal year, had total assets of $5 million or less;[244] or (2) a broker-dealer with total capital (net worth plus subordinated liabilities) of less than $500,000 on the date in the prior fiscal year as of which its audited financial statements were prepared pursuant to Rule 17a–5(d) under the Exchange Act,[245] or, if not required to file such statements, a broker-dealer with total capital (net worth plus subordinated liabilities) of less than $500,000 on the last day of the preceding fiscal year (or in the time that it has been in business, if shorter); and is not affiliated with any person (other than a natural person) that is not a small business or small organization.[246]

In initially proposing rules regarding the registration process, duties and core principles applicable to SDRs, the Commission stated that it preliminarily did not believe that any persons that would register as repositories would be considered small entities.[247] The Commission further stated that it preliminarily believed that most, if not all, SDRs would be part of large business entities with assets in excess of $5 million and total capital in excess of $500,000, and, as a result, the Commission certified that the proposed rules would not have a significant impact on a substantial number of small entities and requested comments on this certification.[248] The Commission reiterated that conclusion earlier this year in adopting final rules generally addressing repository registration, duties and core principles.[249]

The Commission continues to hold the view that any persons that would register as SDRs would not be considered small entities. Accordingly, the Commission certifies that the proposed rules—related to regulatory access to data held by SDRs and providing a conditional exemption from

[238] *See* note 98, *supra*.

[239] *See* part II.B.1, *supra*.

[240] *See* part II.A.4, *supra*.

[241] Public Law 104–121, Title II, 110 Stat. 857 (1996) (codified in various sections of 5 U.S.C., 15 U.S.C. and as a note to 5 U.S.C. 601).

[242] 5 U.S.C. 603(a).

[243] 5 U.S.C. 605(b).

[244] *See* 17 CFR 240.0–10(a).

[245] 17 CFR 240.17a–5(d).

[246] *See* 17 CFR 240.0–10(c).

For purposes of the Regulatory Flexibility Act, the definition of "small entity" also encompasses "small governmental jurisdictions," which in relevant part means governments of locales with a population of less than fifty thousand. 5 U.S.C. 601(5), (6). Although the Commission anticipates that this proposal may be expected to have an economic impact on various governmental entities that access data pursuant to Dodd-Frank's data access provisions, the Commission does not anticipate that any of those governmental entities would be small entities.

[247] *See* 75 FR 77365.

[248] *See id.* (basing the conclusions on review of public sources of financial information about the current repositories that are providing services in the OTC derivatives market).

[249] *See* SDR Adopting Release, 80 FR 14549 (noting that the Commission did not receive any comments that specifically addressed whether the applicable rules would have a significant economic impact on small entities).

the associated indemnification requirement—would not have a significant economic impact on a substantial number of small entities for purposes of the RFA. The Commission encourages written comments regarding this certification. The Commission solicits comment as to whether the proposed rules could have an effect on small entities that has not been considered. The Commission requests that commenters describe the nature of any impact on small entities and provide empirical data to support the extent of such impact.

Statutory Basis and Text of Proposed Rules

Pursuant to the Exchange Act, and particularly sections 3(b), 13(n), 23(a) and 36 thereof, 15 U.S.C. 78c(b), 78m(n), 78w(a) and 78mm, the Commission is proposing to amend rule 13n–4 by adding paragraphs (b)(9), (b)(10), (d) and (e) to that rule.

List of Subjects in 17 CFR Part 240

Confidential business information, Reporting and recordkeeping requirements, Securities.

Text of Proposed Rules

For the reasons stated in the preamble, the Commission is proposing to amend Title 17, Chapter II, of the Code of Federal Regulations as follows:

PART 240—GENERAL RULES AND REGULATIONS, SECURITIES EXCHANGE ACT OF 1934

■ 1. The authority citation for part 240 continues to read, in part, as follows:

Authority: 15 U.S.C. 77c, 77d, 77g, 77j, 77s, 77z–2, 77z–3, 77eee, 77ggg, 77nnn, 77sss, 77ttt, 78c, 78c–3, 78c–5, 78d, 78e, 78f, 78g, 78i, 78j, 78j–1, 78k, 78k–1, 78*l*, 78m, 78n, 78n–1, 78*o*, 78*o*–4, 78*o*–10, 78p, 78q, 78q–1, 78s, 78u–5, 78w, 78x, 78*ll*, 78mm, 80a–20, 80a–23, 80a–29, 80a–37, 80b–3, 80b–4, 80b–11, 7201 *et seq.*, and 8302; 7 U.S.C. 2(c)(2)(E); 12 U.S.C. 5221(e)(3); 18 U.S.C. 1350; and Pub. L. 111–203, 939A, 124 Stat. 1376 (2010), unless otherwise noted.

* * * * *

■ 2. In § 240.13n–4, amend paragraph (b)(8) by removing the word "and" at the end of the paragraph and adding paragraphs (b)(9), (b)(10), (d), and (e).

The additions read as follows:

§ 240.13n–4 Duties and core principles of security-based swap data repository.

* * * * *

(b) * * *

(9) On a confidential basis, pursuant to section 24 of the Act (15 U.S.C. 78x), upon request, and after notifying the Commission of the request in a manner consistent with paragraph (e) of this section, make available security-based swap data obtained by the security-based swap data repository, including individual counterparty trade and position data, to the following:

(i) The Board of Governors of the Federal Reserve System and any Federal Reserve Bank;

(ii) The Office of the Comptroller of the Currency;

(iii) The Federal Deposit Insurance Corporation;

(iv) The Farm Credit Administration;

(v) The Federal Housing Finance Agency;

(vi) The Financial Stability Oversight Council;

(vii) The Commodity Futures Trading Commission;

(viii) The Department of Justice;

(ix) The Office of Financial Research; and

(x) Any other person that the Commission determines to be appropriate, conditionally or unconditionally, by order, including, but not limited to—

(A) Foreign financial supervisors (including foreign futures authorities);

(B) Foreign central banks; and

(C) Foreign ministries;

(10) Before sharing information with any entity described in paragraph (b)(9) of this section, there shall be in effect an arrangement between the Commission and the entity (in the form of a memorandum of understanding or otherwise) to address the confidentiality of the security-based swap information made available to the entity; this arrangement shall be deemed to satisfy the requirement, set forth in section 13(n)(5)(H)(i) of the Act (15 U.S.C. 78m(n)(5)(H)(i)), that the security-based swap data repository receive a written agreement from the entity stating that the entity shall abide by the confidentiality requirements described in section 24 of the Act (15 U.S.C. 78x) relating to the information on security-based swap transactions that is provided; and

* * * * *

(d) *Exemption from the indemnification requirement.* The indemnification requirement set forth in section 13(n)(5)(H)(ii) of the Act (15 U.S.C. 78m(n)(5)(H)(ii)) shall not be applicable to an entity described in paragraph (b)(9) of this section with respect to disclosure of security-based swap information by the security-based swap data repository to such entity if:

(1) Such information relates to persons or activities within the entity's regulatory mandate, or legal responsibility or authority; and

(2) There is in effect one or more arrangements (in the form of memoranda of understanding or otherwise) between the Commission and such entity that:

(i) Address the confidentiality of the security-based swap information provided and any other matters as determined by the Commission; and

(ii) Specify the types of security-based swap information that would relate to persons or activities within the entity's regulatory mandate, legal responsibility or authority for purposes of paragraph (d)(1) of this section.

(e) *Notification requirement compliance.* To satisfy the notification requirement of the data access provisions of paragraph (b)(9) of this section, a security-based swap data repository shall inform the Commission upon its receipt of the first request for security-based swap data from a particular entity (which may include any request to be provided ongoing online or electronic access to the data), and the repository shall maintain records of all information related to the initial and all subsequent requests for data access from that entity, including records of all instances of online or electronic access, and records of all data provided in connection with such requests or access.

* * * * *

By the Commission.

Dated: September 4, 2015.

Brent J. Fields,

Secretary.

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FEDERAL REGISTER

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Part III

The President

Proclamation 9317—World Suicide Prevention Day, 2015

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Title 3—

The President

Proclamation 9317 of September 9, 2015

World Suicide Prevention Day, 2015

By the President of the United States of America

A Proclamation

All people deserve the opportunity to live healthy, rewarding lives. No American should have their potential limited, have their life cut short, or be deprived of their fullest measure of happiness because they do not have the mental health support they need. On World Suicide Prevention Day, we reaffirm our belief that mental health is an essential part of overall health, and together, we renew our commitment to supporting and empowering all Americans to seek the care they need.

Suicide is often related to serious depression, substance use disorders, and other mental health conditions. That is why recognizing severe psychological distress and ensuring access to the care and services needed to diagnose and treat mental illness are crucial to our efforts to prevent suicide. Individuals can also experience emotional and mental health crises in response to a wide range of situations—from difficulties in personal relationships to the loss of a job to bullying at school. And for some of our Nation's veterans and military service members, these challenges are compounded by the invisible wounds of war. Tragically, these crises can sometimes involve thoughts of suicide—and we must do more to support those suffering.

All Americans can take part in promoting mental well-being and preventing suicide. Everyone can contribute to a culture where individuals are supported and accepted for who they are—no matter what they look like, who they love, or what challenges they face—and where it is okay to ask for help.

We can do more to recognize the signs of mental health issues early and encourage those in need to reach out for support. And we must remind our loved ones that seeking treatment is not a sign of weakness; it is a sign of strength. If you or someone you know is in need of help, the National Suicide Prevention Lifeline offers immediate assistance for all Americans at 1–800–273–TALK. Veterans, service members, and their loved ones can call this number to reach the Veterans Crisis Line, and they can also send a text message to 838255.

The Affordable Care Act extends mental health and substance use disorder benefits and parity protections to over 60 million Americans, helping men and women across our country access critical care. Protections under the health care law prohibit insurers from denying coverage because of pre-existing conditions, like a diagnosis of mental illness, and require most insurance plans to cover recommended preventive services without copays, including behavioral assessments for children and depression screenings.

In February, I was proud to sign the Clay Hunt Suicide Prevention for American Veterans Act to help fill serious gaps in serving veterans with post-traumatic stress and other illnesses. This law builds upon our ongoing efforts to end the tragedy of suicide among our troops and veterans. Last year, I announced 19 Executive actions to make it easier for service members and veterans to access the care they need when they need it, and our Government has focused additional resources on mental health services, including increasing the number of mental health providers at the Department of Veterans Affairs.

My Administration is also committed to doing all we can to empower those facing challenges and hardship. We are dedicated to combating bullying, harassment, and discrimination in our schools and communities. We are doing more to guarantee all veterans and members of our Armed Forces—as well as their families—get the help they deserve while they are serving our Nation, as they transition to civilian life, and long after they have returned home. And across the Federal Government, we are working to ensure all Americans are supported in times of crisis.

Suicide prevention is the responsibility of all people. One small act—the decision to reach out to your neighbor, offer support to a friend, or encourage a veteran in need to seek help—can make a difference. It can help energize a national conversation and a changing attitude across America. If you are hurting, know this: You are not forgotten. You are never alone. Your country is here for you, and help is available. As we pause to raise awareness of the importance of suicide prevention, let us remember all those we have lost and the loved ones they left behind. As one people, we stand with all who struggle with mental illness, and we continue our work to prevent this heartbreak in our communities.

NOW, THEREFORE, I, BARACK OBAMA, President of the United States of America, by virtue of the authority vested in me by the Constitution and the laws of the United States, do hereby proclaim September 10, 2015, as World Suicide Prevention Day. I call upon citizens, government agencies, organizations, health care providers, and research institutions to raise awareness of the mental health resources and support services available in their communities and encourage all those in need to seek the care and treatment necessary for a long and healthy life.

IN WITNESS WHEREOF, I have hereunto set my hand this ninth day of September, in the year of our Lord two thousand fifteen, and of the Independence of the United States of America the two hundred and fortieth.

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LIST OF PUBLIC LAWS

Note: No public bills which have become law were received by the Office of the Federal Register for inclusion in today's **List of Public Laws.**

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service-connected disability, the Director of the Compensation Service or his or her delegatee, upon field station submission, is authorized to approve on the basis of the criteria set forth in this paragraph (b), an extra-schedular evaluation commensurate with the actual impairment of earning capacity due exclusively to the referred disability. The governing norm in these exceptional cases is a finding by the Director of the Compensation Service or delegatee that application of the regular schedular standards is impractical because the referred disability is so exceptional or unusual due to such related factors as marked interference with employment or frequent periods of hospitalization.

* * * * *

(Authority: 38 U.S.C. 501(a), 1155)

[FR Doc. 2016–08937 Filed 4–19–16; 8:45 am]

BILLING CODE 8320–01–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[EPA–R01–OAR–2015–0243; A–1–FRL–9945–11–Region 1]

Air Plan Approval; Vermont; Stage I Vapor Recovery Requirements

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) is proposing to approve a State Implementation Plan (SIP) revision submitted by the State of Vermont. This revision includes regulatory amendments that clarify Stage I vapor recovery requirements at gasoline dispensing facilities (GDFs). The intended effect of this action is to approve Vermont's revised Stage I vapor recovery regulations. This action is being taken in accordance with the Clean Air Act.

DATES: Written comments must be received on or before May 20, 2016.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–R01–OAR–2015–0243 at *http://www.regulations.gov,* or via email to *Arnold.Anne@epa.gov.* For comments submitted at Regulations.gov, follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from Regulations.gov. For either manner of submission, the EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.* on the web, cloud, or other file sharing system). For additional submission methods, please contact the person identified in the **FOR FURTHER INFORMATION CONTACT** section. For the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *http://www2.epa.gov/dockets/commenting-epa-dockets.*

FOR FURTHER INFORMATION CONTACT: Ariel Garcia, Air Quality Planning Unit, U.S. Environmental Protection Agency, EPA New England Regional Office, 5 Post Office Square, Suite 100 (mail code: OEP05–2), Boston, MA 02109–3912, telephone number (617) 918–1660, fax number (617) 918–0660, email *garcia.ariel@epa.gov.*

SUPPLEMENTARY INFORMATION: In the Final Rules Section of this **Federal Register**, EPA is approving the State's SIP submittal as a direct final rule without prior proposal because the Agency views this as a noncontroversial submittal and anticipates no adverse comments. A detailed rationale for the approval is set forth in the direct final rule. If no adverse comments are received in response to this action rule, no further activity is contemplated. If EPA receives adverse comments, the direct final rule will be withdrawn and all public comments received will be addressed in a subsequent final rule based on this proposed rule. EPA will not institute a second comment period. Any parties interested in commenting on this action should do so at this time. Please note that if EPA receives adverse comment on an amendment, paragraph, or section of this rule and if that provision may be severed from the remainder of the rule, EPA may adopt as final those provisions of the rule that are not the subject of an adverse comment.

For additional information, see the direct final rule which is located in the Rules Section of this **Federal Register.**

Dated: April 1, 2016.

H. Curtis Spalding,

Regional Administrator, EPA New England.

[FR Doc. 2016–09067 Filed 4–19–16; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[EPA–R06–OAR–2014–0821; FRL–9945–10–Region 6]

Approval and Promulgation of Implementation Plans; Louisiana; Revisions to the New Source Review State Implementation Plan; Air Permit Procedure Revisions

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) is proposing approval of portions of ten revisions to the Louisiana New Source Review (NSR) State Implementation Plan (SIP) submitted by the Louisiana Department of Environmental Quality (LDEQ). These revisions to the Louisiana SIP provide updates to the minor NSR and nonattainment new source review (NNSR) permit programs in Louisiana contained within the Chapter 5 Permit Procedures and Chapter 6 Regulations on Control of Emissions through the Use of Emission Reduction Credits (ERC) Banking rules as initially submitted on November 15, 1993, and the subsequent rule amendments for Air Permit Procedure revisions submitted through November 3, 2014. The EPA's final action will incorporate these rules into the federally approved SIP. The rules generally enhance the SIP and were evaluated in accordance with CAA guidelines for the EPA action on SIP submittals and general rulemaking authority. This proposed action is consistent with the requirements of section 110 of the CAA.

DATES: Written comments must be received on or before May 20, 2016.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–R06–OAR–2014–0821, at *http://www.regulations.gov* or via email to *kordzi.stephanie@epa.gov.* Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from Regulations.gov. The EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not

consider comments or comment contents located outside of the primary submission (*i.e.* on the web, cloud, or other file sharing system). For additional submission methods, please contact Stephanie Kordzi, 214–665–7520, *kordzi.stephanie@epa.gov.* For the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *http://www2.epa.gov/dockets/commenting-epa-dockets.*

Docket: The index to the docket for this action is available electronically at *www.regulations.gov* and in hard copy at the EPA Region 6, 1445 Ross Avenue, Suite 700, Dallas, Texas. While all documents in the docket are listed in the index, some information may be publicly available only at the hard copy location (*e.g.,* copyrighted material), and some may not be publicly available at either location (*e.g.,* CBI).

FOR FURTHER INFORMATION CONTACT: Stephanie Kordzi, telephone (214) 665–7520, *kordzi.stephanie@epa.gov.* To inspect the hard copy materials, please schedule an appointment with Stephanie Kordzi at 214–665–7520 or Mr. Bill Deese at 214–665–7253.

SUPPLEMENTARY INFORMATION: Throughout this document whenever "we," "us," or "our" is used, we mean the EPA.

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I. Summary of State SIP Submittals for Chapter 5 and Chapter 6 Air Permit Program

The EPA is proposing approval of the SIP revisions submitted by the State of Louisiana. The proposed revisions modify Louisiana's minor NSR and NNSR Chapters 5 Permit Procedure and Chapter 6 Regulations on Control of Emissions through the Use of Emission Reduction Credits (ERC) Banking rules enacted at Louisiana Administrative Code (LAC) 33:III.501, 502, 503, 504, 511, 513.A.2., 513.A.3, 513.A.4., 513.A.5., 513.A.6., 513.B., 513.C., 515, 517, 519.A., 519.B., 521, 523, 525, 527, 529, 601, 603, 605, 607, 615, and 619. The revisions provide clarity to the rules, correct contradictory language, update permit application and fee requirements, revise the rules to conform to the latest Louisiana laws, and add to the "Insignificant Activities List".

A. November 15, 1993, Submittal

On November 15, 1993, the LDEQ submitted revisions to the SIP. This SIP submittal incorporated revisions to the Louisiana Administrative Code (LAC) during the year 1993. It includes final revised regulation enacted at LAC 33:III, sections 501, 502, 503, 504, 505, 507, 511, 513, 515, 517, 519, 521, 523, 525, 527, 529, and 533. The EPA is proposing to take action on sections 501, 502, 503, 511, 513, 515, 517, 519, 523, 525, 527, and 529. The EPA already approved section 504 (NNSR Procedures) into the SIP on October 10, 1997, 62 FR 52948. The 504 rules were then subsumed into later SIP approval revisions. The EPA returned sections 505, 507, and 533 due to their association with the Title V operating permit program requirements to the LDEQ on August 4, 2015. The EPA is not taking action and severing section 513.A.1 (which references section 531), section 519.C. (which references section 531), and section 531 regarding public notice. Those specific sections will be addressed in a separate action. The EPA is not taking action and is severing section 501.B.1.d. at this time.

B. November 10, 1994, Submittal

On November 10, 1994, the LDEQ submitted revisions to the SIP. This SIP submittal incorporated revisions to the LAC published in the Louisiana Register on November 20, 1994. It includes final revised regulations enacted at LAC 33:III, sections 501, 507, 517, 521, 527, and 533. The EPA is proposing to take action on sections 501, 517, 521, and 527. The EPA returned sections 507 and 533 due to their association with the title V operating permit program requirements to LDEQ on August 4, 2015.

C. July 25, 1997, Submittal

On July 25, 1997, the LDEQ submitted the 1996 General revisions to the SIP. This SIP submittal incorporated revisions to LAC 33:III, sections 501, 504, 509, and 517 adopted during 1996. The EPA is proposing action on section 517. The EPA already approved sections 501, 504 and 509 on November 5, 2015 (80 FR 68451). Section 504 was approved in 1997 as noted above and revisions have been subsumed into the SIP since the EPA's last action approving changes to the 504 rules on September 30, 2002 (67 FR 61260).

D. June 22, 1998, Submittal

On June 22, 1998, the LDEQ submitted the 1997 General revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the year 1997 and revisions to the LAC not previously federally approved. It includes final revised regulation at LAC 33:III, sections 501, 509, and 517. The EPA is proposing action on sections 501 and 517. The EPA already approved section 509 on November 5, 2015 (80 FR 68451).

E. June 27, 2003, Submittal

On June 27, 2003, the LDEQ submitted the 2002 General revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the year 2002. It includes final revised regulation LAC 33:III, section 501 covering the insignificant activities list. The EPA is proposing action on section 501.

F. May 5, 2006, Submittal

On May 5, 2006, the LDEQ submitted the 2005 General revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the year 2005 and revisions to the LAC not previously federally approved. It includes final revised regulation sections LAC 33:III.501, 504, 505, 507, 509, 517, and 521. The EPA is proposing action on sections 501, 517, and 521. Since the last approval of section 504 in 2002, the EPA approved changes to section 504 as well as section 509 on November 5, 2015 (80 FR 68451). The EPA returned to LDEQ sections 505 and 507.C.3. due to their association with the title V operating permit program requirements on August 4, 2015. The EPA returned to LDEQ sections 507.H.4 and 507.H.5.d. due to their association with the title V operating permit program requirements on February 2, 2016.

G. November 9, 2007, Submittal

On November 9, 2007, the LDEQ submitted the 2006 General revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the year 2006 and revisions to the LAC not previously federally approved. It includes final revised regulation sections at LAC 33:III.501, 504, 509,

513, 531, and 607. The EPA is proposing action on sections 513.A.2. and 513.A.6. The EPA already approved sections 501, 504, 509, and 607 on November 5, 2015 (80 FR 68451). The EPA is not taking action and severing section 513.A.1. (which references section 531) and section 531 regarding public notice. Those specific sections will be addressed in a separate action.

H. August 14, 2009, Submittal

On August 14, 2009, the LDEQ submitted the 2007 General revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the year 2007 and includes revisions to the LAC not previously federally approved. It includes final revised regulation sections LAC 33:III.501, 504, 505, 506, and 507 contained in Chapter 5. It also includes final revised regulation sections LAC 33:III.603, 605, 607, 613, and 615 contained in Chapter 6. The EPA is proposing action on section 501. The EPA already approved sections 504, 603, 605, 607, 613, and 615 on November 5, 2015 (80 FR 68451). The EPA already approved section 506 on April 17, 2014, (79 FR 21631). The EPA returned section 505 to LDEQ on February 2, 2016, because it addresses the Acid Rain Program Permitting Requirements, which are implemented in the title V program rather than the SIP. The EPA returned section 507 to LDEQ on February 2, 2016, because it concerns the title V program which is not part of a SIP.

I. August 29, 2013, Submittal

On August 29, 2013, the LDEQ submitted the 2008–2010 Volatile Organic Compounds Rule SIP Revision. This SIP submittal incorporated revisions to the LAC during the years 2008–2010 and includes revisions to final revised regulation section LAC 33:III.523. The EPA is proposing action on section 523.

J. November 3, 2014, Submittal

On November 3, 2014, the LDEQ submitted the 2011–2013 Permit Rule revisions to the SIP. This SIP submittal incorporated revisions to the LAC during the years 2011–2012. It includes final revised regulation sections LAC 33:III.211, 223, 317, 319, 501, 502, 503, 504, 523, 537, 601, 603, 605, 607, 615, 619, and 2132. The EPA is proposing action on sections 501, 502, 503, 504, 523, 601, 603, 605, 607, 615, and 619. The LDEQ withdrew sections 211 and 223 from SIP consideration by letter on December 2, 2015. The EPA is not acting on sections 317, 319, and 2132 because this action only addresses Chapters 5 and 6. The EPA is not taking action on section 537 (AQ286) and revised citation 501.B.2.d.i.(a) (AQ270) because the original 2008–2010 rule revision containing these sections was never submitted to the EPA. The EPA is not taking action and is severing section 501.B.1.d. at this time.

Table 1 below summarizes the changes that are in the SIP revision submittals. A summary of the EPA's evaluation of each section and the basis for our proposed approval is included in this rulemaking. The accompanying Technical Support Document (TSD) includes a detailed evaluation of the submittals and our rationale. The TSD may be accessed online at *www.regulations.gov,* Docket No. EPA–R06–OAR–2014–0821.

TABLE 1—SUMMARY OF EACH NSR SIP SUBMITTAL AFFECTED BY THIS ACTION

Title of SIP submittal	Date submitted to EPA	Date of state adoption	Regulations affected
Air Permit Procedure Revisions	11/15/1993	1993	Sections 501, 502, 503, 511, 513, 515, 517, 519.A., 519.B., 521, 523, 525, 527, and 529.
Air Permit Procedure Revisions	11/10/1994	11/20/1994	Sections 501, 517, 521, and 527.
Air Permit Procedure Revisions	7/25/1997	1996	Section 517.
Air Permit Procedure Revisions	6/22/1998	1997	Sections 501 and 517.
Air Permit Procedure Revisions	6/27/2003	2002	Section 501.
Air Permit Procedure and ERC Banking Revisions	5/5/2006	2005	Sections 501, 517, and 521.
Air Permit Procedure and ERC Banking Revisions	11/9/2007	2006	Section 513.
Air Permit Procedure Revisions	8/14/2009	2007	Section 501.
2008–2010 Volatile Organic Compounds Rule	8/29/2013	9/20/2008	Section 523.
2011–2013 Permit Rule SIP Revision	11/3/2014	2011	Sections 501, 502, 503, 504, 523, 601, 603, 605, 615, and 619.

II. Evaluation

A. Revisions to the NSR Air Permit Procedures

We evaluated the SIP submissions and are proposing approval of the Louisiana Permit Procedures Revisions and ERC Banking Provisions, as identified, beginning with the November 15, 1993, through the November 3, 2014, submissions. The Act at section 110(a)(2)(C) requires states to develop and submit to the EPA for approval into the SIP, preconstruction review programs applicable to new and modified stationary sources of air pollutants for attainment and nonattainment areas that cover both major and minor new sources and modifications, collectively referred to as the NSR SIP. The CAA NSR SIP program is composed of three separate programs: Prevention of Significant Deterioration (PSD), NNSR, and Minor NSR. PSD is established in part C of title I of the CAA and applies in areas that meet the National Ambient Air Quality Standards (NAAQS), *i.e.,* "attainment areas", as well as areas where there is insufficient information to determine if the area meets the NAAQS, *i.e.,* "unclassifiable areas." The NNSR SIP program is established in part D of title I of the CAA and applies in areas that are not in attainment of the NAAQS, *i.e.,* "nonattainment areas." The Minor NSR SIP program addresses construction or modification activities that do not emit, or have the potential to emit, beyond certain major source thresholds and thus do not qualify as "major" and applies regardless of the designation of the area in which a source is located. This particular SIP action will address the minor NSR and NNSR permitting programs.

The EPA regulations governing the criteria that states must satisfy for the EPA approval of the NSR programs as part of the SIP are contained in 40 CFR 51.160–51.166. However, the PSD rules are not being evaluated in this action and therefore 40 CFR 51.166 does not provide a basis for a decision in this proposal. In addition, there are several provisions in 40 CFR part 51 that apply generally to all SIP revisions. As stated

above, 40 CFR 51.160 establishes the enforceable procedures that all NSR programs must include. 40 CFR 51.160–51.164 require that a SIP revision demonstrate that the adopted rules will not interfere with any applicable requirement concerning attainment and reasonable further progress, or any other applicable requirement of the CAA. Based upon our evaluation of the submittals, the EPA has concluded that the submittals as ultimately revised meet the requirements of the CAA section 110(a).

Our evaluation found that May 20, 2012 and November 20, 2012 adopted revisions to the NNSR program, submitted on November 3, 2014 revised the program to address all nonattainment area pollutants and was necessary to ensure the Louisiana NNSR offset bank is able to be used in future instances where the State is designated nonattainment for other criteria pollutants. Prior to this action, the EPA proposed full approval of the major PSD and NNSR permitting program update, (80 FR 50240), specifically those NNSR requirements submitted prior to November 3, 2014. That action was finalized on November 5, 2015 (80 FR 68451).

Our evaluation of the proposed minor NSR revisions found the proposed revisions address requirements that enhance the SIP. These changes (1) define insignificant activities that will not require permitting; (2) correct contradictory language in the insignificant activities list; (3) provide edits to the Permit Procedure Rule as requested by the EPA; (4) include procedures for incorporating test results; (5) unify and streamline name and ownership changes for all media; and (6) revise references to various LDEQ divisions. All of these changes will help to ensure that the LA Minor NSR rules to meet the CAA requirements.

B. Does the proposed approval of the Louisiana minor and nonattainment NSR Air Permit procedure revisions interfere with attainment, reasonable further progress, or any other applicable requirement of the Act?

We have determined that the regulations submitted to the EPA for approval as SIP revisions meet the requirements of CAA section 110(l). The EPA's conclusion is based upon a line-by-line comparison of the proposed revisions with the federal requirements. The goal is to demonstrate that the proposed revisions will not interfere with the attainment of the NAAQS, Rate of Progress, RFP or any other applicable requirement of the CAA.

The EPA prepared a CAA section 110(l) analysis in its review of the proposed list to serve as a basis for demonstrating noninterference for the affected pollutants for any applicable requirement for attainment and reasonable further progress such as: (1) Turning a maintenance area back into a nonattainment area; (2) turning an attainment/unclassifiable area into a nonattainment area; (3) leading to a PSD increment exceedance; (4) causing the nonattainment area to have higher violations; or (5) causing a nonattainment area to have a greater number of NAAQS standard exceedances. This evaluation is contained in the individual tables for each regulatory section and is found in Section IV Conclusion of the TSD. The TSD can be found in the docket for this action. The comparison demonstrates that the changes made to the Louisiana rules reflect either the same regulatory language, or are consistent with the requirements found in the federal rules. Further, the Additional Comments to the table contained in section IV for the proposed revisions to section 501 in the TSD contain supporting technical documentation establishing in detail a CAA section 110(l) analysis regarding the tables of Insignificant Activities defined in section 501. Specifically, the Section 501.B.3, Insignificant Activities list, submitted on 5/5/2006, revised the former submittal 11/10/1994, which was then subsumed by the 6/27/2003 submittal.

Our finding is based in part on the historic trends of ambient air quality for the NAAQS pollutants, including ozone and sulfur dioxide (SO_2), since those pollutants have caused past air quality issues.[1] The EPA took into consideration the following factors when making the decision to propose approval into the SIP of the permit exemptions listed in the Insignificant Activities tables in section 501:

- Compliance with the 8-hour ozone standard has improved state-wide with ozone pollutant concentrations trending downward with an average 23% decrease in ozone since the late 1980's. This average decrease represents air monitoring values in the Louisiana cities of Baton Rouge, Lake Charles, Monroe, New Orleans, and Point Coupee Parish. 8-Hour ozone trends are listed in the table below:

LA cities	8-Hour ozone (ppb) 1986	8-Hour ozone (ppb) 2015	Reduction (%)
Baton Rouge	98	71	28
Lake Charles (Calcasieu Parish)	92	67	27
Monroe	73	61	16
New Orleans	89	70	22
Pointe Coupe Parish	85	67	21

- The Baton Rouge marginal ozone nonattainment area is currently monitoring attainment for the 2008 ozone NAAQS. The 8-Hour ozone values have dropped from 83 ppb in 2006–2008 down to 71 ppb design value for 2015 in Baton Rouge.
- Compliance with the SO_2 standard has improved significantly state-wide with SO_2 pollutant concentrations trending downward with an average 55% decrease in SO_2 since the mid 2000's. This average value represents the Louisiana air monitoring locations of Baton Rouge, Lake Charles, Chalmette, Port Allen, Shreveport, and Meraux. SO_2 trends are listed in the table below:

[1] Supporting documentation is contained in the monitoring data of ambient air quality for NAAQS criteria for cities located throughout Louisiana. See *http://www.deq.louisiana.gov/portal/DIVISIONS/Assessment/AirFieldServices/AmbientAirMonitoringProgram/AmbientAirMonitoringDataandReports.aspx.*

LA cities	SO_2 (ppb) 2007	SO_2 (ppb) 2013	Reduction (%)
Shreveport	21	12	43
Lake Charles	42	32	24
Baton Rouge	65	19	71
Meraux	32	19	41
Chalmette	331	112	66
Port Allen	143	23	84

• The EPA determined the St. Bernard 2010 SO_2 NAAQS nonattainment area was caused primarily by one large source of SO_2 emissions, the Rain CII Carbon LLC—Chalmette Coke Plant. The LDEQ is currently preparing a proposed SIP attainment demonstration, "*St. Bernard Parish SO_2 Nonattainment Area Louisiana SIP Revision,*" which was submitted to the EPA on April 1, 2015, for review. The EPA provided comments and is working with the LDEQ to ensure the SIP revision contains the appropriate emission limits to bring the area into attainment status. The St. Bernard SO_2 nonattainment area has documented SO_2 pollutant concentrations decreasing from a 331 ppm SO_2 design value in 2009 down to a 159 ppm SO_2 design value in 2014.

• Compliance with the Particulate Matter (PM_{10}) standard is maintained and is below regulatory NAAQS levels. PM_{10} emission concentrations have trended downward an average 25% statewide since the mid 2000's. The average statewide 24-hour PM_{10} concentration is 28 ug/m^3 which is 19% of the NAAQS level for PM_{10}. The average value represents the Louisiana air monitoring locations of Baton Rouge, New Orleans, Chalmette, Shreveport, and Lafayette.

• Compliance with the average statewide annual $PM_{2.5}$ standards is maintained with an average annual maximum concentration of 10.8 ug/m^3, which is below the average annual primary standard for $PM_{2.5}$ of 12 ug/m^3.

• The Baton Rouge Capitol air monitor is the only monitor collecting samples and analyzing for Carbon Monoxide (CO). The 2014 annual average CO value was 0.26 ppm and the maximum monitored value was 5.34 ppm which is below the 9 ppm standard (8 hour averaging time).

Since the list of exempted sources included in the proposed revisions have historically operated without coverage by an air permit and there are no anticipated increases in emissions or in the number of these type of sources resulting from the approval of the exempted list into the SIP, the EPA has determined the possibility of a low level of potential impacts on ambient air quality as a result of the emission sources and activities included in the proposed LAC 33:III section 501 exemptions list and this conclusion is supported by ambient air monitoring trends in the State of Louisiana.

Our determination is consistent with our assessment of the environmental insignificance of these emissions. In addition, the LDEQ has been carrying out the minor NSR air permitting program based on the codification of their permitting policy without any indication that these permit exempted sources have interfered with attainment or reasonable further progress or increased PSD increment. Therefore, the EPA proposes to approve the exemptions lists in section 501 into the Louisiana SIP.

Based on supporting air quality monitoring data documenting air quality improvements throughout the State, the EPA proposes to approve Section 501 containing the list of the exempted sources into the Louisiana SIP since it meets the requirements of CAA section 110(l) and since state agencies are provided the latitude to define the types and sizes of facilities, buildings, structures, or installations subject to review in accordance with 40 CFR 51.160(e). We believe the implementation of this rule will not interfere with any applicable requirement concerning attainment and reasonable further progress, maintaining PSD increment, or any other applicable requirement of the CAA.

III. Proposed Action

The EPA proposes approval of the identified sections of the revisions to the air permitting procedures as submitted as revisions to the Louisiana NSR SIP Permit program on November 15, 1993, November 10, 1994, July 25, 1997, June 22, 1998, June 27, 2003, May 5, 2006, November 9, 2007, August 14, 2009, August 29, 2013, and November 3, 2014, submittals. The EPA has made the determination in accordance with the CAA and the EPA regulations at 40 CFR 51.160–51.165. Therefore, under section 110 and part C of the Act, and for the reasons presented above and in our accompanying TSD, the EPA proposes approval of the revisions to the Louisiana SIP identified in Table 2 below which summarizes each regulatory citation that is affected by this action.

TABLE 2—SUMMARY OF EACH REGULATION THAT IS AFFECTED BY THIS ACTION

Section	Date submitted to EPA as SIP amendment	Affected regulation
Section 501—Scope and Applicability		
Section 501.A	11/15/1993	Sections 501.A.1. and A.2.
Section 501.B	11/15/1993	Sections 501.B.1.a., B.1.b., B.1.c., B.2., B.3., B.4., B.5., B.6., and B.7.
	11/10/1994	Sections 501.B.5.A and 501.B.5.B.
	6/22/1998	Sections 501.B.3.c. and 501.B.3.d.
	6/27/2003	Section 501.B.5.
	5/5/2006	Sections 501.B.5, 501.B.32, and 501.D.a.–d.
	11/3/2014	Sections 501.B.1.c., 501.B.1.e., 501.B.4.a.i., 501.B.5. Table 1, and 501.B.8.
Section 501.C	11/15/1993	Sections 501.C.1., C.2., C.3., C.4., C.5., C.6., C.7., C.8., and C.9.
	5/5/2006	Section 501.C.1.
	11/9/2007	Sections 501.C.11., C.12., and C.13.

TABLE 2—SUMMARY OF EACH REGULATION THAT IS AFFECTED BY THIS ACTION—Continued

Section	Date submitted to EPA as SIP amendment	Affected regulation
	8/14/2009	Section 501.C.1.
Section 502—Definitions		
Section 502	11/15/1993	Section 502 Definitions—*Clean Air Act, EPA, Final Permit, Fugitive Emissions, Permit Revision, Permit Renewal, Permitting Authority, Potential to Emit, Proposed Permit, Stationary Source.*
		Portions of definitions as outlined in Technical Support Document for: Emissions Unit, Regulated Air Pollutant, Responsible Official, and title I Modification.
	11/3/2014	Section 502.A. Definitions—*Nonroad Engine.*
Section 503—Minor Source Permit Requirements		
Section 503.A	11/15/1993	Section 503.A.
Section 503.B	11/15/1993	Sections 503.B., 503.B.1., 503.B.2., and 503.B.3.
	11/3/2014	Section 503.B.2.
Section 504—Nonattainment New Source Review (NNSR) Procedures and Offset Requirements in Specified Parishes		
504.A	11/3/2014	Sections 504.A.2., 504.A.3., and 504.A.4.
504.D	11/3/2014	Section 504.D.5.
504.F	11/3/2014	Sections 504.F.1., 504.F.2.
504.M	11/3/2014	Sections 504.M.., 504.M.1, 504.M.2.a.–c., 504.M.3., and 504.M.4.
Section 511—Emission Reductions		
Section 511	11/15/1993	Section 511.
Section 513—General Permits, Temporary Sources, and Relocation of Portable Facilities		
Section 513.A	11/15/1993	Sections 513.A.2., 513.A.3., 513.A.4., and 513.A.5.
	11/9/2007	Sections 513.A.2., 513.A.6.
Section 513.B	11/15/1993	Sections 513.B.1., B.2., B.3., and B.4.
Section 513.C	11/15/1993	Sections 513.C.1., 513.C.2., and 513.C.3.
Section 515—Oil and Gas Wells and Pipelines Permitting Provisions		
Section 515	11/15/1993	Section 515.
Section 515.A	11/15/1993	Sections 515.A.1., 515.A.2, 515.A.3., 515.A.4., 515.A.5.
Section 515.B	11/15/1993	Sections 515.B.1., 515.B.2.
Section 517—Permit Applications and Submittal of Information		
Section 517.A	11/15/1993	Sections 517.A., 517.A.1., 517.A.2., 517.A.3.
	6/22/1998	Section 517.A.3.
Section 517.B	11/15/1993	Sections 517.B., 517.B.1., 517.B.2., and 517.B.3.
Section 517.C	11/15/1993	Section 517.C.
Section 517.D	11/15/1993	Sections 517.D., 517.D.1, 517.D.2., 517.D.3., 517.D.4., 517.D.5., 517.D.6., 517.D.7., 517.D.8., 517.D.9., 517.D.10., 517.D.11., 517.D.12., 517.D.13., 517.D.14., 517.D.15., 517.D.16., 517.D.17., and 517.D.18.
Section 517.E	11/15/1993	Sections 517.E., 517.E.1., 517.E.2., 517.E.3., 517.E.4., 517.E.5., 517.E.6., 517.E.7., and 517.E.8.
Section 517.F	11/15/1993	Sections 517.F., 517.F.1., 517.F.2., 517.F.3., 517.F.4., 517.F.5., 517.F.6., 517.F.7., and 517.F.8.
	11/10/1994	Section 517.F.1.
	7/25/1997	Section 517.F.
Section 517.G	11/15/1993	Section 517.G.
	5/5/06	Section 517.G.
Section 519—Permit Issuance Procedures for New Facilities, Initial Permits, Renewals and Significant Modifications		
Section 519.A	11/15/1993	Sections 519.A., 519.A.1., 519.A.2., 519.A.3., and 519.A.4.
Section 519.B	11/15/1993	Sections 519.B., 519.B.1., and 519.B.2.
Section 521—Administrative Amendments		
Section 521.A	5/5/06	Section 521.A.3.
	11/10/1994	Section 521.A.6.

TABLE 2—SUMMARY OF EACH REGULATION THAT IS AFFECTED BY THIS ACTION—Continued

Section	Date submitted to EPA as SIP amendment	Affected regulation
Section 523—Procedures for Incorporating Test Results		
Section 523.A	11/15/1993	Sections 523.A.1. and A.2.
	11/3/2014	Section 523.A.1.b.
Section 523.B	11/15/1993	Sections 523.B.1., B.2., B.3., and B.4.
	8/29/2013	Sections 523.B.3., 523.B.4., and 523.B.5.
Section 525—Minor Modifications		
Section 525.A	11/15/1993	Sections 525.A., 525.A.1., 525.A.2., and 525.A.3.
Section 525.B	11/15/1993	Sections 525.B., 525.B.1., and 525.B.2.
Section 527—Significant Modifications		
Section 527.A	11/15/1993	Sections 527.A., 527.A.1., 527.A.2., and 527.A.3.
	11/10/1994	Sections 527.A.2., 527.A.2.c.
Section 527.B	11/15/1993	Sections 527.B., 527.B.1., 527.B.2., 527.B.3., 527.B.4., and 527.B.5.
	11/10/1994	Section 527.B.
Section 529—Reopenings for Cause		
Section 529.A	11/15/1993	Sections 529.A., 529.A.1., and 529.A.2.
Section 529.B	11/15/1993	Sections 529.B., 529.B.1., 529.B.2., 529.B.3., and 529.B.4.
Section 601—Purpose		
Section 601.A	11/3/2014	Section 601.A.
Section 603—Applicability		
Section 603.A	11/3/2014	Section 603.A.
Section 603.B	11/3/2014	Section 603.B.
Section 605—Definitions		
Section 605.A	11/3/2014	Section 605.A. Definitions—*Bankable Emission Reductions and Offset,* Repealed Definitions—*Base Case Inventory, Base Line Inventory, Current Total Point-Source Emissions Inventory, Modeled Parishes.*
Section 607—Determination of Creditable Emission Reductions		
Section 607.C	11/3/2014	Sections 607.C., 607.C.1., and 607.C.4.
Section 615—Schedule for Submitting Applications		
Section 615.B	11/3/2014	Section 615.B.
Section 619—Emission Reduction Credit Bank		
Section 619.A	11/3/2014	Section 619.A.

IV. Incorporation by Reference

In this action, we are proposing to include in a final rule regulatory text that includes incorporation by reference. In accordance with the requirements of 1 CFR 51.5, we are proposing to incorporate by reference revisions to the Louisiana regulations as described in the Proposed Action section above. We have made, and will continue to make, these documents generally available electronically through *www.regulations.gov* and/or in hard copy at the EPA Region 6 office.

V. Statutory and Executive Order Reviews

Under the CAA, the Administrator is required to approve a SIP submission that complies with the provisions of the Act and applicable Federal regulations. 42 U.S.C. 7410(k); 40 CFR 52.02(a). Thus, in reviewing SIP submissions, the EPA's role is to approve state choices, provided that they meet the criteria of the CAA. Accordingly, this action merely proposes to approve state law as meeting Federal requirements and does not impose additional requirements beyond those imposed by state law. For that reason, this action:

- Is not a "significant regulatory action" subject to review by the Office of Management and Budget under Executive Orders 12866 (58 FR 51735, October 4, 1993) and 13563 (76 FR 3821, January 21, 2011);
- Does not impose an information collection burden under the provisions of the Paperwork Reduction Act (44 U.S.C. 3501 *et seq.*);
- Is certified as not having a significant economic impact on a substantial number of small entities

under the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*);

- Does not contain any unfunded mandate or significantly or uniquely affect small governments, as described in the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4);
- Does not have Federalism implications as specified in Executive Order 13132 (64 FR 43255, August 10, 1999);
- Is not an economically significant regulatory action based on health or safety risks subject to Executive Order 13045 (62 FR 19885, April 23, 1997);
- Is not a significant regulatory action subject to Executive Order 13211 (66 FR 28355, May 22, 2001);
- Is not subject to requirements of section 12(d) of the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note) because application of those requirements would be inconsistent with the CAA; and
- Does not provide EPA with the discretionary authority to address, as appropriate, disproportionate human health or environmental effects, using practicable and legally permissible methods, under Executive Order 12898 (59 FR 7629, February 16, 1994).

In addition, the SIP is not approved to apply on any Indian reservation land or in any other area where EPA or an Indian tribe has demonstrated that a tribe has jurisdiction. In those areas of Indian country, the proposed rule does not have tribal implications and will not impose substantial direct costs on tribal governments or preempt tribal law as specified by Executive Order 13175 (65 FR 67249, November 9, 2000).

List of Subjects in 40 CFR Part 52

Environmental protection, Air pollution control, Carbon monoxide, Incorporation by reference, Intergovernmental relations, Lead, Nitrogen dioxide, Ozone, Particulate matter, Reporting and recordkeeping requirements, Sulfur oxides, and Volatile organic compounds.

Authority: 42 U.S.C. 7401 *et seq.*

Dated: April 7, 2016.

Ron Curry,

Regional Administrator, Region 6.

[FR Doc. 2016–08927 Filed 4–19–16; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[EPA–HQ–OW–2015–0804; FRL–9945–03–OW]

RIN 2040–AF59

Proposal of Certain Federal Water Quality Standards Applicable to Maine

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) proposes federal Clean Water Act (CWA) water quality standards (WQS) that would apply to certain waters under the state of Maine's jurisdiction. EPA proposes human health criteria (HHC) to protect the sustenance fishing use in those waters in Indian lands and for waters subject to sustenance fishing rights under the Maine Implementing Act (MIA) based on a fish consumption rate that represents an unsuppressed level of fish consumption by the four federally recognized tribes. EPA proposes six additional WQS for waters in Indian lands in Maine, two WQS for all waters in Maine including waters in Indian lands, and one WQS for waters in Maine outside of Indian lands. These proposed WQS take into account the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, to protect human health and aquatic life. EPA proposes these WQS to address various disapprovals of Maine's standards that EPA issued in February, March, and June 2015, and to address the Administrator's determination that Maine's disapproved HHC are not adequate to protect the designated use of sustenance fishing for certain waters.

DATES: Comments must be received on or before June 20, 2016.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA–HQ–OW–2015–0804 at *http://www.regulations.gov*. Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or removed from Regulations.gov. EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.* on the Web, cloud, or other file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit *http://www.epa.gov/dockets/commenting-epa-dockets*. EPA is offering two virtual public hearings so that interested parties may also provide oral comments on this proposed rule. The first hearing will be on Tuesday, June 7, 2016 from 5:00 p.m. to 7:00 p.m. Eastern Daylight Time. The second hearing will be on Thursday, June 9, 2016 from 9:00 a.m. to 11:00 a.m. Eastern Daylight Time. For more details on the public hearings and a link to register, please visit *http://www.epa.gov/wqs-tech/proposed-rule-maine-water-quality-standards*.

FOR FURTHER INFORMATION CONTACT: Jennifer Brundage, Office of Water, Standards and Health Protection Division (4305T), Environmental Protection Agency, 1200 Pennsylvania Avenue NW., Washington, DC 20460; telephone number: (202) 566–1265; email address: *Brundage.jennifer@epa.gov*.

SUPPLEMENTARY INFORMATION: This proposed rule is organized as follows:

I. General Information
  Does this action apply to me?
II. Background
  A. Statutory and Regulatory Background
  B. EPA's Disapprovals of Portions of Maine's Water Quality Standards
  C. Scope of Waters
  D. Applicability of EPA Promulgated Water Quality Standards When Final
III. CWA 303(c)(4)(B) Determination of Necessity for Human Health Criteria That Protect Sustenance Fishing
IV. Proposed Water Quality Standards
  A. Proposed WQS for Waters in Indian Lands in Maine and for Waters Outside of Indian Lands in Maine Where the Sustenance Fishing Designated Use Established by 30 M.R.S. 6207(4) and (9) Applies
  B. Proposed WQS for Waters in Indian Lands in Maine
  C. Proposed WQS for All Waters in Maine
  D. Proposed WQS for Waters in Maine Outside of Indian Lands
V. Economic Analysis
  A. Identifying Affected Entities
  B. Method for Estimating Costs
  C. Results
VI. Statutory and Executive Order Reviews
  A. Executive Order 12866 (Regulatory Planning and Review) and Executive Order 13563 (Improving Regulation and Regulatory Review)
  B. Paperwork Reduction Act

Order 13132 (64 FR 43255, August 10, 1999);

- Is not an economically significant regulatory action based on health or safety risks subject to Executive Order 13045 (62 FR 19885, April 23, 1997);
- Is not a significant regulatory action subject to Executive Order 13211 (66 FR 28355, May 22, 2001);
- Is not subject to requirements of section 12(d) of the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note) because application of those requirements would be inconsistent with the CAA; and
- Does not provide EPA with the discretionary authority to address, as appropriate, disproportionate human health or environmental effects, using practicable and legally permissible methods, under Executive Order 12898 (59 FR 7629, February 16, 1994).

In addition, the SIP is not approved to apply on any Indian reservation land or in any other area where EPA or an Indian tribe has demonstrated that a tribe has jurisdiction. In those areas of Indian country, the rule does not have tribal implications as specified by Executive Order 13175 (65 FR 67249, November 9, 2000), nor will it impose substantial direct costs on tribal governments or preempt tribal law.

The Congressional Review Act, 5 U.S.C. 801 *et seq.*, as added by the Small Business Regulatory Enforcement Fairness Act of 1996, generally provides that before a rule may take effect, the agency promulgating the rule must submit a rule report, which includes a copy of the rule, to each House of the Congress and to the Comptroller General of the United States. EPA will submit a report containing this action and other required information to the U.S. Senate, the U.S. House of Representatives, and the Comptroller General of the United States prior to publication of the rule in the **Federal Register**. A major rule cannot take effect until 60 days after it is published in the **Federal Register**. This action is not a "major rule" as defined by 5 U.S.C. 804(2).

Under section 307(b)(1) of the CAA, petitions for judicial review of this action must be filed in the United States Court of Appeals for the appropriate circuit by January 27, 2017. Filing a petition for reconsideration by the Administrator of this final rule does not affect the finality of this action for the purposes of judicial review nor does it extend the time within which a petition for judicial review may be filed, and shall not postpone the effectiveness of such rule or action. This action may not be challenged later in proceedings to enforce its requirements. *See* section 307(b)(2).

List of Subjects in 40 CFR Part 52

Environmental protection, Air pollution control, Incorporation by reference, Intergovernmental relations, Nitrogen dioxide, Ozone, Reporting and recordkeeping requirements, Volatile organic compounds.

Dated: November 7, 2016.

Heather McTeer Toney,

Regional Administrator, Region 4.

40 CFR part 52 is amended as follows:

PART 52—APPROVAL AND PROMULGATION OF IMPLEMENTATION PLANS

■ 1. The authority citation for part 52 continues to read as follows:

Authority: 42 U.S.C. 7401 *et seq.*

Subpart RR—Tennessee

■ 2. In § 52.2220, the table in paragraph (e) is amended by adding the entry "110(a)(1) and (2) Infrastructure Requirements for the 2010 1-hour SO_2 NAAQS" at the end of the table to read as follows:

§ 52.2220 Identification of plan.

* * * * *

(e) * * *

EPA-APPROVED TENNESSEE NON-REGULATORY PROVISIONS

Name of non-regulatory SIP provision	Applicable geographic or non-attainment area	State effective date	EPA approval date	Explanation
*	*	*	*	*
110 (a)(1) and (2) Infrastructure Requirements for the 2010 1-hour SO_2 NAAQS.	Tennessee	03/13/2014	11/28/16, [insert **Federal Register** citation].	With the exception of interstate transport requirements of section 110(a)(2)(D)(i)(I) and (II) (prongs 1, 2, and 4).

[FR Doc. 2016–28429 Filed 11–25–16; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[EPA–HQ–OW–2015–0174; FRL–9955–40–OW]

RIN 2040–AF56

Revision of Certain Federal Water Quality Criteria Applicable to Washington

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: On September 14, 2015, the Environmental Protection Agency (EPA) proposed revisions to the federal Clean Water Act (CWA) human health criteria applicable to waters under the State of Washington's jurisdiction to ensure that the criteria are set at levels that will adequately protect Washington residents, including tribes with treaty-reserved rights, from exposure to toxic pollutants. EPA promulgated Washington's previous criteria for the protection of human health in 1992 as part of the National Toxics Rule (NTR) (amended in 1999 for Polychlorinated Biphenyls (PCBs)), using the Agency's recommended criteria values at the time. EPA derived those previously applicable criteria using a fish consumption rate (FCR) of 6.5 grams per day (g/day) based on national surveys. The best available data now demonstrate that fish consumers in Washington consume much more fish than 6.5 g/day. There are also new data and scientific information available to update the toxicity and exposure parameters used to calculate human health criteria. On August 1, 2016, the State of Washington adopted and submitted human health criteria for certain pollutants, reflecting some of these new data and information. Concurrent with this final rule, EPA is taking action under CWA 303(c) to approve in part, and disapprove in part, the human health criteria submitted by Washington. For those criteria that EPA disapproved, EPA is finalizing federal human health criteria in this final rule.

EPA is not finalizing criteria in this final rule for those state-adopted criteria that EPA approved, or for certain criteria that EPA has determined involve scientific uncertainty, as explained below.

DATES: This final rule is effective on December 28, 2016.

ADDRESSES: EPA has established a docket for this action under Docket ID No. EPA–HQ–OW–2015–0174. All documents in the docket are listed on the *http://www.regulations.gov* Web site. Although listed in the index, some information is not publicly available, *e.g.,* CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy form. Publicly available docket materials are available electronically through *http://www.regulations.gov.*

FOR FURTHER INFORMATION CONTACT: Erica Fleisig, Office of Water, Standards and Health Protection Division (4305T), Environmental Protection Agency, 1200 Pennsylvania Avenue NW., Washington, DC 20460; telephone number: (202) 566–1057; email address: *fleisig.erica@epa.gov.*

SUPPLEMENTARY INFORMATION: This final rule is organized as follows:

I. General Information
A. Does this action apply to me?
B. How did EPA develop this final rule?
II. Background
A. Statutory and Regulatory Background
B. EPA's CWA 303(c) Action on Washington's Human Health Criteria
C. General Recommended Approach for Deriving Human Health Criteria
III. Derivation of Human Health Criteria for Washington
A. Scope of Pollutants and Waters Covered by This Final Rule
B. Washington's Designated Uses and Tribal Reserved Fishing Rights
C. Washington-Specific Human Health Criteria Inputs
D. Final Human Health Criteria for Washington
E. Applicability of Criteria
F. Alternative Regulatory Approaches and Implementation Mechanisms
IV. Economic Analysis
A. Identifying Affected Entities
B. Method for Estimating Costs
C. Results
V. Statutory and Executive Order Reviews
A. Executive Order 12866 (Regulatory Planning and Review) and Executive Order 13563 (Improving Regulation and Regulatory Review)
B. Paperwork Reduction Act
C. Regulatory Flexibility Act
D. Unfunded Mandates Reform Act
E. Executive Order 13132 (Federalism)
F. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)
G. Executive Order 13045 (Protection of Children From Environmental Health and Safety Risks)
H. Executive Order 13211 (Actions That Significantly Affect Energy Supply, Distribution, or Use)
I. National Technology Transfer and Advancement Act of 1995
J. Executive Order 12898 (Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations)
K. Congressional Review Act (CRA)

I. General Information

A. Does this action apply to me?

Entities such as industries, stormwater management districts, or publicly owned treatment works (POTWs) that discharge pollutants to waters of the United States under the State of Washington's jurisdiction could be indirectly affected by this rulemaking, because federal water quality standards (WQS) promulgated by EPA are applicable to CWA regulatory programs, such as National Pollutant Discharge Elimination System (NPDES) permitting. Citizens concerned with water quality in Washington could also be interested in this rulemaking. Categories and entities that could potentially be affected include the following:

Category	Examples of potentially affected entities
Industry	Industries discharging pollutants to waters of the United States in Washington.
Municipalities	Publicly owned treatment works or other facilities discharging pollutants to waters of the United States in Washington.
Stormwater Management Districts	Entities responsible for managing stormwater runoff in the State of Washington.

This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities that could be indirectly affected by this action. Any parties or entities who depend upon or contribute to the water quality of Washington's waters could be indirectly affected by this rule. To determine whether your facility or activities could be indirectly affected by this action, you should carefully examine this rule. If you have questions regarding the applicability of this action to a particular entity, consult the person listed in the **FOR FURTHER INFORMATION CONTACT** section.

B. How did EPA develop this final rule?

In developing this final rule, EPA carefully considered the public comments and feedback received from interested parties. EPA originally provided a 60-day public comment period after publishing the proposed rule in the **Federal Register** on September 14, 2015.[1] On October 28, 2015, in response to stakeholder requests,[2] EPA extended the public comment period for an additional 45 days.[3] In addition, EPA held two virtual public hearings on December 15th and 16th, 2015, to discuss the contents of the proposed rule and accept verbal public comments.

Over 60 organizations and individuals submitted comments on a range of issues. EPA also received over 400 letters from individuals associated with mass letter writing campaigns. Some comments addressed issues beyond the scope of the rulemaking, and thus EPA did not consider them in finalizing this rule. In each section of this preamble, EPA discusses certain public comments so that the public is aware of the Agency's position. For a full response to these and all other comments, see EPA's Response to Comments document in the official public docket.

II. Background

A. Statutory and Regulatory Background

CWA section 101(a)(2) establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the CWA. EPA

[1] See Revision of Certain Federal Water Quality Criteria Applicable to Washington: Proposed Rule, 80 FR 55063, September 14, 2015.

[2] EPA received requests from the Association of Washington Business—Washington State's Chamber of Commerce, Washington Public Ports Association (on behalf of the Association of Washington Cities and the Washington State Association of Counties), Western Wood Preservers Institute, ALCOA, American Forest and Paper Association, McFarland Cascade, Schnitzer Steel Industries, and Weyerhaeuser.

[3] See Extension of Public Comment Period for the Revision of Certain Federal Water Quality Criteria Applicable to Washington, 80 FR 65980, October 28, 2015.

interprets "fishable" uses to include, at a minimum, designated uses providing for the protection of aquatic communities and human health related to consumption of fish and shellfish.[4]

CWA section 303(c) (33 U.S.C. 1313(c)) directs states to adopt WQS for their waters subject to the CWA. CWA section 303(c)(2)(A) and EPA's implementing regulations at 40 CFR part 131 require, among other things, that a state's WQS specify appropriate designated uses of the waters, and water quality criteria that protect those uses. EPA's regulations at 40 CFR 131.11(a)(1) provide that "[s]uch criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use." In addition, 40 CFR 131.10(b) provides that "[i]n designating uses of a water body and the appropriate criteria for those uses, the state shall take into consideration the water quality standards of downstream waters and ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."

States are required to review applicable WQS at least once every three years and, if appropriate, revise or adopt new standards (CWA section 303(c)(1)). Any new or revised WQS must be submitted to EPA for review and approval or disapproval (CWA section 303(c)(2)(A) and (c)(3)). If EPA disapproves a state's new or revised WQS, the CWA provides the state 90 days to adopt a revised WQS that meets CWA requirements, and if it fails to do so, EPA shall promptly propose and then within 90 days promulgate such standard unless EPA approves a state replacement WQS first (CWA section 303(c)(3) and (c)(4)(A)). CWA section 303(c)(4)(B) authorizes the Administrator to determine that a new or revised standard is needed to meet CWA requirements. Upon making such a determination, the CWA specifies that EPA shall promptly propose, and then within 90 days promulgate, any such new or revised standard unless prior to such promulgation, the state has adopted a revised or new WQS that EPA determines to be in accordance with the CWA.

Under CWA section 304(a), EPA periodically publishes criteria recommendations for states to consider when adopting water quality criteria for particular pollutants to protect the CWA section 101(a)(2) goal uses. In 2015, EPA updated its 304(a) recommended criteria for human health for 94 pollutants.[5] Where EPA has published recommended criteria, states should establish numeric water quality criteria based on EPA's CWA section 304(a) criteria, section 304(a) criteria modified to reflect site-specific conditions, or other scientifically defensible methods (40 CFR 131.11(b)(1)). In all cases criteria must be sufficient to protect the designated use and be based on sound scientific rationale (40 CFR 131.11(a)(1)). CWA section 303(c)(2)(B) requires states to adopt numeric criteria for all toxic pollutants listed pursuant to CWA section 307(a)(1) for which EPA has published 304(a) criteria, as necessary to support the states' designated uses.

In 1992, EPA promulgated the NTR at 40 CFR 131.36, establishing chemical-specific numeric criteria for 85 priority toxic pollutants for 14 states and territories (states), including Washington, that were not in compliance with the requirements of CWA section 303(c)(2)(B). When states covered by the NTR subsequently adopted their own criteria for toxic pollutants that EPA approved as consistent with the CWA and EPA's implementing regulations, EPA amended the NTR to remove those criteria for those states.

B. EPA's CWA 303(c) Action on Washington's Human Health Criteria

On September 14, 2015, EPA made a CWA 303(c)(4)(B) determination that new or revised WQS for the protection of human health in Washington were necessary to meet the requirements of the CWA, and proposed revised human health criteria for the state (see 80 FR 55063). At that time, Washington had not yet adopted its own criteria for the protection of human health.[6] On August 1, 2016, Washington adopted and submitted statewide human health criteria and new and revised implementation provisions. Concurrent with this final rule, EPA approved 45 and disapproved 143 of Washington's human health criteria under CWA 303(c). EPA is finalizing 144 human health criteria in this rule in accordance with CWA section 303(c)(3) and (c)(4) requirements.[7] After the effective date of this final rule, these federal criteria will be in effect for CWA purposes along with the human health criteria that Washington adopted and EPA approved.

Several commenters provided comments on the timing of EPA's rule, and the relationship between EPA's federal rulemaking and the state rulemaking process. These comments are now, for the most part, mooted by EPA's finalization of its federal rule and action on the state's submittal. For additional responses to specific comments, see EPA's Response to Comment document in the docket for this rule.

C. General Recommended Approach for Deriving Human Health Criteria

Human health criteria are designed to minimize the risk of adverse cancer and non-cancer effects occurring from lifetime exposure to pollutants through the ingestion of drinking water and consumption of fish and shellfish obtained from inland and nearshore waters (by nearshore waters, EPA refers to waters out to three miles from the coast). EPA's practice is to establish a human health 304(a) recommended criterion for both drinking water and consumption of fish and shellfish from inland and nearshore waters combined, and a separate human health criterion based only on ingestion of fish and shellfish from inland and nearshore waters. This latter criterion applies in cases where the designated uses of a waterbody include supporting fish and shellfish for human consumption but not drinking water supply sources (*e.g.*, in non-potable estuarine waters).

The criteria are based on two types of biological endpoints: (1) Carcinogenicity and (2) systemic toxicity (*i.e.*, all adverse effects other than cancer). EPA takes an integrated approach and considers both cancer and non-cancer effects when deriving human health criteria. Where sufficient data are available, EPA derives criteria using

[4] USEPA. 2000. Memorandum #WQSP–00–03, U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/sites/production/files/2015-01/documents/standards-shellfish.pdf.*

[5] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[6] Washington adopted criteria for the protection of aquatic life from toxic pollutants at WAC 173–201A–240.

[7] EPA is finalizing a different number of human health criteria (144) than it is disapproving (143) in Washington's 2016 submittal. Washington did not adopt organism-only criteria for methylmercury or water-plus-organism and organism-only criteria for bis(2-chloro-1-methylethyl) ether. These are priority pollutants listed pursuant to CWA section 307(a)(1) for which EPA has 304(a) recommended criteria, and, as such, CWA section 303(c)(2)(B) requires that states adopt numeric criteria for these pollutants, as necessary to support the states' designated uses. Therefore, EPA is including these three criteria in this final rule for Washington. This final rule, however, does not include revised water-plus-organism and organism-only criteria for arsenic, as explained below in section III.A, even though EPA is disapproving the arsenic criteria in Washington's submittal.

both carcinogenic and non-carcinogenic toxicity endpoints and recommends the lower value. Human health criteria for carcinogenic effects are calculated using the following input parameters: Cancer slope factor (CSF), cancer risk level, body weight, drinking water intake rate, fish consumption rate, and a bioaccumulation factor(s). Human health criteria for non-carcinogenic and nonlinear carcinogenic effects are calculated using a reference dose (RfD) in place of a CSF and cancer risk level, and a relative source contribution (RSC) factor, which is intended to ensure that an individual's total exposure to a given pollutant from all sources does not exceed the RfD. Each of these inputs is discussed in more detail below and in EPA's 2000 Human Health Methodology (hereafter referred to as EPA's "2000 Methodology").[8]

a. Cancer Risk Level

EPA's 304(a) national recommended human health criteria are typically based on the assumption that carcinogenicity is a "non-threshold phenomenon," which means that there are no "no-effect" levels, because even extremely small doses are assumed to cause a finite increase in the incidence of cancer. Therefore, EPA calculates 304(a) human health criteria for carcinogenic effects as pollutant concentrations corresponding to lifetime increases in the risk of developing cancer.[9] EPA calculates its 304(a) human health criteria values at a 10^{-6} (one in one million) cancer risk level and recommends cancer risk levels of 10^{-6} or 10^{-5} (one in one hundred thousand) for the general population.[10] EPA notes that states and authorized tribes can also choose a more stringent risk level, such as 10^{-7} (one in ten million), when deriving human health criteria.

If the pollutant is not considered to have the potential for causing cancer in humans (*i.e.*, systemic toxicants), EPA assumes that the pollutant has a threshold (the RfD) below which a physiological mechanism exists to avoid or overcome the adverse effects of the pollutant.

b. Cancer Slope Factor and Reference Dose

A dose-response assessment is required to understand the quantitative relationships between exposure to a pollutant and the onset of human health effects. EPA evaluates dose-response relationships derived from animal toxicity and human epidemiological studies to derive dose-response metrics. For carcinogenic toxicological effects, EPA uses an oral CSF to derive human health criteria. The oral CSF is an upper bound, approximating a 95 percent confidence limit, on the increased cancer risk from a lifetime oral exposure to a stressor. For non-carcinogenic effects, EPA uses the RfD to calculate human health criteria. A RfD is an estimate of a daily oral exposure of an individual to a substance that is likely to be without an appreciable risk of deleterious effects during a lifetime. A RfD is typically derived from a laboratory animal dosing study in which a no-observed-adverse-effect level (NOAEL), lowest-observed-adverse-effect level (LOAEL), or benchmark dose can be obtained. Uncertainty factors are applied to reflect the limitations of the data. EPA's Integrated Risk Information System (IRIS) [11] was the primary source of toxicity values (*i.e.*, RfD and CSF) for EPA's 2015 updated 304(a) human health criteria.[12] For some pollutants, however, more recent peer-reviewed and publicly available toxicological data were available from other EPA program offices (*e.g.*, Office of Pesticide Programs, Office of Water, Office of Land and Emergency Management), other national and international programs, and state programs.

c. Exposure Assumptions

EPA's latest 304(a) national human health criteria use a default drinking water intake rate of 2.4 liters per day (L/day) and default rate of 22 g/day for consumption of fish and shellfish from inland and nearshore waters, multiplied by pollutant-specific bioaccumulation factors (BAFs) to account for the amount of the pollutant in the edible portions of the ingested species. EPA's 2000 Methodology for deriving human health criteria emphasizes using, when possible, measured or estimated BAFs, which account for chemical accumulation in aquatic organisms from all potential exposure routes.[13] In the 2015 national 304(a) human health criteria update, EPA primarily used field-measured BAFs, and laboratory-measured bioconcentration factors (BCFs) with applicable food chain multipliers available from peer-reviewed, publicly available databases, to develop national BAFs for three trophic levels of fish. If this information was not available, EPA selected octanol-water partition coefficients (K_{ow} values) from peer-reviewed sources for use in calculating national BAFs.[14]

EPA's national default drinking water intake rate of 2.4 L/day represents the per capita estimate of combined direct and indirect community water ingestion at the 90th percentile for adults ages 21 and older.[15] EPA's national default FCR of 22 g/day represents the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the U.S. adult population 21 years of age and older, based on National Health and Nutrition Examination Survey (NHANES) data from 2003 to 2010.[16] [17] EPA calculates

[8] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[9] As noted above, EPA recommends the criterion derived for non-carcinogenic effects if it is more protective (lower) than that derived for carcinogenic effects.

[10] EPA's 2000 Methodology also states: "Criteria based on a 10^{-5} risk level are acceptable for the general population as long as states and authorized tribes ensure that the risk to more highly exposed subgroups (sport fishers or subsistence fishers) does not exceed the 10^{-4} level." Since EPA is establishing final criteria to protect a target general population of tribes with reserved subsistence fishing rights in Washington waters, the applicable EPA-recommended cancer risk levels would relate to that target general population, as opposed to the general population of Washington residents overall. See section III for additional discussion.

[11] USEPA. Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC *www.epa.gov/iris.*

[12] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[13] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[14] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[15] USEPA. 2011. EPA Exposure Factors Handbook. 2011 edition (EPA 600/R–090/052F). *http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.*

[16] USEPA. 2014. Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003–2010). United States Environmental Protection Agency, Washington, DC EPA 820–R–14–002.

[17] EPA's national FCR is based on the total rate of consumption of fish and shellfish from inland and nearshore waters (including fish and shellfish from local, commercial, aquaculture, interstate, and international sources). This is consistent with a principle that each state does its share to protect people who consume fish and shellfish that originate from multiple jurisdictions. USEPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions. https://www.epa.gov/wqc/human-health-ambient-water-quality-criteria-and-fish-consumption-rates-frequently-asked.*

human health criteria using a default body weight of 80 kilograms (kg), the average weight of a U.S. adult age 21 and older, based on NHANES data from 1999 to 2006.

Although EPA uses these default values to calculate national 304(a) recommended human health criteria, EPA's 2000 Methodology notes a preference for the use of local data to calculate human health criteria (*e.g.*, locally derived FCRs, drinking water intake rates and body weights, and waterbody-specific bioaccumulation rates) over national default values, where data are sufficient to do so, to better represent local conditions.[18] It is also important, where sufficient data are available, to select a FCR that reflects consumption that is not suppressed by concerns about the safety of available fish.[19] [20] Deriving human health criteria using an unsuppressed FCR furthers the restoration goals of the CWA and ensures protection of human health-related designated uses (as pollutant levels decrease, fish habitats are restored, and fish availability increases over time). See section III for additional discussion regarding use of an unsuppressed FCR to protect a subsistence or sustenance fishing use, especially where the subsistence or sustenance use is based in whole or in part on tribal treaty or other reserved fishing rights.[21]

d. Relative Source Contribution

When deriving human health criteria for non-carcinogens and nonlinear carcinogens, EPA recommends including a RSC factor to account for sources of exposure other than drinking water and fish and shellfish from inland and nearshore waters, so that the pollutant effect threshold (*i.e.*, RfD) is not apportioned to drinking water and fish consumption alone. The rationale for this approach is that for pollutants exhibiting threshold effects, the objective of the human health criteria is to ensure that an individual's total exposure from all sources does not exceed that threshold level. These other exposures include exposure to a particular pollutant from ocean fish and shellfish consumption (which is not included in EPA's default national FCR), non-fish food consumption (*e.g.*, fruits, vegetables, grains, meats, poultry), dermal exposure, and inhalation exposure. EPA's guidance includes a procedure for determining an appropriate RSC value ranging from 0.2 to 0.8 for a given pollutant.

III. Derivation of Human Health Criteria for Washington

A. Scope of Pollutants and Waters Covered by This Final Rule

In 1992, EPA did not establish human health criteria in the NTR for some priority toxic pollutants because, as stated in the preamble to the final rule at 57 FR 60848, December 22, 1992, EPA had no 304(a) recommendations for those pollutants at the time. EPA now has 304(a) recommendations for 99 priority toxic pollutants listed pursuant to CWA section 307(a)(1) (85 for which EPA established criteria in the NTR, plus 14 additional pollutants).

After consideration of all comments received on EPA's proposed rule, and EPA's CWA 303(c) action on Washington's submittal, EPA is finalizing 144 new and revised Washington-specific criteria for priority toxic pollutants in this rule. For arsenic, dioxin and thallium, EPA is not revising Washington's existing criteria from the NTR at this time, as explained below and in EPA's Response to Comments document in the docket for the final rule. For those priority pollutants for which EPA does not have 304(a) national recommended criteria, and are therefore not included in Washington's submittal or this final rule, EPA expects that Washington will continue to apply its existing narrative toxics criterion in the state's WQS at WAC 173–201A–260(2)(a).

Several commenters raised concerns about the scientific defensibility of EPA's proposed human health criteria for arsenic, and one commenter raised similar concerns about EPA's proposed criteria for 2,3,7,8–TCDD (dioxin). Additionally, after EPA proposed revised human health criteria for thallium in Washington, EPA further evaluated the scientific uncertainty around the appropriate RfD for thallium. EPA carefully considered all of these comments and information regarding these three pollutants, along with the comments that articulated it is important for Washington to have protective numeric criteria in place for priority toxic pollutants such as arsenic and dioxin. Given the scientific uncertainty regarding aspects of the science upon which the proposed human health criteria for arsenic, dioxin, and thallium were based, EPA is withdrawing its proposal of revised criteria for these three pollutants at this time and leaving the existing criteria from the NTR in effect for CWA purposes.[22] EPA did not update the 304(a) national recommended criteria for these three pollutants in 2015. As noted earlier, IRIS was the primary source of toxicity values (*i.e.*, RfD and CSF) for EPA's 2015 updated 304(a) human health criteria. For thallium, EPA's IRIS database does not currently contain an estimate of thallium's toxicity (*i.e.*, a RfD).[23] For dioxin, IRIS does not currently contain a measure of dioxin's cancer-causing ability (*i.e.*, a CSF).[24] Without such values, EPA has concluded that further analysis is necessary in order to promulgate scientifically sound revised criteria for these two pollutants. For arsenic, there is uncertainty surrounding the toxicological assessment with respect to human health effects. EPA's current plan for addressing the arsenic issues is described in the *Assessment Development Plan for the Integrated Risk Information System (IRIS) Toxicological Review of Inorganic Arsenic* (EPA/630/R–14/101, November 2015). EPA intends to reevaluate the existing federal arsenic, dioxin and thallium human health criteria for Washington by 2018, with particular consideration of any relevant toxicity and bioaccumulation information.

This rule revises the criteria that EPA promulgated for Washington in the NTR (with the exception of criteria for arsenic, dioxin, and thallium, and criteria that EPA approved in Washington's August 1, 2016 submittal), and establishes new human health criteria for 8 additional chemicals for which EPA now has 304(a) recommended criteria (and for which EPA did not approve Washington's submitted criteria): Selenium, Zinc, 1,2-Trans-Dichloroethylene, Acenaphthene, Butylbenzyl Phthalate, 2-Chloronaphthalene, 1,1,1-Trichloroethane, and 1,2,4-Trichlorobenzene. In 2001, EPA

[18] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[19] USEPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions. https://www.epa.gov/wqc/human-health-ambient-water-quality-criteria-and-fish-consumption-rates-frequently-asked.*

[20] National Environmental Justice Advisory Council, *Fish Consumption and Environmental Justice,* p.44 (2002) *available at https://www.epa.gov/sites/production/files/2015-02/documents/fish-consump-report_1102.pdf.*

[21] The term "subsistence" is coterminous with "sustenance" in this context. Hereafter, the document uses the term "subsistence."

[22] EPA is moving Washington's existing arsenic, dioxin and thallium criteria from the NTR into 40 CFR 131.45 to have one comprehensive human health criteria rule for Washington.

[23] *http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showQuickView&substance_nmbr=1012.*

[24] *http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showQuickView&substance_nmbr=1024.*

replaced its 304(a) recommended human health criteria for total mercury with a fish tissue-based human health criterion for methylmercury.[25] Washington did not include human health criteria for mercury or methylmercury in its August 1, 2016 submittal. Therefore, with this final rule, EPA replaces the criteria for total mercury that EPA promulgated for Washington in the NTR with a methylmercury fish tissue criterion, based on EPA's 2001 304(a) recommendation but adjusted to incorporate the 175 g/day FCR that EPA used to derive revised human health criteria in Washington, as well as EPA's 2015 updated national default body weight of 80 kg.

A few commenters expressed concern that Washington would not have the data or implementation guidance to properly implement a fish tissue criterion for methylmercury, and requested that EPA leave the NTR total mercury criteria in effect in Washington. The fish tissue methylmercury criterion reflects EPA's 2000 Methodology, the best available science, and supersedes all previous 304(a) human health mercury criteria recommendations published by EPA (except for the waters of the Great Lakes System), including the 304(a) recommended criteria that served as the basis for the total mercury criteria that EPA promulgated for Washington in the NTR. EPA recommends a fish tissue water quality criterion for methylmercury for many reasons. A fish tissue water quality criterion integrates spatial and temporal complexity that occurs in aquatic systems and affects methylmercury bioaccumulation. For this pollutant, a fish tissue criterion is more closely tied to the goal of protecting human health because it is based directly on the dominant human exposure route for methylmercury in the U.S., which is consumption of fish and shellfish. The concentration of methylmercury is also generally easier to quantify in fish tissue than in water and is less variable in fish and shellfish tissue over the time periods in which WQS are typically implemented in water quality-based controls, such as NPDES permits. Finally, fish consumption advisories for mercury are also based on the amount of methylmercury in fish tissue.[26] While the purpose of a fish advisory is different from the purpose of a water quality criterion, it will be helpful to the public to have water quality criteria and fish consumption advisories for methylmercury expressed using the same terms. In response to comments regarding implementation of the methylmercury criterion, in 2010, EPA published the comprehensive *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* (EPA 823–R–10–001), to aid states in implementing the fish tissue-based methylmercury water quality criterion. EPA is confident that Washington will be able to implement the fish tissue criterion using the information contained in that document, and EPA remains available to offer assistance in doing so. Thus there is no need or requirement to leave the NTR total mercury criteria in place in Washington.

This final rule does not change or supersede any criteria that EPA previously promulgated for other states in the NTR, nor does it change any other elements of the NTR such as EPA's original basis for promulgation. For clarity in organization, EPA is withdrawing Washington from the NTR at 40 CFR 131.36 and incorporating the Washington-specific criteria in this rule (as well as the existing NTR criteria for arsenic, dioxin and thallium) into 40 CFR 131.45 so there is a single comprehensive set of federally promulgated criteria for Washington.

This rule applies to waters under the State of Washington's jurisdiction, and not to waters within Indian country,[27] unless otherwise specified in federal law. Some waters located within Indian country already have CWA-effective human health criteria, while others do not.[28] Several tribes are working with EPA to either revise their existing CWA-effective WQS, or obtain treatment in a similar manner as a state (TAS) status in order to adopt CWA-effective WQS in the near future. EPA will continue to work closely with tribes in Washington to ensure that they adopt human health criteria that are scientifically supported and protective of designated uses, in accordance with the CWA and EPA's regulations. In addition, on September 29, 2016, EPA published an Advanced Notice of Proposed Rulemaking in the **Federal Register** that seeks input on an approach that involves EPA promulgating baseline WQS for reservations that currently have no CWA-effective WQS, including such reservations within the State of Washington.[29]

B. Washington's Designated Uses and Tribal Reserved Fishing Rights

a. EPA's Consideration of Tribal Treaty Rights

Under the Supremacy Clause of the U.S. Constitution, federal treaties have the same legal force as federal statutes.[30] As such, the provisions of federal statutes should generally be read in harmony with treaties where they both apply. In certain instances, statutes may contain provisions indicating that they *must* be read in harmony with treaties. Such is the case with the CWA, which provides that the Act "shall not be construed as . . . affecting or impairing the provisions of any treaty of the United States." [31]

In determining whether WQS satisfy the CWA and EPA's regulations, and when setting criteria for the protection of human health, it is necessary to consider other applicable laws, such as federal treaties (*e.g.,* U.S. Treaties with Indians). While treaties do not expand EPA's authority, they are binding on the federal government. As a result, EPA has an obligation to ensure that its actions do not conflict with tribal treaty rights.[32] For the foregoing reasons, and

[25] USEPA. 2001. Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–823–R–01–001. *https://www.epa.gov/wqc/guidance-implementing-january-2001-methylmercury-water-quality-criterion.*

[26] While both water quality criteria and fish consumption advisories are designed ultimately to protect human health, they represent very different values and goals. Water quality criteria express or establish a desired condition and must protect the designated use, such as subsistence fishing. Fish consumption advisories start with existing levels of fish contamination resulting from impaired water quality, and provide advice to populations consuming such fish on limiting levels of consumption in order to reduce risk from contamination.

[27] See 18 U.S.C. 1151 for the definition of Indian country.

[28] Indian country waters with CWA-effective WQS include those where (a) EPA has authorized a tribe to adopt WQS under the CWA for its reservation and the tribe has adopted standards that EPA has approved, and (b) EPA has promulgated federal WQS.

[29] For more information, see: *https://www.epa.gov/wqs-tech/advance-notice-proposed-rulemaking-federal-baseline-water-quality-standards-indian.*

[30] U.S. Const. art. IV, § 2: The "Constitution . . . of the United States . . . and all Treaties made, or which shall be made, under the Authority of the United States, shall be the supreme Law of the Land; and the Judges in every State shall be bound thereby, any Thing in the Constitution or Laws of any State to the Contrary notwithstanding."

[31] CWA Section 511, 33 U.S.C. 1371.

[32] U.S. Const. art. IV, § 2; *see United States* v. *Forty-Three Gallons of Whiskey,* 93 U.S. 188, 196 (1833) (recognizing that "the Constitution declares a treaty to be the supreme law of the land," and that "a treaty is to be regarded . . . as equivalent to an act of the legislature") and *Worcester* v. *Georgia,* 31 U.S. 515, 594 (1832) ("So long as . . . treaties exist, having been formed within the sphere of the federal powers, they must be respected and enforced by the appropriate organs of the federal government."). *See also* EPA policies on considering treaty rights: *Working Effectively With Tribal Governments: Resource Guide* at pp. 49–52, 53 (August 1998) (explaining the key principles underlying the application of Indian treaty rights, and noting that "[f]ederal, state, and local agencies need to refrain

as further explained below, it is therefore necessary and appropriate to consider tribal treaties to ensure that EPA's actions under the CWA are in harmony with such treaties. See also EPA's Response to Comment document in the docket for this rule.

b. Treaty-Reserved Subsistence Fishing Rights in Washington

The majority of waters under the jurisdiction of the State of Washington are subject to federal treaties with tribes.[33] There are eight Stevens-Palmer Treaties relevant to the State of Washington through which 24 tribes reserved for themselves identical or nearly identical fishing rights within the boundaries of present-day Washington; specifically, the treaty-reserved "right of taking fish at usual and accustomed places, in common with all citizens of the Territory." [34] The right to take fish at usual and accustomed places extends to lands formerly ceded by the tribes to the U.S. as described in the treaties, as well as to all places beyond the boundaries of the ceded territories that tribal members regularly used at treaty time.[35]

The parties to the treaties all recognized the importance of the fishing right for the tribes' subsistence, ceremonial, as well as commercial purposes.[36] In *U.S. v Washington,* the district court made detailed findings of facts regarding the reserved fishing right, including the importance of subsistence fishing to the treaty tribes:

> At the treaty negotiations, a primary concern of the tribes, whose way of life was so heavily dependent upon harvesting anadromous fish, was that they have freedom to move about to gather food, particularly salmon, . . . at their usual and accustomed fishing places. . . . Subsequent to the execution of the treaties and in reliance thereon, the members of the [treaty tribes with reserved fishing rights in Washington] have continued to fish for subsistence, sport, and commercial purposes at their usual and accustomed places. Such fishing provided and still provides an important part of their livelihood, subsistence and cultural identity. The Indian cultural identification with fishing is primarily dietary, related to the subsistence fishery, and secondarily associated with religious ceremonies and commercial fishing.[37]

Relevant case law, including Supreme Court precedents, unequivocally confirms that the treaty-reserved right to take fish includes the right to take fish for subsistence purposes.[38] Historical and current evidence of tribal members' exercise of the treaty-reserved subsistence fishing right can be found in heritage FCR reports and contemporary FCR surveys (for tables of relevant FCRs, see EPA's Response to Comment document in the docket for this rule).

As explained above, the Stevens-Palmer Treaties provide tribes the right to exercise subsistence fishing practices on waters throughout the State of Washington. EPA concludes that the purpose for which tribes reserved such fishing rights through treaties with the U.S. has important implications for water quality regulation under the CWA. Fundamentally, the tribes' ability to take fish for their subsistence purposes under the treaties would be substantially affected or impaired if it were not supported by water quality sufficient under the CWA to ensure that tribal members can safely eat the fish for their own subsistence.

Many areas where treaty-reserved fishing rights are exercised cannot be directly protected or regulated by tribal governments to ensure adequate water quality, and therefore the responsibility falls to the federal government (and the states) to ensure their protection. It is therefore appropriate and necessary for EPA (and states) to consider the tribal reserved rights within the framework of the CWA, to ensure water quality protection for treaty-reserved subsistence fishing rights. EPA's consideration of treaty-reserved fishing rights within the framework of the CWA leads to the conclusion, as described below, that the human health fishing uses for waters in Washington include subsistence fishing, as informed by the tribes' legally protected right to continue to take fish for subsistence purposes.[39]

from taking actions that are not consistent with tribal rights wherever they exist"); *Commemorating the 30th Anniversary of the EPA's Indian Policy,* Memorandum from Gina McCarthy to All EPA Employees, p. 1 (December 1, 2014) (reiterating that "EPA must ensure that its actions do not conflict with tribal treaty rights" and stating that "EPA programs should be implemented to enhance the protection of tribal treaty rights and treaty-covered resources when we have the discretion to do so"); *EPA Policy for the Administration of Environmental Programs on Indian Reservations* (November 8, 1984) (known as "EPA 1984 Indian Policy").

[33] *See http://wdfw.wa.gov/hunting/tribal/treaty_history.html.*

[34] *See e.g.* Treaty with the Yakima art. 3, June 9, 1855, 12 Stat. 951. In *United States* v. *Winans,* 198 U.S. 371 (1905), the Supreme Court adopted a "reservation of rights" approach in interpreting the Stevens Treaty with the Yakima Nation: "the treaty was not a grant of rights to the Indians, but a grant of rights from them—a reservation of those not granted." *Id.* at 381. In contrast, "off reservation fishing by other citizens and residents of the state is not a right but merely a privilege which may be granted, limited or withdrawn by the state as the interests of the state or the exercise of treaty fishing rights may require." *U.S. v Washington,* 384 F. Supp. 312, 332 (W.D. Wash. 1974) *aff'd* 520 F.2d 676 (9th Cir. 1975), *cert. denied* 423 U.S. 1086 (1976).

[35] *See Seufert Bros. Co.* v. *U.S.,* 249 U.S. 194, 199 (1919). In *U.S. v Washington,* the court stated, citing *Seufert Bros. Co.,* "every fishing location where members of a tribe customarily fished from time to time at and before treaty times, however distant from the then usual habitat of the tribe, and whether or not other tribes then also fished in the same waters, is a usual and accustomed ground or station at which the treaty tribe reserved, and its members presently have, the right to take fish." 384 F. Supp. at 332.

[36] For a thorough discussion on the treaty negotiation and execution and meaning of the reserved fishing right, *see e.g., U.S. v Washington,* 384 F. Supp. at 348–359 (containing finding of facts regarding, *inter alia,* treaty status, pre-treaty role of fishing among northwest Indians, treaty background, negotiation and execution of the treaties, and post-treaty Indian fishing); *see also id.* at 340 ("The right to fish for all species available in the waters from which, for so many ages, their ancestors derived most of their subsistence is the single most highly cherished interest and concern of the present members of plaintiff tribes, with rare exceptions even among tribal members who personally do not fish or derive therefrom any substantial amount of their subsistence."); *id.* at 343 ("The evidence shows beyond doubt that at treaty time the opportunity to take fish for personal subsistence and religious ceremonies was the single matter of utmost concern to all treaty tribes and their members."); and *U.S.* v. *Washington,* No. 13–35474, 2016 U.S. App. LEXIS 11709, at *29 (9th Cir. June 27, 2016) ("The Indians reasonably understood Governor Stevens to promise not only that they would have access to their usual and accustomed fishing places, but also that there would be fish sufficient to sustain them.").

[37] *U.S.* v *Washington,* 384 F. Supp. at 355–358 (internal citations to exhibits omitted).

[38] *See e.g., Washington* v. *Washington State Commercial Passenger Fishing Vessel Ass'n,* 443 U.S. 658, 678–679 (1979) (Because the Indians had always exercised the right to meet their subsistence and commercial needs by taking fish from treaty area waters, they would be unlikely to perceive a "reservation" of that right as merely the chance, shared with millions of other citizens, occasionally to dip their nets into the territorial waters. Moreover, the phrasing of the clause quite clearly avoids placing each individual Indian on an equal footing with each individual citizen of the State."); *U.S.* v. *Washington,* 2016 U.S. App. LEXIS 11709 at *28 (Observing that to the Tribes, the Stevens Treaties' "principal purpose was to secure a means of supporting themselves once the Treaties took effect," and to that end, "[s]almon were a central concern.").

[39] While EPA's action is based on harmonizing the requirements of the CWA with the terms of the treaty-reserved subsistence fishing right, the action also is consistent with federal Indian law principles addressing subsidiary treaty rights. A written legal opinion from the Solicitor of the U.S. Department of Interior (DOI) to EPA analyzed whether tribal reserved fishing rights include subsidiary rights to sufficient water quality. Letter from Hilary C. Tompkins, Solicitor, DOI, to Avi Garbow, General Counsel, EPA, regarding Maine's WQS and Tribal Fishing Rights of Maine Tribes (January 30, 2015). Although DOI's legal opinion primarily involved an analysis of fishing rights of tribes in Maine in connection with EPA's February 2, 2015 decision to disapprove WQS applied to waters of Indian Lands in Maine, its discussion of tribal fishing rights and water quality has relevance to tribes with reserved fishing rights in Washington. DOI's legal opinion identified several court decisions, including Supreme Court decisions interpreting the reserved fishing right in the Stevens Treaties, which have held that fishing rights for tribes encompass subsidiary rights that are necessary to render those rights meaningful. In *Washington* v. *Wash. State Commercial Passenger Fishing Vessel Ass'n,* the United States Supreme Court held that tribes with

Continued

c. Use(s) of the Water(s) in Question

Consistent with EPA's September 14, 2015 proposed rule for Washington, in order to effectuate and harmonize treaty-reserved fishing rights with the CWA, EPA has determined that such rights must be appropriately considered when determining which criteria are sufficient to adequately protect Washington's designated uses. Looking at the treaty-reserved subsistence fishing right within the CWA water quality framework, the first step is to examine the use of the water(s) in question. The CWA generally assigns to a state the responsibility of determining the designated uses of its waters (subject to certain restrictions at 40 CFR 131.10),[40] and in Washington the state's designated uses include fish and shellfish harvesting.[41] As explained above, through treaties, tribes reserved specific fishing rights in Washington's waters, including the right to take fish from such waters for their subsistence. In order to effectuate these rights in harmony with the CWA, EPA has interpreted the state's EPA-approved designated fish and shellfish harvesting use to include or encompass a subsistence fishing component based on, and consistent with, the rights reserved to the tribes through the treaties. As discussed in more detail below, EPA construes the CWA to require that, when establishing WQS for these waters, the tribal members must be considered the target general population for the purposes of setting risk levels to protect the subsistence fishing use.

d. Target General Population for Deriving Criteria Protective of the Use(s)

Developing criteria to protect the fish and shellfish harvesting use, which includes subsistence fishing as informed by reserved fishing rights, necessarily involves identifying tribal members with reserved fishing rights as the target population for protection. EPA's conclusion to identify tribes as the target population is based on EPA's CWA implementing regulations requiring criteria to support the most sensitive use (*i.e.*, subsistence fishing) and EPA's 2000 Methodology recommendation that priority be given to identifying and protecting highly exposed populations. Further, in order to derive water quality criteria sufficient under the CWA to ensure that the tribes' treaty-reserved right to take fish for subsistence purposes is not substantially affected or impaired, it is reasonable and appropriate to identify tribes as the target *general* population for protection, rather than a subpopulation, and apply the 2000 Methodology's recommendations on exposure for the general population to the tribal target population.

Per EPA's regulations at 40 CFR 131.11(a)(1), water quality criteria must contain sufficient parameters or constituents to protect the designated use, and for waters with multiple uses, the criteria must support the most sensitive use. In the case of Washington's human health-related uses, the most sensitive use is fish and shellfish harvesting, which, as explained above, EPA has interpreted to include or encompass a subsistence fishing component based on, and consistent with, the rights reserved to the tribes through the treaties. Developing water quality criteria to protect the subsistence fishing component of the fish or shellfish harvesting use necessarily involves identifying the population exercising that use.

EPA's decision to identify tribes as the target population is further supported by EPA guidance for developing water quality criteria to protect human health. As explained in EPA's 2000 Methodology, the choice of the particular population to protect is an important decision to make when setting human health criteria.[42] EPA recommends that states provide adequate protection from adverse health effects to the general population, as well as to highly exposed populations, such as recreational and subsistence fishers, two distinct groups with FCRs that may be greater than the general population.[43] In fact, EPA's 2000 Methodology recommends considering how to protect both susceptible and highly exposed populations when setting criteria:

> EPA recommends that priority be given to identifying and adequately protecting the most highly exposed population. Thus, if the State or Tribe determines that a highly exposed population is at greater risk and would not be adequately protected by criteria based on the general population, and by the national 304(a) criteria in particular, EPA recommends that the State or Tribe adopt more stringent criteria using alternative exposure assumptions.[44]

Therefore, consistent with the guidance, EPA identifies the tribal population as the target population for protection and the subsistence fishing use must be the focus of the risk assessment supporting water quality criteria to adequately protect that use. Deriving criteria protective of the tribal target population necessarily involves determining the appropriate inputs for calculating protective criteria for tribal subsistence fishers, such as the FCR and cancer risk level.

EPA's approach in the 2000 Methodology, and its approach used for deriving national 304(a) recommended criteria, is for human health water quality criteria to provide a high level of protection for the general population (for example, FCRs designed to represent "the general population of fish consumers," or a cancer risk level that "reflects an appropriate risk for the general population"), while recognizing that more highly exposed "subpopulations" may face greater levels of risk.[45] The 2000 Methodology does not, however, speak to or envision the unique situation of setting WQS that cover areas where tribes have treaty-reserved rights to practice subsistence

reserved fishing rights are entitled to something more tangible than "merely the chance . . . occasionally to dip their nets into the territorial seas." 443 U.S. 658, 679 (1979). Consistent with this reasoning, courts have held that treaty-reserved fishing rights entail the right to access fishing grounds and the right to water quantity sufficient to support fish habitat. *See e.g., United States* v. *Winans,* 198 U.S. 371, 384 (1905) (tribe must be allowed to cross private property to access traditional fishing ground); *Seufert Bros. Co.* v. *United States,* 249 U.S. 194 (1919) (tribe entitled to cross over and temporarily use any sites which they were accustomed to using at treaty time, including sites outside their ceded territories); *United States* v. *Adair,* 723 F .2d 1394, 1409–10 (9th Cir. 1983) (holding that the tribe's fishing right implicitly reserved sufficient waters to "secure to the Tribe a continuation of its traditional . . . fishing lifestyle"; *Colville Confederated Tribes* v. *Walton,* 647 F.2d 42, 47–48 (9th Cir. 1981) (implying reservation of water to preserve tribe's replacement fishing grounds). Consistent with these precedents, in June 2016 the U.S. Court of Appeals for the Ninth Circuit affirmed the district court's finding that barrier culverts constructed by the State of Washington obstructing fish passage were in violation of tribal fishing rights set forth in the Stevens Treaties, noting that "the Tribes' right of access to their usual and accustomed fishing places would be worthless without harvestable fish." *United States* v. *Washington,* 2016 U.S. App. LEXIS 11709 at *31. The court also acknowledged that the fishing clause of the Stevens Treaties could give rise to other environmental obligations, but that those would need to be addressed on a case-by-case basis depending on the precise nature of the action. *Id.* at *18–19. Consistent with this body of case law, DOI's legal opinion concludes that "fundamental, longstanding tenets of federal Indian law support the interpretation of tribal fishing rights to include the right to sufficient water quality to effectuate the fishing right." DOI Letter at 10.

[40] 33 U.S.C. 1251(a)(2), 1313(c)(2)(A).

[41] See WAC 173–201A–600 and WAC 173–201A–610.

[42] EPA's 2000 Methodology, 2–1.

[43] *Id.* at 2–2.

[44] EPA's 2000 Methodology, 2–1—2. *See also* EPA's 2000 Methodology, 4–17 ("When choosing exposure factor values to include in the derivation of a criterion for a given pollutant, EPA recommends considering values that are relevant to population(s) that is (are) most susceptible to that pollutant. In addition, highly exposed populations should be considered when setting criteria.").

[45] *See* EPA's 2000 Methodology, 2–6—7, 4–24—25.

fishing.[46] Nevertheless, it is possible to apply the general principles outlined in the 2000 Methodology to this situation, as informed by the treaties.

In light of the presence of the treaty-reserved fishing rights in Washington, interpreted by the U.S. Supreme Court to encompass, among other things, subsistence fishing, and EPA's interpretation of Washington's fish and shellfish harvesting use to include subsistence fishing, it is reasonable and appropriate to require that tribes with such rights be considered as the target general population for deriving criteria protective of the use rather than a sensitive subpopulation within the overall population of Washington. Treating tribes as the target general population will help derive water quality criteria sufficient under the CWA to ensure that the tribes' treaty-reserved right to take fish for subsistence purposes is not substantially affected or impaired. Therefore, the 2000 Methodology's recommendations on exposure for the target general population can be applied accordingly. EPA's conclusion to treat tribes as the target general population, as opposed to a subpopulation, is further supported by relevant case law interpreting the treaty-reserved fishing rights applicable in Washington; specifically the phrase "in common with all citizens of the territory."

Treating tribes as the target population instead of a sensitive subpopulation also impacts another important input parameter used to derive human health criteria, the cancer risk level. For carcinogenic pollutants, EPA's 2000 Methodology recommends that states protect the general population to a level of incremental cancer risk no greater than one in one hundred thousand to one in one million (1×10^{-5} to 10^{-6}). For over 20 years, Washington has used 10^{-6} as the level of risk that must be used to establish human health criteria for carcinogenic pollutants. EPA's 2000 Methodology indicates that if there are highly exposed groups or subpopulations within that target general population, such as subsistence consumers, WQS should protect those consumers to a level of incremental risk no greater than one in ten thousand (1×10^{-4}).[47] However, where treaty-reserved tribal fishing rights apply to particular waters, it would be unreasonable to expose the communities exercising those rights to levels of risk above what would be reasonable for the general population of the state. See section III.C.b for more information on cancer risk level.

e. Water Quality Criteria Sufficient To Protect the Use(s)

The data used to determine the FCR are critical to deriving criteria that will protect the subsistence fishing portion of the fish and shellfish harvesting designated use. EPA provides a recommended national default FCR for the general population but strongly recommends the use of local or regional data, where available, over default values.[48] Further, as EPA explained in its January 2013 *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions,* it is important to avoid selecting a FCR that reflects consumption that is suppressed due to concerns about the safety of available fish. Under certain circumstances, it may also be relevant to look at the availability of fish when considering suppression effects on current FCRs.[49] EPA maintains that it is important, as a CWA goal, to avoid the suppression effect that may occur when criteria are derived using a FCR for a given target population that reflects an artificially diminished level of fish consumption from an appropriate baseline level of consumption for that population.[50] To use a FCR that is suppressed would not result in criteria that actually protect a fishing use because it would merely reinforce the existing suppressed use, or worse, set in motion a "downward spiral" [51] of further reduction/suppression of fish consumption due to concerns about the safety of available fish or depleted fisheries. The CWA is meant not merely to maintain the status quo, but to *restore* and maintain the chemical, physical, and biological integrity of the Nation's waters. Therefore, deriving criteria using an unsuppressed FCR furthers the restoration goals of the CWA and ensures protection of human health-related designated uses (as pollutant levels decrease, fish habitats are restored, and fish availability increases over time).

CWA section 303(c)(2)(A) requires that water quality criteria be "based upon" applicable designated uses, and that such uses and criteria "shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this [Act]." The "purposes of this [Act]" are in section 101, and include, among other things, "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water." EPA's implementing water quality regulations at 40 CFR 131.11 require water quality criteria to be based on sound scientific rationale and sufficient to protect the designated use, regardless of whether that use is currently being met. A subsistence fishing designated use, by definition, represents a level of fish consumption that is adequate to provide subsistence, regardless of whether such consumption is occurring today. It is entirely consistent with the CWA and regulations for EPA to determine that to protect the designated use, it is necessary and appropriate to derive the human health criteria using a fish consumption rate that reflects a subsistence level of consumption that is not artificially suppressed as a result of concerns about pollution or fish contamination where such data are available.

Any fish consumption rate used in setting criteria to protect a subsistence fishing use must allow for the consumption of fish from local waters at levels that could sustain and be protective of members of the target population practicing a subsistence lifestyle. Water quality criteria derived

[46] In response to comments on EPA's 1998 draft Human Health Methodology revisions, the Agency responded: "As stated in the 1998 draft Methodology revisions, 'risk levels and criteria need to be protective of tribal rights under federal law (*e.g.*, fishing, hunting, or gathering rights) that are related to water quality.' We believe the best way to ensure that Tribal treaty and other rights under Federal law are met, consistent with the Federal trust responsibility, is to address these issues at the time EPA reviews water quality standards submissions." (See 65 FR 66444, 66457 November 3, 2000).

[47] 2000 Methodology, 2–6.

[48] EPA's 2000 Methodology, 4–24—4–25 ("EPA's first preference is that States and authorized Tribes use the results from fish intake surveys of local watersheds within the State or Tribal jurisdiction to establish fish intake rates that are representative of the defined populations being addressed for the particular waterbody.")

[49] As noted by the National Environmental Justice Advisory Council in the 2002 publication *Fish Consumption and Environmental Justice,* "a suppression effect may arise when fish upon which humans rely are no longer available in historical quantities (and kinds), such that humans are unable to catch and consume as much fish as they had or would. Such depleted fisheries may result from a variety of affronts, including an aquatic environment that is contaminated, altered (due, among other things, to the presence of dams), overdrawn, and/or overfished. Were the fish not depleted, these people would consume fish at more robust baseline levels. . . . In the Pacific Northwest, for example, compromised aquatic ecosystems mean that fish are no longer available for tribal members to take, as they are entitled to do in exercise of their treaty rights."). National Environmental Justice Advisory Council, *Fish Consumption and Environmental Justice,* p.44, 46 (2002) *available at https://www.epa.gov/sites/production/files/2015-02/documents/fish-consump-report_1102.pdf.*

[50] *See id.* at 43.

[51] *See id.* at 47.

using a FCR below a level that would be adequate to sustain members of the target population exercising a subsistence use, such as tribal members who have a history of subsistence fishing in Washington, would not be protective of that use. In this context, use of an unsuppressed rate, where data to determine that rate are available, would ensure that the resulting criteria are protective of the subsistence use.

The importance of relying on an unsuppressed FCR, where data are available, is especially evident where the subsistence use is based in whole or in part on tribal treaty and other reserved subsistence fishing rights. This is because if human health criteria are set at a level that assumes only suppressed fish consumption, the waters will only be protected to support that level of suppressed fish consumption and thus never fully support—and potentially even may directly impair—the tribes' legal right to take fish for subsistence purposes. Accordingly, where adequate data are available to clearly demonstrate what the current unsuppressed FCR is for the relevant target population, the selected FCR must reflect that value. In the absence of such data, states, tribes, and EPA could consider upper percentile FCRs of local contemporary fish consumption surveys (such as the 95th or 99th percentile), heritage FCR data for the target population, and/or FCRs that provide for a subsistence fishing lifestyle. Consultation with tribes is important to ensure that all data and information relevant to this issue are considered.

Although treaties do not cover all waters in Washington, they cover the vast majority of the state's waters. Additionally, where treaty and non-treaty reserved rights apply on waters downstream of waters without reserved fishing rights, upstream WQS must provide for the attainment and maintenance of downstream WQS in accordance with EPA's regulations at 40 CFR 131.10(b). Based on a GIS analysis included in the docket for this final rulemaking, EPA concluded that greater than 90 percent of waters in Washington are covered by treaty rights and/or are upstream of waters with such rights or waters in Oregon (see section III.C.a). For any remaining waters in Washington, where reserved rights do not apply and that are not upstream of waters with such rights or waters in Oregon, it would be administratively burdensome to develop separate criteria to apply to such a small subset of waters, and would be difficult to implement separate criteria with a patchwork of protection among these areas when administering the WQS, NPDES permitting, and other programs. Therefore, EPA applies these final criteria to all waters under Washington's jurisdiction.

Many commenters supported EPA's decisions to derive criteria protective of the tribal population exercising their treaty-reserved fishing rights in Washington as the target general population, and to apply the resulting criteria to all waters under Washington's jurisdiction. Many other commenters did not support these decisions, and argued that EPA did not have a scientific or legal basis to interpret Washington's designated uses to encompass subsistence fishing and to treat the tribal population with treaty-reserved fishing rights as the target general population for protection under such use. For additional responses to these comments, see EPA's Response to Comment document in the docket for this rule.

C. Washington-Specific Human Health Criteria Inputs

a. Fish Consumption Rate

In Washington there are 24 tribes with treaty-reserved fishing rights, rights that encompass the right to fish for subsistence purposes, and several local and regional FCR surveys and heritage tribal consumption reports with widely varying estimates of tribal FCRs in Washington (for tables of relevant FCRs, see EPA's Response to Comment document in the docket for this rule). Available heritage FCRs range from 401 to 995 g/day, and contemporary survey FCRs range from 63 to 214 g/day (mean FCRs) and from 113 to 489 g/day (90th percentile FCRs). The discrepancy between contemporary and heritage FCRs suggests that current FCRs for certain tribal consumers in Washington may be suppressed.[52] [53] It is currently unclear how a contemporary fish consumption survey might quantitatively account for suppression, resulting in estimates of current FCRs that are unsuppressed to the maximum degree practicable. There is no local survey of contemporary fish consumption in Washington adjusted specifically to account for suppression, and no survey is a clear representation of current unsuppressed consumption for all tribes in Washington. Consistent with the principles outlined above, EPA considered the available, scientifically sound fish consumption data for Washington tribes and consulted with tribal governments to select a FCR for this final rulemaking.

The Washington tribes have generally agreed that 175 g/day is acceptable for deriving protective criteria at this time, when accompanied by other protective input parameters to calculate the criteria. However, EPA recognizes that some tribes have raised concerns as to whether a FCR of 175 g/day reasonably reflects current unsuppressed consumption rates of tribes within the State of Washington, based on the best currently available information. A FCR of 175 g/day approximates the 95th percentile consumption rate of surveyed tribal members from the CRITFC study[54] and includes anadromous fish, which is reasonable given that these marine species reside in Washington's nearshore (*i.e.*, within three miles of the coast) waters, especially Puget Sound, and accumulate pollutants discharged to these waters during a significant portion of their lives. The CRITFC survey also includes four tribes (three of which have treaty-reserved rights in Washington, the most of any one contemporary FCR survey in Washington) along the Columbia River in Washington, Idaho, and Oregon. Given this, and also considering the variability in heritage and contemporary FCRs and the uncertainty regarding suppression effects on current FCRs, the CRITFC survey provides scientifically sound estimates of fish consumption for the purpose of deriving a Washington statewide FCR for the tribal target general population.

Additionally, Oregon, much of which is downstream from Washington (or cross-stream in the Columbia River where it forms the border between the two states), used a FCR of 175 g/day to derive statewide human health criteria, which EPA approved in 2011. Use of this FCR to derive Washington's criteria will thus help ensure the attainment and maintenance of downstream WQS in Oregon.

Many commenters supported EPA's selected FCR, as well as the Agency's position that it is important to consider suppression effects on the FCR in general, and necessary and appropriate to do so where subsistence fishing is a reserved right and encompassed by the designated use of the waters. Some

[52] The number of fish advisories and closures due to contamination also suggest that contemporary FCRs may be suppressed due to concerns about pollution. *See* Washington Department of Health, Fish Consumption Advisories, available at *http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.*

[53] Heritage rates refer to the rates of fish intake consistent with traditional tribal practices, prior to contact with European settlers.

[54] *Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission (CRITFC), 1994).

commenters expressed concern that 175 g/day was not high enough to reflect current or historical consumption rates of all tribes in Washington. Many other commenters expressed the opposite concern, that 175 g/day was unreasonably high in order to protect Washington residents, and argued that treaty-reserved rights do not confer the right to eat fish at unsuppressed levels. Some of those commenters also argued that the CWA does not mention suppression. For detailed responses to these comments, see EPA's Response to Comment document in the docket for this rule.

b. Cancer Risk Level

EPA derives final human health criteria for carcinogens in Washington using a cancer risk level of one in one million (10^{-6}), based on Washington's longstanding use of that cancer risk level, EPA guidance, tribal reserved fishing rights, and downstream protection requirements.

To derive final human health criteria for each state in the NTR, EPA selected a cancer risk level based on each state's policy or practice regarding what risk level should be used when regulating carcinogens in surface waters. In its official comments on EPA's proposed NTR in 1992, Washington asked EPA to promulgate human health criteria using a cancer risk level of 10^{-6}, stating, "The State of Washington supports adoption of a risk level of one in one million for carcinogens. If EPA decides to promulgate a risk level below one in one million, the rule should specifically address the issue of multiple contaminants so as to better control overall site risks." (57 FR 60848, December 22, 1992). Accordingly, in the NTR, EPA used a cancer risk level of 10^{-6} (one in one million) to derive human health criteria for Washington. Subsequently, Washington adopted and EPA approved a provision in the state's WQS that reads: "Risk-based criteria for carcinogenic substances shall be selected such that the upper-bound excess cancer risk is less than or equal to one in a million" (WAC 173–201A–240(6)). In Washington's August 1, 2016 submittal, the cancer risk level is identified in the new text and reformatted toxics criteria table at WAC 173–201A–240.

Subsequent to promulgating the NTR, EPA issued its 2000 Methodology, which states that when promulgating water quality criteria for states and tribes, EPA intends to use the 10^{-6} cancer risk level, which reflects an appropriate risk for the general population.[55] In this action, as described above, tribes with treaty-reserved rights in Washington are the target general population for the purpose of deriving revised criteria to protect the subsistence fishing uses of Washington's waters. Because those tribes are the general population in this case, EPA's selection of a 10^{-6} cancer risk level for the tribal target general population is consistent with current EPA guidance, specifically the 2000 Methodology.

In addition, use of a cancer risk rate of 10^{-6} ensures that the resulting human health criteria for carcinogens protect the subsistence fishing component of the designated use. Due to uncertainty regarding suppression effects (see sections II.C, III.B, and III.C.a, and EPA's Response to Comment document in the docket for this rule), using a cancer risk level of 10^{-6} along with a FCR of 175 g/day ensures that tribal members with treaty-reserved fishing rights will be protected at an acceptable risk level for the target general population. Throughout tribal consultation, the tribes generally supported 175 g/day as an acceptable FCR for purposes of revising Washington's human health criteria at this time, when accompanied by other protective input parameters (*e.g.*, a cancer risk level of 10^{-6}), to account for the uncertainty around an appropriate FCR value reflective of tribal subsistence fishing.

Finally, as discussed in section III.C.a, many of Washington's rivers are in the Columbia River Basin, upstream of Oregon's portion of the Columbia River. Oregon's criteria are based on a FCR of 175 g/day and a cancer risk level of 10^{-6}. EPA's decision to derive human health criteria for Washington using a cancer risk level of 10^{-6} along with a FCR of 175 g/day helps ensure that Washington's criteria will ensure the attainment and maintenance of Oregon's downstream WQS as required by 40 CFR 131.10(b).

Many commenters supported EPA's selection of a 10^{-6} cancer risk level, and EPA's rationale for doing so. Many other commenters disagreed and argued that deriving human health criteria for Washington using a 10^{-5} cancer risk level is appropriate and consistent with EPA guidance and past practice. Many of these commenters stated that tribal treaties did not confer rights to a particular level of risk. Additionally, some commenters supported EPA's consideration of downstream WQS in Oregon when establishing the criteria upstream, while others expressed concern that EPA was suggesting that Washington's upstream criteria must be identical to Oregon's downstream criteria and in doing so, acting inconsistently with its 2014 Frequently Asked Questions document on downstream protection.[56] For detailed responses to these comments, see EPA's Response to Comment document in the docket for this rule.

c. Relative Source Contribution

EPA recommends using a RSC for non-carcinogens and nonlinear carcinogens to account for sources of exposure other than drinking water and consumption of inland and nearshore fish and shellfish (see section II.C.d). In 2015, after evaluating information on chemical uses, properties, occurrences, releases to the environment and regulatory restrictions, EPA developed chemical-specific RSCs for non-carcinogens and nonlinear carcinogens ranging from 0.2 (20 percent) to 0.8 (80 percent) following the Exposure Decision Tree approach described in EPA's 2000 Methodology.[57] [58] EPA proposed to use these same RSCs to derive human health criteria for Washington, and where EPA did not update the nationally recommended criteria for certain pollutants in 2015, EPA proposed to use a RSC of 0.2 to derive human health criteria for those pollutants in Washington to ensure protectiveness.

Several commenters supported EPA's use of RSCs to account for other sources of pollutant exposure. Several others disagreed, arguing that water quality criteria under the CWA cannot control or consider sources of exposure other than from drinking water and eating fish and shellfish, so human health criteria should not account for these sources. Many of the commenters, in addition to criticizing the concept of RSCs as overly-conservative, argued that EPA was double-counting exposure to anadromous fish (which EPA considers marine in the national dataset) by both including them in the FCR and using the pollutant-specific RSCs that EPA pairs with an inland and nearshore-only

[55] EPA's 2000 Methodology, pages 2–6.

[56] *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100LIJF.PDF?Dockey=P100LIJF.PDF.*

[57] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[58] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

FCR in its 304(a) national recommended human health criteria. Commenters argued that this is inconsistent with EPA's guidance, which recommends that states adjust the RSC to reflect a greater proportion of the RfD being attributed to water, fish and shellfish intake in instances where the FCR includes freshwater, estuarine and all marine fish consumption.[59] For detailed responses to the comments, see EPA's Response to Comment document in the docket for this rule.

Additionally, after further evaluation of the proposed revised human health criteria for antimony, EPA determined that the existing 304(a) national recommended criteria for antimony (last updated in 2002) use a pollutant-specific RSC of 0.4. EPA intended to apply a 0.2 RSC as a protective approach only where pollutant-specific RSCs were not already developed, which is not the case for antimony.[60]

While the selected FCR of 175 g/day does not include all marine fish (*e.g.*, it does not include consumption of species such as swordfish, tuna, etc.), EPA acknowledges that the criteria as proposed may have double-counted potential exposure to some pollutants in certain marine fish that are anadromous (*e.g.*, salmon). Therefore, EPA reviewed the RSCs in the proposed rule in light of EPA's guidance, which includes both the Exposure Decision Tree and associated discussion in EPA's 2000 Methodology, as well as EPA's recommendation to adjust the RSC when the FCR includes freshwater, estuarine, and all marine fish consumption. Arguably, EPA's guidance does not consider this exact scenario where the selected FCR includes some, but not all, species that EPA classifies as marine in the national NHANES dataset (and excludes some species that EPA classifies as nearshore in the national NHANES dataset, *i.e.*, shellfish).

One way to adjust the RSC values to account for inclusion of marine fish in the FCR is to examine the ratio of the national data characterizing all fish consumption rates versus inland and nearshore-only fish consumption rates derived from the NHANES dataset, and apply this ratio to the proportion of the RfD reserved for inland and nearshore fish consumption in the RSC. This approach assumes that the pollutant concentrations in anadromous fish are the same as the pollutant concentrations in inland and nearshore fish, which is the same assumption inherent in including multiple fish categories in the FCR for criteria calculation. This approach further assumes that the ratio of all fish to inland and nearshore fish from NHANES data approximates the ratio of inland, nearshore, and anadromous fish to just inland and nearshore fish from CRITFC data. At the 90th percentile rate of consumption, the national adult consumption rate from NHANES data for all fish is 53 g/day and 22 g/day for inland and nearshore-only fish, or a ratio of 2.4. Applying this to a RSC of 0.2 yields 0.48, or 0.5 rounding to a single decimal place. Because the selected FCR includes some but not all marine species, EPA decided to use this approach to adjust the RSC values. However, EPA only adjusted RSC values to 0.5 for criteria calculations previously using a RSC between 0.2 and 0.5.

There are important considerations in assigning a RSC, such as the total number of potential exposure routes from sources other than fish consumption, which compels caution in using this approach in all cases. As such, EPA decided to retain RSC values of 0.5 and above, recognizing the compelling need to account for the other potential exposure sources, including marine fish not accounted for in the FCR of 175 g/day, consistent with the logic and procedures used in establishing the national 304(a) criteria recommendations. The Exposure Decision Tree in EPA's 2000 Methodology only recommends using a RSC above 0.5 when there are no significant known or potential uses/sources other than the source of concern (Box 7, Figure 4–1 in EPA's 2000 Methodology) or there are sufficient data available on each source to characterize the exposure to those sources (Box 8C, Figure 4–1). Neither of these conditions are met for most of the pollutants in the final rule for Washington. EPA is not adjusting the RSCs for pollutants that already have national recommended RSCs greater than or equal to 0.5 (2-Chloronaphthalene (0.8), Endrin (0.8), gamma-BHC/Lindane (0.5), and methylmercury (2.7×10^{-5} subtracted from the RfD, which equates to a RSC of approximately 0.73). See Table 1, column B2 for a list of EPA's final RSCs by pollutant.

d. Body Weight

EPA calculates final human health criteria for Washington using a body weight of 80 kg, which represents the average weight of a U.S. adult and is consistent with EPA's 2015 updated national default body weight (see section II.C.c).[61] Local tribal survey data relevant to Washington are also consistent with EPA's national adult body weight of 80 kg.[62] Most commenters were silent on EPA's proposal to use a body weight of 80 kg to calculate human health criteria for Washington. A few commenters were concerned that 80 kg would not ensure adequate protection of women and children, and may not be representative of all residents in Washington based on limited local or regional data on body weight specific to Washington residents. EPA understands these concerns, but decided that the survey on which EPA's national default of 80 kg is based provides the most comprehensive dataset to establish a body weight value for deriving statewide human health criteria for Washington, and is consistent with the local tribal survey data mentioned above. The data cited by commenters do not provide sufficient evidence to come up with an alternative statewide body weight input parameter since the studies cited are limited in scope and pertain to specific subpopulations. For detailed responses to the comments, see EPA's Response to Comment document in the docket for this rule.

e. Drinking Water Intake

EPA calculates final human health criteria for Washington using a drinking water intake rate of 2.4 L/day, consistent with EPA's 2015 updated national default drinking water intake rate (see section II.C.c).[63] Most commenters were

[59] USEPA. January 2013. *Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions. https://www.epa.gov/wqc/human-health-ambient-water-quality-criteria-and-fish-consumption-rates-frequently-asked.*

[60] *http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20003IEI.txt See* also: National Primary Drinking Water Regulations-Synthetic Organic Chemicals and Inorganic Chemicals; National Primary Drinking Water Regulations Implementation, 57 FR 31776, July 17, 1992.

[61] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[62] USEPA Region 10. August 2007. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. Appendix B. *http://yosemite.epa.gov/r10/CLEANUP.NSF/7780249be8f251538825650f0070bd8b/e12918970debc8e488256da6005c428e/$FILE/Tribal%20Shellfish%20Framework.pdf.*

[63] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

silent on or agreed with EPA's proposal to use a drinking water intake rate of 2.4 L/day to calculate human health criteria for Washington. However, two commenters stated this input was unnecessary in human health criteria derivation. Since at least the 1980s, EPA has included the drinking water exposure pathway in the development of human health criteria in order to protect water bodies with a drinking water designated use. EPA also provides the option of using organism-only human health criteria for water bodies where there is no drinking water use. One commenter stated that 2.4 L/day was an underestimate, and expressed concern that this value is not protective of tribal members who consume more water. EPA determined that it is appropriate to use its 2015 final national default drinking water intake rate, since it was adjusted pursuant to public comments after EPA issued the draft national default rate of 3 L/day in 2014. EPA acknowledges the concerns about members of the target general population who may consume larger amounts of water, but EPA does not have data (and did not receive any during the public comment period) with which to calculate a Washington-specific drinking water intake rate. For detailed responses to the comments, see EPA's Response to Comment document in the docket for this rule.

f. Pollutant-Specific Reference Doses and Cancer Slope Factors

As part of EPA's 2015 updates to its 304(a) recommended human health criteria, EPA conducted a systematic search of eight peer-reviewed, publicly available sources to obtain the most current toxicity values for each pollutant (RfDs for non-carcinogenic effects and CSFs for carcinogenic effects).[64] EPA calculates final human health criteria for Washington using the same toxicity values that EPA used in its 2015 304(a) criteria updates, to ensure that the resulting criteria are based on a sound scientific rationale. Where EPA did not update criteria for certain pollutants in 2015 and those pollutants are included in this final rule, EPA uses the toxicity values that the Agency used the last time it updated its 304(a) criteria for those pollutants as the best available scientific information. See Table 1, columns B1 and B3 for a list of EPA's final toxicity factors by pollutant.

In general, commenters were supportive of EPA using the latest and most scientifically defensible toxicity values to derive human health criteria for Washington. Some commenters expressed concern that where EPA did not update its 304(a) national recommended human health criteria for particular pollutants in 2015, the toxicity values from the existing 304(a) criteria for those pollutants were no longer valid. In particular, those commenters expressed concern about the CSFs for arsenic and PCBs, and the RfD for methylmercury, and argued that EPA should not revise Washington's criteria for those pollutants until toxicity factors are updated in the future. Unlike the situation with the toxicity factors for arsenic, dioxin and thallium (see section III.A), there is not sufficient scientific uncertainty surrounding the CSF for PCBs or the RfD for methylmercury to warrant delaying revision to Washington's human health criteria for these pollutants. For detailed responses to the comments, see EPA's Response to Comment document in the docket for this rule.

g. Pollutant-Specific Bioaccumulation Factors

For the 2015 national 304(a) human health criteria update, EPA estimated chemical-specific BAFs using a framework for deriving national BAFs described in EPA's 2000 Methodology.[65] Because the surveyed population upon which the 175 g/day FCR is based consumed almost exclusively trophic level four fish (*i.e.*, predator fish species), EPA uses the trophic level four BAF from the 2015 304(a) human health criteria updates in conjunction with the 175 g/day FCR, in order to derive protective criteria.[66] Where in 2015, EPA estimated BAFs from laboratory-measured BCFs and therefore derived a single pollutant-specific BAF for all trophic levels, EPA uses those single BAFs from the 2015 304(a) human health criteria updates. Where EPA's existing 304(a) recommended human health criteria for certain pollutants still incorporate a BCF, and those pollutants are included in this final rule, EPA uses those BCFs as the best available scientific information. See Table 1, columns B4 and B5 for a list of EPA's final bioaccumulation factors by pollutant.

Many commenters supported EPA's choice to use the latest and most scientifically defensible BAFs to derive human health criteria for Washington, and to use BCFs only when BAFs were not available for a given pollutant. Other commenters asserted that BCFs are no less scientifically defensible than BAFs, and that EPA did not provide sufficient information regarding how it developed BAFs in 2015 for commenters to fully evaluate EPA's proposed approach.

EPA's 2000 Methodology recommends use of BAFs that account for uptake of a contaminant from all sources by fish and shellfish, rather than BCFs that only account for uptake from the water column. EPA's 2015 national recommended BAFs are based on peer-reviewed, publicly available data and were developed consistent with EPA's 2000 Methodology and its supporting documents. EPA provided the basis for its 2015 BAFs in individual pollutant-specific criteria documents. The final human health criteria for Washington are consistent with EPA's 2000 Methodology, which makes clear that BAFs are a more scientifically defensible representation of bioaccumulation than BCFs. For detailed responses to the comments, see EPA's Response to Comment document in the docket for this rule.

D. Final Human Health Criteria for Washington

EPA finalizes 144 human health criteria for 74 different pollutants (72 organism-only criteria and 72 water-plus-organism criteria) to protect the applicable designated uses of Washington's waters (see Table 1). The water-plus-organism criteria in column C1 and the methylmercury criterion in column C2 of Table 1 are the applicable criteria for any waters that include the Domestic Water (domestic water supply) use defined in Washington's WQS (WAC 173–201A–600). The organism-only criteria in column C2 of Table 1 apply to waters that do not include the Domestic Water (domestic water supply) use and that Washington defines at WAC 173–201A–600 and 173–201A–610 as the following: Fresh waters—Harvesting (fish harvesting), and Recreational Uses; Marine waters—Shellfish Harvesting (shellfish—clam, oyster, and mussel—harvesting), Harvesting (salmonid and other fish

[64] Final Updated Ambient Water Quality Criteria for the Protection of Human Health, (80 FR 36986, June 29, 2015). See also: USEPA. 2015. Final 2015 Updated National Recommended Human Health Criteria. U.S. Environmental Protection Agency, Office of Water, Washington, DC *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[65] USEPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. U.S. Environmental Protection Agency, Office of Water, Washington, DC EPA–822–B–00–004. *https://www.epa.gov/wqc/human-health-water-quality-criteria.*

[66] *Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission (CRITFC), 1994)

harvesting, and crustacean and other shellfish—crabs, shrimp, scallops, etc.—harvesting), and Recreational Uses.

TABLE 1—HUMAN HEALTH CRITERIA FOR WASHINGTON

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg-d) (B1)	Relative source contribution, RSC (-) (B2)	Reference dose, RfD (mg/kg-d) (B3)	Bio-accumulation factor (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
1. 1,1,1-4Trichloroethane	71556		0.50	2	10		20,000	50,000
2. 1,1,2,2-Tetrachloroethane	79345	0.2	-		8.4		0.1	0.3
3. 1,1,2-Trichloroethane	79005	0.057	-		8.9		0.35	0.90
4. 1,1-Dichloroethylene	75354		0.50	0.05	2.6		700	4,000
5. 1,2,4-Trichlorobenzene	120821	0.029	-		430		0.036	0.037
6. 1,2-Dichlorobenzene	95501		0.50	0.3	82		700	800
7. 1,2-Dichloroethane	107062	0.0033	-		1.9		8.9	73
8. 1,2-Dichloropropane	78875		-					
9. 1,2-Diphenylhydrazine	122667	0.8	-		27		0.01	0.02
10. 1,2-Trans-Dichloroethylene	156605		0.50	0.02	4.7		200	1,000
11. 1,3-Dichlorobenzene	541731		0.50	0.002	190		2	2
12. 1,3-Dichloropropene	542756	0.122	-		3.0		0.22	1.2
13. 1,4-Dichlorobenzene	106467		0.50	0.07	84		200	200
14. 2,3,7,8–TCDD (Dioxin)**	1746016	156,000	-			5,000	1.3E–08	1.4E–08
15. 2,4,6-Trichlorophenol	88062		-					
16. 2,4-Dichlorophenol	120832		0.50	0.003	48		10	10
17. 2,4-Dimethylphenol	105679		-					
18. 2,4-Dinitrophenol	51285		0.50	0.002	4.4		30	100
19. 2,4-Dinitrotoluene	121142		-					
20. 2-Chloronaphthalene	91587		0.80	0.08	240		100	100
21. 2-Chlorophenol	95578		-					
22. 2-Methyl-4,6-Dinitrophenol	534521		0.50	0.0003	10		3	7
23. 3,3'-Dichlorobenzidine	91941		-					
24. 3-Methyl-4-Chlorophenol	59507		-					
25. 4,4'-DDD	72548	0.24	-		240,000		7.9E–06	7.9E–06
26. 4,4'-DDE	72559	0.167	-		3,100,000		8.8E–07	8.8E–07
27. 4,4'-DDT	50293	0.34	-		1,100,000		1.2E–06	1.2E–06
28. Acenaphthene	83329		0.50	0.06	510		30	30
29. Acrolein	107028		-					
30. Acrylonitrile	107131		-					
31. Aldrin	309002	17	-		650,000		4.1E–08	4.1E–08
32. alpha-BHC	319846	6.3	-		1,500		4.8E–05	4.8E–05
33. alpha-Endosulfan	959988		0.50	0.006	200		6	7
34. Anthracene	120127		0.50	0.3	610		100	100
35. Antimony	7440360		0.50	0.0004		1	6	90
36. Arsenic**	7440382	1.75	-			44	[a]0.018	[a]0.14
37. Asbestos	1332214		-					
38. Benzene	71432		-					
39. Benzidine	92875		-					
40. Benzo(a) Anthracene	56553	0.73	-		3,900		0.00016	0.00016
41. Benzo(a) Pyrene	50328	7.3	-		3,900		1.6E–05	1.6E–05
42. Benzo(b) Fluoranthene	205992	0.73	-		3,900		0.00016	0.00016
43. Benzo(k) Fluoranthene	207089	0.073	-		3,900		0.0016	0.0016
44. beta-BHC	319857	1.8	-		180		0.0013	0.0014
45. beta-Endosulfan	33213659		-					
46. Bis(2-Chloroethyl) Ether	111444		-					
47. Bis(2-Chloro-1-Methylethyl) Ether*	108601		0.50	0.04	10		400	900
48. Bis(2-Ethylhexyl) Phthalate	117817	0.014	-		710		0.045	0.046
49. Bromoform	75252	0.0045	-		8.5		4.6	12
50. Butylbenzyl Phthalate	85687	0.0019	-		19,000		0.013	0.013
51. Carbon Tetrachloride	56235		-					
52. Chlordane	57749	0.35	-		60,000		2.2E–05	2.2E–05
53. Chlorobenzene	108907		0.50	0.02	22		100	200
54. Chlorodibromomethane	124481	0.04	-		5.3		0.60	2.2
55. Chloroform	67663		0.50	0.01	3.8		100	600
56. Chrysene	218019	0.0073	-		3,900		0.016	0.016
57. Copper	7440508		-					
58. Cyanide	57125		0.50	0.0006		1	9	100
59. Dibenzo(a,h) Anthracene	53703	7.3	-		3,900		1.6E–05	1.6E–05
60. Dichlorobromomethane	75274	0.034	-		4.8		0.73	2.8
61. Dieldrin	60571	16	-		410,000		7.0E–08	7.0E–08
62. Diethyl Phthalate	84662		0.50	0.8	920		200	200
63. Dimethyl Phthalate	131113		0.50	10	4,000		600	600
64. Di-n-Butyl Phthalate	84742		0.50	0.1	2,900		8	8
65. Endosulfan Sulfate	1031078		0.50	0.006	140		9	
66. Endrin	72208		0.80	0.0003	46,000		0.002	0.002
67. Endrin Aldehyde	7421934		-					
68. Ethylbenzene	100414		0.50	0.022	160		29	31
69. Fluoranthene	206440		0.50	0.04	1,500		6	6
70. Fluorene	86737		0.50	0.04	710		10	10
71. gamma-BHC; Lindane	58899		0.50	0.0047	2,500		0.43	0.43

TABLE 1—HUMAN HEALTH CRITERIA FOR WASHINGTON—Continued

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (-) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
72. Heptachlor	76448	4.1	-		330,000		3.4E–07	3.4E–07
73. Heptachlor Epoxide	1024573	5.5	-		35,000		2.4E–06	2.4E–06
74. Hexachlorobenzene	118741	1.02	-		90,000		5.0E–06	5.0E–06
75. Hexachlorobutadiene	87683	0.04	-		1,100		0.01	0.01
76. Hexachlorocyclopentadiene	77474		0.50	0.006	1,300		1	1
77. Hexachloroethane	67721	0.04	-		600		0.02	0.02
78. Indeno(1,2,3-cd) Pyrene	193395	0.73	-		3,900		0.00016	0.00016
79. Isophorone	78591		-					
80. Methyl Bromide	74839		0.50	0.02	1.4		300	
81. Methylene Chloride	75092	0.002	-		1.6		10	100
82. Methylmercury	22967926		2.7E–05	0.0001				[b]0.03 (mg/kg)
83. Nickel	7440020		0.50	0.02		47	80	100
84. Nitrobenzene	98953		0.50	0.002	3.1		30	100
85. N-Nitrosodimethylamine	62759		-					
86. N-Nitrosodi-n-Propylamine	621647		-					
87. N-Nitrosodiphenylamine	86306		-					
88. Pentachlorophenol (PCP)	87865	0.4	-		520		0.002	0.002
89. Phenol	108952		0.50	0.6	1.9		9,000	70,000
90. Polychlorinated Biphenyls (PCBs)		2	-			31,200	[c]7E–06	[c]7E–06
91. Pyrene	129000		0.50	0.03	860		8	8
92. Selenium	7782492		0.50	0.005		4.8	60	200
93. Tetrachloroethylene	127184	0.0021	-		76		2.4	2.9
94. Thallium**	7440280		-	0.000068		116	1.7	6.3
95. Toluene	108883		0.50	0.0097	17		72	130
96. Toxaphene	8001352		-					
97. Trichloroethylene	79016	0.05	-		13		0.3	0.7
98. Vinyl Chloride	75014	1.5	-		1.7			0.18
99. Zinc	7440666		0.50	0.3		47	1,000	1,000

[a] This criterion refers to the inorganic form of arsenic only.
[b] This criterion is expressed as the fish tissue concentration of methylmercury (mg methylmercury/kg fish). See *Water Quality Criterion for the Protection of Human Health: Methylmercury* (EPA–823–R–01–001, January 3, 2001) for how this value is calculated using the criterion equation in EPA's 2000 Human Health Methodology rearranged to solve for a protective concentration in fish tissue rather than in water.
[c] This criterion applies to total PCBs (*e.g.*, the sum of all congener or isomer or homolog or Aroclor analyses).
* Bis(2-Chloro-1-Methylethyl) Ether was previously listed as Bis(2-Chloroisopropyl) Ether.
** These criteria were promulgated for Washington in the National Toxics Rule at 40 CFR 131.36, and are moved into 40 CFR 131.45 to have one comprehensive human health criteria rule for Washington.

E. Applicability of Criteria

These new and revised human health criteria apply for CWA purposes in addition to any existing criteria already applicable to Washington's waters, including the state's narrative toxics criteria statement at WAC 173–201A–260(2)(a), and those human health criteria that Washington submitted on August 1, 2016, and EPA approved concurrent with this final rule.

EPA replicates in 40 CFR 131.45 the same general rules of applicability for human health criteria as in 40 CFR 131.36(c), with one exception. For waters suitable for the establishment of low flow return frequencies (*i.e.*, streams and rivers), this final rule provides that Washington must not use a low flow value below which numeric standards can be exceeded that is less stringent than the harmonic mean flow (a long-term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows), so that the criteria are implemented to be protective of the applicable designated use. Per the *Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (65 FR 66444, November 3, 2000), EPA now recommends harmonic mean flow be used to implement human health criteria for both carcinogens and non-carcinogens.[67] EPA received one comment on this provision, asking for clarification on whether this is consistent with Washington's current permitting approach of using the 30Q5 flow for non-carcinogens.[68] In response, Washington's use of low flow statistics more stringent than the harmonic mean flow is consistent with EPA's final rule.

Under the CWA, Congress gave states primary responsibility for developing and adopting WQS for their navigable waters (CWA section 303(a)-(c)). Although EPA revises and establishes new human health criteria for Washington in this final rule, Washington continues to have the option to adopt and submit to EPA human health criteria for the pollutants in this final rule, consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131.

In its September 14, 2015 proposed rule, EPA proposed that if Washington adopted and submitted human health criteria, and EPA approved those criteria before finalizing its federal rule, EPA would not proceed with finalizing those criteria and Washington's approved criteria would be solely applicable for CWA purposes. EPA did not receive any comments opposing this provision, thus EPA is proceeding with such an approach. In this final rule, EPA is withdrawing Washington from the NTR at 40 CFR 131.36, and, with the exception of criteria for which EPA has approved Washington's criteria, EPA is incorporating the Washington-specific criteria in this rule (as well as the existing NTR criteria for arsenic, dioxin

[67] See also USEPA. 2014. Water Quality Standards Handbook—Chapter 5: General Policies. U.S. Environmental Protection Agency. Office of Water. Washington, DC EPA–820–B–14–004. *https://www.epa.gov/wqs-tech/water-quality-standards-handbook.*

[68] The 30Q5 flow is the lowest 30-day average flow event expected to occur once every five years, on average (determined hydrologically).

and thallium) into 40 CFR 131.45 so there is a single comprehensive set of federally promulgated criteria for Washington. Therefore, the CWA-effective numeric human health criteria in Washington consist of the federally promulgated criteria at 40 CFR 131.45 and those criteria that EPA approved at WAC 173–201A–240 in Washington's August 1, 2016 submittal.

Additionally, in its September 14, 2015 proposed rule, EPA proposed that if Washington adopted and submitted human health criteria after EPA finalized its rule, once EPA approved Washington's WQS, the pollutant-specific or site-specific EPA-approved criteria in Washington's WQS would become the solely effective criteria for CWA purposes and EPA's promulgated criteria for those pollutants or for that site would no longer apply. A few commenters supported this provision, where Washington's criteria for specific pollutants or sites become the only CWA-effective criteria upon EPA's approval, without any delay caused by EPA's withdrawal of the corresponding federal criteria. A few other commenters did not support this provision, and asked that EPA either delete the provision, or make clear that criteria adopted by the state would have to be at least as stringent as the federal criteria for EPA to approve and make the state criteria effective for CWA purposes. Upon further consideration of comments received on its proposed rule, EPA decided not to finalize this provision. Pursuant to 40 CFR 131.21(c), EPA's federally promulgated WQS are and will be applicable for purposes of the CWA until EPA withdraws those federally promulgated WQS. EPA would undertake such a rulemaking to withdraw the federal criteria if and when Washington adopts and EPA approves corresponding criteria that meet the requirements of section 303(c) of the CWA and EPA's implementing regulations at 40 CFR part 131.

F. Alternative Regulatory Approaches and Implementation Mechanisms

Washington has considerable discretion to implement these revised and new federal human health criteria through various water quality control programs including the NPDES program, which limits discharges to waters except in compliance with a NPDES permit. EPA's regulations at 40 CFR 131.14 authorize states and authorized tribes to adopt WQS variances to provide time to achieve the applicable WQS. 40 CFR part 131 defines WQS variances at 131.3(o) as time-limited designated uses and supporting criteria for a specific pollutant(s) or water quality parameter(s) that reflect the highest attainable conditions during the term of the WQS variances. WQS variances adopted in accordance with 40 CFR part 131 allow states and authorized tribes to address water quality challenges in a transparent and predictable way. Variances help states and authorized tribes focus on making incremental progress in improving water quality, rather than pursuing a downgrade of the underlying water quality goals through a designated use change, when the designated use is not attainable throughout the term of the variance due to one of the factors listed in 40 CFR 131.14. EPA's regulations at 40 CFR 122.47 provide the requirements when states and authorized tribes wish to include permit compliance schedules in their NPDES permits if dischargers need additional time to meet their water quality-based limits based on the applicable WQS. EPA's updated regulations at 40 CFR 131.15 require any state or authorized tribe wishing to use permit compliance schedules to also include provisions authorizing the use of permit compliance schedules after appropriate public involvement to ensure that a decision to allow permit compliance schedules derives from and complies with the applicable WQS. (80 FR 51022, August 21, 2015).

40 CFR 131.10 specifies how states and authorized tribes establish, modify or remove designated uses for their waters. 40 CFR 131.11 specifies the requirements for establishing criteria to protect designated uses, including criteria modified to reflect site-specific conditions. In the context of this rulemaking, a site-specific criterion (SSC) is an alternative value to the federal human health criteria that could be applied on a watershed, area-wide, or waterbody-specific basis that meets the regulatory test of protecting the designated use, being scientifically defensible, and ensuring the protection and maintenance of downstream WQS. A SSC may be more or less stringent than the otherwise applicable federal criterion. A SSC may be appropriate when further scientific data and analyses can bring added precision to express the concentration of a particular pollutant that protects the human health-related designated use in a particular waterbody.

A few commenters supported EPA's acknowledgement of the flexibilities that Washington has available when implementing the final criteria in this rule, while others commented that these tools allow Washington to delay or avoid implementing the criteria. EPA did not propose to change, nor does this final rule change, any of the flexibilities already afforded to Washington by EPA's regulations to modify or remove designated uses, adopt variances, issue compliance schedules, or establish site-specific criteria. These implementation tools are important for making incremental progress and allowing the time for adaptive management when designated uses and associated criteria are difficult to attain. Washington may continue to use any of these regulatory flexibilities when implementing the final federal human health criteria.

a. Designating Uses

EPA's final human health criteria apply to waters that Washington has designated for the following: Fresh waters—Harvesting (fish harvesting), Domestic Water (domestic water supply), and Recreational Uses; Marine waters—Shellfish Harvesting (shellfish—clam, oyster, and mussel—harvesting), Harvesting (salmonid and other fish harvesting, and crustacean and other shellfish—crabs, shrimp, scallops, etc.—harvesting), and Recreational Uses (see WAC 173–201A–600 and WAC 173–201A–610). If Washington removes the Domestic Water use but retains any of the other above designated uses for any particular waterbody affected by this final rule, and EPA finds that removal to be consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131, then the federal organism-only criteria will apply in place of the federal water-plus-organism criteria. If Washington removes designated uses such that none of the above uses apply to any particular waterbody affected by this final rule and adopts the highest attainable use, as defined by 40 CFR 131.3(m), consistent with 40 CFR 131.10(g), and EPA finds that removal to be consistent with CWA section 303(c) and EPA's implementing regulations at 40 CFR part 131, then the federal human health criteria will no longer apply to that waterbody. Instead, any criteria associated with the newly designated highest attainable use would apply to that waterbody.

b. Variances and Compliance Schedules

EPA's final human health criteria apply to use designations that Washington has already established. Concurrent with this final rule, EPA approved revisions to Washington's variance and compliance schedule authorizing provisions. Washington may use its EPA-approved variance procedures (see WAC 173–201A–420) to establish time-limited designated uses and criteria to apply for the purposes specified in 40 CFR 131.14 as it pertains

to federal criteria when adopting such variances. Washington has sufficient authority to use variances when implementing the human health criteria as long as such variances are adopted consistent with 40 CFR 131.14, and submitted to EPA for review under CWA section 303(c). Similarly, Washington may use its EPA-approved regulation authorizing the use of permit compliance schedules (see WAC 173–201A–510(4)), consistent with 40 CFR 131.15, to grant compliance schedules, as appropriate, for WQBELs based on the federal criteria. These state regulations are not affected by this final rule.

c. Site-Specific Criteria

As discussed in section III.E, if Washington adopts and EPA approves site-specific criteria that fully meet the requirements of section 303(c) of the CWA and EPA's implementing regulations at 40 CFR part 131, EPA will undertake a rulemaking to withdraw the corresponding federal criteria.

IV. Economic Analysis

Under the CWA, water quality criteria are set on the basis of the latest scientific knowledge. EPA is not required under the CWA nor obligated under Executive Orders 12866 and 13563 to conduct an economic analysis of the criteria. Costs cannot be considered in establishing water quality criteria as part of WQS. Nonetheless, EPA conducted a cost analysis for the criteria in this final rule for the purpose of transparency and presents this information reflecting the potential economic effects of the rule.

These WQS may serve as a basis for development of NPDES permit limits. Washington has NPDES permitting authority, and retains considerable discretion in implementing standards. EPA evaluated the potential costs to NPDES dischargers associated with state implementation of EPA's final criteria. This analysis is documented in *Final Economic Analysis for the Revision of Certain Federal Water Quality Criteria Applicable to Washington,* which can be found in the record for this rulemaking.

Any NPDES-permitted facility that discharges pollutants for which the revised human health criteria are more stringent than the applicable aquatic life criteria (or for which human health criteria are the only applicable criteria) could potentially incur compliance costs. The types of affected facilities could include industrial facilities and POTWs discharging wastewater to surface waters (*i.e.,* point sources). EPA did not attribute compliance with water quality-based effluent limitations (WQBELs) reflective of existing federal human health criteria applicable to Washington (hereafter referred to as "baseline criteria") to the final rule. Once in compliance with WQBELs reflective of baseline criteria, EPA expects that dischargers will continue to use the same types of controls to come into compliance with the revised criteria; EPA did not fully evaluate the potential for costs to nonpoint sources,[69] such as agricultural runoff, that could be incurred under a TMDL for this analysis, but did analyze the administrative costs to the state of preparing TMDLs for potentially incrementally impaired waters. Actual costs of implementation of TMDLs is beyond the scope of this analysis.

A. Identifying Affected Entities

EPA identified 406 point source facilities that could ultimately be affected by this final rule. Of these potentially affected facilities, 73 are major dischargers and 333 are minor dischargers. EPA did not include general permit facilities in its analysis because data for such facilities are limited, and flows are usually negligible. Of the potentially affected facilities, EPA evaluated a sample of 17 major facilities. Minor facilities are unlikely to incur costs as a result of implementation of the rule, because minor facilities are typically those that do not discharge toxics in toxic amounts and discharge less than 1 million gallons per day (mgd). Although lower human health criteria could potentially change this categorization, EPA did not have effluent data on toxic pollutants to evaluate minor facilities for this analysis. Table 2 summarizes these potentially affected facilities by type and category.

TABLE 2—POTENTIALLY AFFECTED FACILITIES

Category	Minor	Major	All
Municipal	184	48	232
Industrial	149	25	174
Total	333	73	406

B. Method for Estimating Costs

EPA evaluated the two major municipal facilities with design flows greater than 100 mgd and a large industrial refinery, to attempt to capture the facilities with the potential for the largest costs. For the remaining major facilities, EPA evaluated a random sample of facilities to represent discharger type and category. For all sample facilities, EPA evaluated existing baseline permit conditions, reasonable potential to exceed human health criteria based on the final rule, and potential to exceed projected effluent limitations based on the last three years of effluent monitoring data (if available). In instances of exceedances of projected effluent limitations under the final criteria, EPA determined the likely compliance scenarios and costs. Only compliance actions and costs that would be needed above the baseline level of controls are attributable to the final rule.

EPA assumed that dischargers will pursue the least cost means of compliance with WQBELs. Incremental compliance actions attributable to the final rule may include pollution prevention, end-of-pipe treatment, and alternative compliance mechanisms (*e.g.,* variances). EPA annualized one-

[69] The CWA does not regulate nonpoint sources. However, EPA recognizes that the state may require controls for nonpoint sources as part of potential incremental TMDLs. It is difficult to model and evaluate the potential cost impacts of this final rule to nonpoint sources because they are intermittent, variable, and occur under hydrologic or climatic conditions associated with precipitation events. Also, data on instream and discharge levels of the pollutants of concern after dischargers have implemented controls to meet current WQS, total maximum daily loads (TMDLs) for impaired waters, or other water quality improvement plans, are not available. Therefore, trying to determine which sources would not achieve WQS based on the revised human health criteria after complying with existing regulations and policies may not be possible. In addition, legacy contamination (*e.g.,* in sediment) may be a source of ongoing loading. Atmospheric deposition may also contribute loadings of the pollutants of concern (*e.g.,* mercury). EPA did not estimate sediment remediation costs, or air pollution controls costs, for this analysis because EPA did not have data on the contribution of these sources, and because control costs for deposition may be covered by Clean Air Act rules.

time costs (capital costs and variance costs) over 20 years using a 3 percent discount rate to obtain total annual costs per facility. For the random sample, EPA extrapolated the annualized costs based on the sampling weight for each sample facility. To obtain an estimate of total costs to point sources, EPA added the results for the certainty sample to the extrapolated random sample costs.

C. Results

Based on the results for 17 sample facilities across 8 industrial and municipal categories,[70] EPA estimated a total annual compliance cost of approximately $126,000 to $150,000 for all major dischargers in the state (using a 3 percent discount rate). Only five facilities are estimated to incur pollution prevention program costs, while two facilities are expected to also incur costs of obtaining a variance. Most of the facilities would not bear any cost. The low end of the range reflects the assumption that the compliance actions (*e.g.,* pollution prevention) will result in compliance with projected effluent limits, whereas the high scenario reflects projected effluent limits not being met, and thus includes the estimated administrative cost of also obtaining a variance. All compliance costs are for industrial facilities, and are attributable to the human health criterion for methylmercury.

If the revised criteria result in an incremental increase in impaired waters, resulting in the need for TMDL development, there could also be some costs to nonpoint sources of pollution. Using available ambient monitoring data, EPA compared pollutant concentrations to the baseline and final criteria, identifying waterbodies that may be incrementally impaired (*i.e.,* impaired under the final criteria but not under the baseline). For the parameters and stations for which EPA had sufficient monitoring data available to evaluate, there were 50 impairments under the baseline criteria and 124 under the final criteria, for a total of 74 potential incremental impairments (or a 148 percent increase relative to the baseline; including for methylmercury, PCBs, and DDT). This increase indicates the potential for nonpoint sources to bear some compliance costs, although data are not available to estimate the magnitude of these costs. The control of nonpoint sources such as in the context of a TMDL could result in different requirements, and thus different costs, for point sources.

If the net increase in potential impairments is any indication of the potential increase in the number of TMDLs, then the total administrative costs for TMDL development could be in the range of $2.7 million to $3.0 million based on national average single-cause single-waterbody TMDL development costs from U.S. EPA (2001; updated to 2014 dollars). However, these costs may be reduced if Ecology develops multi-cause or multi-waterbody TMDLs. If these costs are spread over 8 to 15 years, at a discount rate of 3 percent, the annualized costs of developing TMDLs are $229,000 to $422,000.

Combining the potential facility compliance costs and TMDL administrative costs results in total annual costs of $355,000 to $572,000, at a 3 percent discount rate.

V. Statutory and Executive Order Reviews

A. Executive Order 12866 (Regulatory Planning and Review) and Executive Order 13563 (Improving Regulation and Regulatory Review)

It has been determined that this final rule is not a "significant regulatory action" under the terms of Executive Order 12866 (58 FR 51735, October 4, 1993) and is, therefore, not subject to review under Executive Orders 12866 and 13563 (76 FR 3821, January 21, 2011). The final rule does not establish any requirements directly applicable to regulated entities or other sources of toxic pollutants. However, these WQS may serve as a basis for development of NPDES permit limits. Washington has NPDES permitting authority, and retains considerable discretion in implementing standards. In the spirit of Executive Order 12866, EPA evaluated the potential costs to NPDES dischargers associated with state implementation of EPA's final criteria. This analysis, *Final Economic Analysis for the Revision of Certain Federal Water Quality Criteria Applicable to Washington,* is summarized in section IV of the preamble and is available in the docket.

B. Paperwork Reduction Act

This action does not impose any direct new information collection burden under the provisions of the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* Actions to implement these WQS could entail additional paperwork burden. Burden is defined at 5 CFR 1320.3(b). This action does not include any information collection, reporting, or record-keeping requirements.

C. Regulatory Flexibility Act

I certify that this action will not have a significant economic impact on a substantial number of small entities under the RFA. This action will not impose any requirements on small entities. EPA has the authority to promulgate WQS in any case where the Administrator determines that a new or revised standard is necessary to meet the requirements of the CWA. EPA-promulgated standards are implemented through various water quality control programs including the NPDES program, which limits discharges to navigable waters except in compliance with an NPDES permit. The CWA requires that all NPDES permits include any limits on discharges that are necessary to meet applicable WQS. Thus, under the CWA, EPA's promulgation of WQS establishes standards that the state implements through the NPDES permit process. The state has discretion in developing discharge limits, as needed to meet the standards. As a result of this action, the State of Washington will need to ensure that permits it issues include any limitations on discharges necessary to comply with the standards established in the final rule. In doing so, the state will have a number of choices associated with permit writing. While Washington's implementation of the rule may ultimately result in new or revised permit conditions for some dischargers, including small entities, EPA's action, by itself, does not impose any of these requirements on small entities; that is, these requirements are not self-implementing.

D. Unfunded Mandates Reform Act

This action contains no federal mandates under the provisions of Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), 2 U.S.C. 1531–1538 for state, local, or tribal governments or the private sector. As these water quality criteria are not self-implementing, EPA's action imposes no enforceable duty on any state, local or tribal governments or the private sector. Therefore, this action is not subject to the requirements of sections 202 or 205 of UMRA.

This action is also not subject to the requirements of section 203 of UMRA because it contains no regulatory requirements that could significantly or uniquely affect small governments.

E. Executive Order 13132 (Federalism)

This action does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the national

[70] Seven industrial categories (mining, food and kindred products, paper and allied products, chemicals and allied products, petroleum refining and related industries, primary metal industries, and transportation and public utilities (except POTWs)) and municipal POTWs.

government and the states, or on the distribution of power and responsibilities among the various levels of government. This rule does not alter Washington's considerable discretion in implementing these WQS, nor will it preclude Washington from adopting WQS in the future that EPA concludes meet the requirements of the CWA, which will eliminate the need for federal standards. Thus, Executive Order 13132 does not apply to this action.

F. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)

This action has tribal implications. However, it will neither impose substantial direct compliance costs on federally recognized tribal governments, nor preempt tribal law. In the State of Washington, there are 29 federally recognized Indian tribes. To date, nine of these Indian tribes have been approved for TAS for CWA sections 303 and 401.[71] Of these nine tribes, seven have EPA-approved WQS in their respective jurisdictions.[72] This rule could affect federally recognized Indian tribes in Washington because the numeric criteria for Washington will apply to waters adjacent to (or upstream or downstream of) the tribal waters, where many of those tribes have treaty rights to take fish for their subsistence. Additionally, there are ten federally recognized Indian tribes in the Columbia River Basin located in the states of Oregon and Idaho that this rule could impact because their waters could affect or be affected by the water quality of Washington's downstream or upstream waters.

EPA consulted with federally recognized tribal officials under EPA's Policy on Consultation and Coordination with Indian Tribes early in the process of developing this rule to permit them to have meaningful and timely input into its development. In February and March 2015, EPA held tribes-only technical staff and leadership consultation sessions to hear their views and answer questions of all interested tribes on the proposed rule. Representatives from approximately 23 tribes and four tribal consortia participated in two leadership meetings held in March 2015. EPA and tribes have also met regularly since November 2012 to discuss Washington's human health criteria at both the tribal leadership level and technical staff level. The tribes have repeatedly asked EPA to promulgate federal human health criteria for Washington if the state did not do so in a timely and protective manner. At these meetings, the tribes consistently emphasized that the human health criteria should be derived using at least a minimum FCR value of 175 g/day, a cancer risk level of 10^{-6}, and the latest scientific information from EPA's 304(a) recommended criteria. EPA considered the input received during consultation with tribes when developing this final rule (see section III for additional discussion of how EPA considered tribal input).

In subsequent coordination with tribes, EPA received a letter on August 5, 2016, from the Northwest Indian Fisheries Commission disagreeing with EPA's potential adjustments to the RSC from the proposed rule issued on September 14, 2015 to the final rule as a result of public comments. The tribes expressed concern that less stringent human health criteria as a result of the RSC adjustment would result in lower protection of designated uses and limit the ability to exercise tribal treaty rights, especially in light of a FCR that underestimates tribal consumption. EPA considered this information carefully before finalizing this rule, but for the reasons stated above, decided to adjust the RSC to account for inclusion of some marine fish in the FCR. This results in protective criteria that account for other routes of exposure in addition to drinking water and fish and shellfish from inland and nearshore waters and is consistent with EPA's guidance.

G. Executive Order 13045 (Protection of Children From Environmental Health and Safety Risks)

This rule is not subject to Executive Order 13045, because it is not economically significant as defined in Executive Order 12866, and because the environmental health or safety risks addressed by this action do not present a disproportionate risk to children.

H. Executive Order 13211 (Actions That Significantly Affect Energy Supply, Distribution, or Use)

This action is not a "significant energy action" because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy.

I. National Technology Transfer and Advancement Act of 1995

This final rulemaking does not involve technical standards.

J. Executive Order 12898 (Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations)

This action will not have disproportionately high and adverse human health or environmental effects on minority or low-income populations. Conversely, this action identifies and ameliorates disproportionately high and adverse human health effects on minority populations and low-income populations in Washington. EPA developed the human health criteria included in this final rule specifically to protect Washington's designated uses, using the most current science, including local and regional information on fish consumption. Applying these criteria to waters in the State of Washington will afford a greater level of protection to both human health and the environment.

K. Congressional Review Act (CRA)

This action is subject to the CRA, and EPA will submit a rule report to each House of the Congress and to the Comptroller General of the United States. This action is not a "major rule" as defined by 5 U.S.C. 804(2).

List of Subjects in 40 CFR Part 131

Environmental protection, Indians-lands, Intergovernmental relations, Reporting and recordkeeping requirements, Water pollution control.

Dated: November 15, 2016.

Gina McCarthy,

Administrator.

For the reasons set forth in the preamble, EPA amends 40 CFR part 131 as follows:

PART 131—WATER QUALITY STANDARDS

■ 1. The authority citation for part 131 continues to read as follows:

Authority: 33 U.S.C. 1251 *et seq.*

Subpart D—Federally Promulgated Water Quality Standards

§ 131.36 [Amended]

■ 2. In § 131.36, remove paragraph (d)(14).

■ 3. Add § 131.45 to read as follows:

§ 131.45 Revision of certain Federal water quality criteria applicable to Washington.

(a) *Scope.* This section promulgates human health criteria for priority toxic

[71] *http://water.epa.gov/scitech/swguidance/standards/wqslibrary/approvtable.cfm.*

[72] *http://yosemite.epa.gov/r10/water.nsf/34090d07b77d50bd88256b79006529e8/dd2a4df00fd7ae1a88256e0500680e86!OpenDocument.* Note that this number does not include the Confederated Tribes of the Colville Reservation, which has federally promulgated WQS from 1989. EPA is currently reviewing the Colville Tribe's application for TAS.

pollutants in surface waters in Washington.

(b) *Criteria for priority toxic pollutants in Washington.* The applicable human health criteria are shown in Table 1.

TABLE 1—HUMAN HEALTH CRITERIA FOR WASHINGTON

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg-d) (B1)	Relative source contribution, RSC (-) (B2)	Reference dose, RfD (mg/kg-d) (B3)	Bio-accumulation factor (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
1. 1,1,1-Trichloroethane	71556		0.50	2	10		20,000	50,000
2. 1,1,2,2-Tetrachloroethane	79345	0.2	-		8.4		0.1	0.3
3. 1,1,2-Trichloroethane	79005	0.057	-		8.9		0.35	0.90
4. 1,1-Dichloroethylene	75354		0.50	0.05	2.6		700	4,000
5. 1,2,4-Trichlorobenzene	120821	0.029	-		430		0.036	0.037
6. 1,2-Dichlorobenzene	95501		0.50	0.3	82		700	800
7. 1,2-Dichloroethane	107062	0.0033	-		1.9		8.9	73
8. 1,2-Dichloropropane	78875		-					
9. 1,2-Diphenylhydrazine	122667	0.8	-		27		0.01	0.02
10. 1,2-Trans-Dichloroethylene	156605		0.50	0.02	4.7		200	1,000
11. 1,3-Dichlorobenzene	541731		0.50	0.002	190		2	2
12. 1,3-Dichloropropene	542756	0.122	-		3.0		0.22	1.2
13. 1,4-Dichlorobenzene	106467		0.50	0.07	84		200	200
14. 2,3,7,8-TCDD (Dioxin)**	1746016	156,000	-			5,000	1.3E-08	1.4E-08
15. 2,4,6-Trichlorophenol	88062		-					
16. 2,4-Dichlorophenol	120832		0.50	0.003	48		10	10
17. 2,4-Dimethylphenol	105679		-					
18. 2,4-Dinitrophenol	51285		0.50	0.002	4.4		30	100
19. 2,4-Dinitrotoluene	121142		-					
20. 2-Chloronaphthalene	91587		0.80	0.08	240		100	100
21. 2-Chlorophenol	95578		-					
22. 2-Methyl-4,6-Dinitrophenol	534521		0.50	0.0003	10		3	7
23. 3,3'-Dichlorobenzidine	91941		-					
24. 3-Methyl-4-Chlorophenol	59507		-					
25. 4,4'-DDD	72548	0.24	-		240,000		7.9E-06	7.9E-06
26. 4,4'-DDE	72559	0.167	-		3,100,000		8.8E-07	8.8E-07
27. 4,4'-DDT	50293	0.34	-		1,100,000		1.2E-06	1.2E-06
28. Acenaphthene	83329		0.50	0.06	510		30	30
29. Acrolein	107028		-					
30. Acrylonitrile	107131		-					
31. Aldrin	309002	17	-		650,000		4.1E-08	4.1E-08
32. alpha-BHC	319846	6.3	-		1,500		4.8E-05	4.8E-05
33. alpha-Endosulfan	959988		0.50	0.006	200		6	7
34. Anthracene	120127		0.50	0.3	610		100	100
35. Antimony	7440360		0.50	0.0004		1	6	90
36. Arsenic**	7440382	1.75	-			44	[a]0.018	[a]0.14
37. Asbestos	1332214		-					
38. Benzene	71432		-					
39. Benzidine	92875		-					
40. Benzo(a) Anthracene	56553	0.73	-		3,900		0.00016	0.00016
41. Benzo(a) Pyrene	50328	7.3	-		3,900		1.6E-05	1.6E-05
42. Benzo(b) Fluoranthene	205992	0.73	-		3,900		0.00016	0.00016
43. Benzo(k) Fluoranthene	207089	0.073	-		3,900		0.0016	0.0016
44. beta-BHC	319857	1.8	-		180		0.0013	0.0014
45. beta-Endosulfan	33213659		-					
46. Bis(2-Chloroethyl) Ether	111444		-					
47. Bis(2-Chloro-1-Methylethyl) Ether*	108601		0.50	0.04	10		400	900
48. Bis(2-Ethylhexyl) Phthalate	117817	0.014	-		710		0.045	0.046
49. Bromoform	75252	0.0045	-		8.5		4.6	12
50. Butylbenzyl Phthalate	85687	0.0019	-		19,000		0.013	0.013
51. Carbon Tetrachloride	56235		-					
52. Chlordane	57749	0.35	-		60,000		2.2E-05	2.2E-05
53. Chlorobenzene	108907		0.50	0.02	22		100	200
54. Chlorodibromomethane	124481	0.04	-		5.3		0.60	2.2
55. Chloroform	67663		0.50	0.01	3.8		100	600
56. Chrysene	218019	0.0073	-		3,900		0.016	0.016
57. Copper	7440508		-					
58. Cyanide	57125		0.50	0.0006		1	9	100
59. Dibenzo(a,h) Anthracene	53703	7.3	-		3,900		1.6E-05	1.6E-05
60. Dichlorobromomethane	75274	0.034	-		4.8		0.73	2.8
61. Dieldrin	60571	16	-		410,000		7.0E-08	7.0E-08
62. Diethyl Phthalate	84662		0.50	0.8	920		200	200
63. Dimethyl Phthalate	131113		0.50	10	4,000		600	600
64. Di-n-Butyl Phthalate	84742		0.50	0.1	2,900		8	8
65. Endosulfan Sulfate	1031078		0.50	0.006	140		9	
66. Endrin	72208		0.80	0.0003	46,000		0.002	0.002
67. Endrin Aldehyde	7421934		-					
68. Ethylbenzene	100414		0.50	0.022	160		29	31
69. Fluoranthene	206440		0.50	0.04	1,500		6	6
70. Fluorene	86737		0.50	0.04	710		10	10
71. gamma-BHC; Lindane	58899		0.50	0.0047	2,500		0.43	0.43

TABLE 1—HUMAN HEALTH CRITERIA FOR WASHINGTON—Continued

A		B					C	
Chemical	CAS No.	Cancer slope factor, CSF (per mg/kg·d) (B1)	Relative source contribution, RSC (-) (B2)	Reference dose, RfD (mg/kg·d) (B3)	Bio-accumulation factor (L/kg tissue) (B4)	Bio-concentration factor (L/kg tissue) (B5)	Water & organisms (µg/L) (C1)	Organisms only (µg/L) (C2)
72. Heptachlor	76448	4.1	-	.....	330,000	.....	3.4E-07	3.4E-07
73. Heptachlor Epoxide	1024573	5.5	-	.....	35,000	.....	2.4E-06	2.4E-06
74. Hexachlorobenzene	118741	1.02	-	.....	90,000	.....	5.0E-06	5.0E-06
75. Hexachlorobutadiene	87683	0.04	-	.....	1,100	.....	0.01	0.01
76. Hexachlorocyclopentadiene	77474	.....	0.50	0.006	1,300	.....	1	1
77. Hexachloroethane	67721	0.04	-	.....	600	.....	0.02	0.02
78. Indeno(1,2,3-cd) Pyrene	193395	0.73	-	.....	3,900	.....	0.00016	0.00016
79. Isophorone	78591	.....	-	.....	.....	.....	.....	.....
80. Methyl Bromide	74839	.....	0.50	0.02	1.4	.....	300	.....
81. Methylene Chloride	75092	0.002	-	.....	1.6	.....	10	100
82. Methylmercury	22967926	.....	2.7E-05	0.0001	.....	.....	.....	[b]0.03 (mg/kg)
83. Nickel	7440020	.....	0.50	0.02	.....	47	80	100
84. Nitrobenzene	98953	.....	0.50	0.002	3.1	.....	30	100
85. N-Nitrosodimethylamine	62759	.....	-	.....	.....	.....	.....	.....
86. N-Nitrosodi-n-Propylamine	621647	.....	-	.....	.....	.....	.....	.....
87. N-Nitrosodiphenylamine	86306	.....	-	.....	.....	.....	.....	.....
88. Pentachlorophenol (PCP)	87865	0.4	-	.....	520	.....	0.002	0.002
89. Phenol	108952	.....	0.50	0.6	1.9	.....	9,000	70,000
90. Polychlorinated Biphenyls (PCBs)	.....	2	-	.....	.....	31,200	[c]7E-06	[c]7E-06
91. Pyrene	129000	.....	0.50	0.03	860	.....	8	8
92. Selenium	7782492	.....	0.50	0.005	.....	4.8	60	200
93. Tetrachloroethylene	127184	0.0021	-	.....	76	.....	2.4	2.9
94. Thallium**	7440280	.....	-	0.000068	.....	116	1.7	6.3
95. Toluene	108883	.....	0.50	0.0097	17	.....	72	130
96. Toxaphene	8001352	.....	-	.....	.....	.....	.....	.....
97. Trichloroethylene	79016	0.05	-	.....	13	.....	0.3	0.7
98. Vinyl Chloride	75014	1.5	-	.....	1.7	.....	.....	0.18
99. Zinc	7440666	.....	0.50	0.3	.....	47	1,000	1,000

[a] This criterion refers to the inorganic form of arsenic only.
[b] This criterion is expressed as the fish tissue concentration of methylmercury (mg methylmercury/kg fish). See *Water Quality Criterion for the Protection of Human Health: Methylmercury* (EPA–823–R–01–001, January 3, 2001) for how this value is calculated using the criterion equation in EPA's 2000 Human Health Methodology rearranged to solve for a protective concentration in fish tissue rather than in water.
[c] This criterion applies to total PCBs (*e.g.*, the sum of all congener or isomer or homolog or Aroclor analyses).
* Bis(2-Chloro-1-Methylethyl) Ether was previously listed as Bis(2-Chloroisopropyl) Ether.
** These criteria were promulgated for Washington in the National Toxics Rule at 40 CFR 131.36, and are moved into 40 CFR 131.45 to have one comprehensive human health criteria rule for Washington.

(c) *Applicability.* (1) The criteria in paragraph (b) of this section apply to waters with Washington's designated uses cited in paragraph (d) of this section and apply concurrently with other applicable water quality criteria.

(2) The criteria established in this section are subject to Washington's general rules of applicability in the same way and to the same extent as are other federally promulgated and state-adopted numeric criteria when applied to the same use classifications in paragraph (d) of this section.

(i) For all waters with mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the waterbody including at the end of any discharge pipe, conveyance or other discharge point within the waterbody.

(ii) The state must not use a low flow value below which numeric non-carcinogen and carcinogen human health criteria can be exceeded that is less stringent than the harmonic mean flow for waters suitable for the establishment of low flow return frequencies (*i.e.*, streams and rivers). Harmonic mean flow is a long-term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

(iii) If the state does not have such a low flow value for numeric criteria, then none will apply and the criteria in paragraph (b) of this section herein apply at all flows.

(d) *Applicable use designations.* (1) All waters in Washington assigned to the following use classifications are subject to the criteria identified in paragraph (d)(2) of this section:

(i) Fresh waters—

(A) Miscellaneous uses: Harvesting (Fish harvesting);

(B) Recreational uses;

(C) Water supply uses: Domestic water (Domestic water supply);

(ii) Marine waters—

(A) Miscellaneous uses: Harvesting (Salmonid and other fish harvesting, and crustacean and other shellfish (crabs, shrimp, scallops, etc.) harvesting);

(B) Recreational uses;

(C) Shellfish harvesting: Shellfish harvest (Shellfish (clam, oyster, and mussel) harvesting)

Note to paragraph (d)(1): The source of these uses is Washington Administrative Code 173–201A–600 for Fresh waters and 173–201A–610 for Marine waters.

(2) For Washington waters that include the use classification of Domestic Water, the criteria in column C1 and the methylmercury criterion in column C2 of Table 1 in paragraph (b) of this section apply. For Washington waters that include any of the following use classifications but do not include the use classification of Domestic Water, the criteria in column C2 of Table 1 in paragraph (b) of this section apply: Harvesting (fresh and marine waters), Recreational Uses (fresh and marine waters), and Shellfish Harvesting.

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Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)

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Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)

Final

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Office of Water
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NOTICE

The policies and procedures set forth in this document are intended solely to describe EPA methods for developing or revising ambient water quality criteria to protect human health, pursuant to Section 304(a) of the Clean Water Act, and to serve as guidance to States and authorized Tribes for developing their own water quality criteria. This guidance does not substitute for the Clean Water Act or EPA's regulations; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, States, Tribes or the regulated community, and may not apply to a particular situation based upon the circumstances.

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This document presents EPA's recommended Methodology for developing ambient water quality criteria as required under Section 304(a) of the Clean Water Act (CWA). The Methodology is guidance for scientific human health assessments used by EPA to develop, publish, and from time to time revise, recommended criteria for water quality accurately reflecting the latest scientific knowledge. The recommended criteria serve States and Tribes' needs in their development of water quality standards under Section 303(c) of the CWA.

The term "water quality criteria" is used in two sections of the Clean Water Act, Section 304(a)(1) and Section 303(c)(2). The term has a different program impact in each section. In Section 304, the term represents a scientific assessment of ecological and human health effects that EPA recommends to States and authorized Tribes for establishing water quality standards that ultimately provide a basis for controlling discharges or releases of pollutants. Ambient water quality criteria associated with specific stream uses when adopted as State or Tribal water quality standards under Section 303 define the maximum levels of a pollutant necessary to protect designated uses in ambient waters. The water quality criteria adopted in the State or Tribal water quality standards could have the same numerical limits as the criteria developed under Section 304. However, in many situations States and authorized Tribes may want to adjust water quality criteria developed under Section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. When adopting their water quality criteria, States and authorized Tribes have four options: (1) adopt EPA's 304(a) recommendations; (2) adopt 304(a) criteria modified to reflect site-specific conditions; (3) develop criteria based on other scientifically defensible methods; or (4) establish narrative criteria where numeric criteria cannot be determined.

EPA will use this Methodology to develop new ambient water quality criteria and to revise existing recommended water quality criteria. It also provides States and authorized Tribes the necessary guidance to adjust water quality criteria developed under Section 304 to reflect local conditions or to develop their own water quality criteria using scientifically defensible methods consistent with this Methodology. EPA encourages States and authorized Tribes to use this Methodology to develop or revise water quality criteria to appropriately reflect local conditions. EPA believes that ambient water quality criteria inherently require several risk management decisions that are, in many cases, better made at the State, Tribal, or regional level. Additional guidance to assist States and authorized Tribes in the modification of criteria based on the Methodology will accompany this document in the form of three companion Technical Support Documents on Risk Assessment, Exposure Assessment, and Bioaccumulation Assessment.

_____

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Potential areas for conflict of interest were investigated via direct inquiry with the peer reviews and review of their current affiliations. No conflicts of interest were identified.

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LIST OF ACRONYMS

ADI	Acceptable Daily Intake
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society of Testing and Materials
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
BAF_{ℓ}^{fd}	Baseline Bioaccumulation Factor
BCF	Bioconcentration Factor
BCF_{ℓ}^{fd}	Baseline Bioconcentration Factor
$BCF_{\mathbf{T}}^{\mathbf{t}}$	Bioconcentration Factor Based on Total Concentrations in Tissue and Water
BMD	Benchmark Dose
BMDL	Lower-Bound Confidence Limit on the BMD
BMF	Biomagnification Factor
BMR	Benchmark Response
BSAF	Biota-Sediment Accumulation Factors
BW	Body Weight
C_{ℓ}	Lipid-normalized Concentration
C_{soc}	Organic Carbon-normalized Concentration
C_t	Concentration of the Chemical in the Specified Wet Tissue
C_w	Concentration of the Chemical in Water
CDC	U.S. Centers for Disease Control and Prevention
CSFII	Continuing Survey of Food Intake by Individuals
CWA	Clean Water Act
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane
DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene
DDD	1,1-dichloro-2,2-bis(p-chlorophenyl)ethane
DI	Drinking Water Intake
DNA	Deoxyribonucleic Acid
DNOC	2,4-dinitro-o-cresol
DOC	Dissolved Organic Carbon
ED_{10}	Dose Associated with a 10 Percent Extra Risk
EPA	Environmental Protection Agency
f_{fd}	Fraction Freely Dissolved
f_{ℓ}	Fraction Lipid
FCM	Food Chain Multiplier
FEL	Frank Effect Level
FI	Fish Intake
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GLI	Great Lakes Water Quality Initiative
HCBD	Hexachlorobutadiene
IARC	International Agency for Research on Cancer
II	Incidental Ingestion
ILSI	International Life Sciences Institute

IRIS	Integration Risk Information System
kg	kilogram
K_{ow}	Octanol-Water Partition Coefficient
L	Liter
LAS	Linear Alkylbenzesulfonate
LED_{10}	The Lower 95 Percent Confidence Limit on a Dose Associated with a 10 Percent Extra Risk
LMS	Linear Multistage Model
LOAEL	Lowest Observed Adverse Effect Level
M_ℓ	Mass of Lipid in Specified Tissue
M_t	Mass of Specified Tissue (Wet Weight)
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MF	Modifying Factor
mg	Milligrams
ml	Milliliters
MOA	Mode of Action
MOE	Margin of Exposure
NCHS	National Center for Health Statistics
NCI	National Cancer Institute
NFCS	Nationwide Food Consumption Survey
NHANES	National Health and Nutrition Examination Survey
NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
NPDES	National Pollutant Discharge Elimination System
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
POD	Point of Departure
POC	Particulate Organic Carbon
RDA	Recommended Daily Allowance
RfC	Reference Concentration
RfD	Reference Dose
RfD_{DT}	Reference Dose for Developmental Effects
RPF	Relative Potency Factor
RSC	Relative Source Contribution
RSD	Risk-Specific Dose
SAB	Science Advisory Board
SDWA	Safe Drinking Water Act
SF	Safety Factor
STORET	Storage Retrieval
TEAM	Total Exposure Assessment Methodology
TEF	Toxicity Equivalency Factor
TMDL	Total Maximum Daily Load
TSD	Technical Support Document
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency

UF	Uncertainty Factor
WQBEL	Water Quality-Based Effluent Limits

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1. INTRODUCTION

1.1 WATER QUALITY CRITERIA AND STANDARDS

Pursuant to Section 304(a)(1) of the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) is required to publish, and from time to time thereafter revise, criteria for water quality accurately reflecting the latest scientific knowledge on the kind and extent of all identifiable effects on human health which may be expected from the presence of pollutants in any body of water.

Historically, the ambient water quality criteria (AWQC or 304(a) criteria) provided two essential types of information: (1) discussions of available scientific data on the effects of the pollutants on public health and welfare, aquatic life, and recreation; and (2) quantitative concentrations or qualitative assessments of the levels of pollutants in water which, if not exceeded, will generally ensure adequate water quality for a specified water use. Water quality criteria developed under Section 304(a) are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. The 304(a) criteria do not reflect consideration of economic impacts or the technological feasibility of meeting the criteria in ambient water. These 304(a) criteria may be used as guidance by States and authorized Tribes to establish water quality standards, which ultimately provide a basis for controlling discharges or releases of pollutants into ambient waters.

In 1980, AWQC were derived for 64 pollutants using guidelines developed by the Agency for calculating the impact of waterborne pollutants on aquatic organisms and on human health. Those guidelines consisted of systematic procedures for assessing valid and appropriate data concerning a pollutant's acute and chronic adverse effects on aquatic organisms, nonhuman mammals, and humans.

1.2 PURPOSE OF THIS DOCUMENT

The *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)* (hereafter the "2000 Human Health Methodology") addresses the development of AWQC to protect human health. The Agency intends to use the 2000 Human Health Methodology both to develop new AWQC for additional pollutants and to revise existing AWQC. Within the next several years, EPA intends to focus on deriving AWQC for chemicals of high priority (including, but not limited to, mercury, arsenic, PCBs, and dioxin). Furthermore, EPA anticipates that 304(a) criteria development in the future will be for bioaccumulative chemicals and pollutants considered highest priority by the Agency. The 2000 Human Health Methodology is also intended to provide States and authorized Tribes flexibility in establishing water quality standards by providing scientifically valid options for developing their own water quality criteria that consider local conditions. States and authorized Tribes are strongly encouraged to use this Methodology to derive their own AWQC. However, the 2000 Human Health Methodology also defines the default factors EPA intends to use in evaluating and determining consistency of State water quality standards with the requirements of the CWA. The Agency intends to use these default factors to calculate national water quality criteria under

Section 304(a) of the Act. EPA will also use this Methodology as guidance when promulgating water quality standards for a State or Tribe under Section 303(c) of the CWA.

This Methodology does not substitute for the CWA or EPA's regulations; nor is it a regulation itself. Thus, the 2000 Human Health Methodology cannot impose legally-binding requirements on EPA, States, Tribes or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA and State/Tribal decision-makers retain the discretion to use different, scientifically defensible, methodologies to develop human health criteria on a case-by-case basis that differ from this Methodology where appropriate. EPA may change the Methodology in the future through intermittent refinements as advances in science or changes in Agency policy occur.

The 2000 Human Health Methodology incorporates scientific advancements made over the past two decades. The use of this Methodology is an important component of the Agency's efforts to improve the quality of the Nation's waters. EPA believes the Methodology will enhance the overall scientific basis of water quality criteria. Further, the Methodology should help States and Tribes address their unique water quality issues and risk management decisions, and afford them greater flexibility in developing their water quality programs.

There are three companion Technical Support Document (TSD) volumes for the 2000 Human Health Methodology: a Risk Assessment TSD; an Exposure Assessment TSD; and a Bioaccumulation TSD. These documents are intended to further support States and Tribes in developing AWQC to reflect local conditions. The Risk Assessment TSD (USEPA, 2000) is being published concurrently with this Methodology. Publication of the Exposure Assessment and Bioaccumulation TSDs are anticipated in 2001.

1.3 HISTORY OF THE AMBIENT WATER QUALITY CRITERIA (AWQC) METHODOLOGY

In 1980, EPA published AWQC for 64 pollutants/pollutant classes identified in Section 307(a) of the CWA and provided a methodology for deriving the criteria (USEPA, 1980). These 1980 AWQC National Guidelines (or the "1980 Methodology") for developing AWQC for the protection of human health addressed three types of endpoints: noncancer, cancer, and organoleptic (taste and odor) effects. Criteria for protection against noncancer and cancer effects were estimated by using risk assessment-based procedures, including extrapolation from animal toxicity or human epidemiological studies. Basic human exposure assumptions were applied to the criterion equation.

The risk assessment-based procedures used to derive the AWQC to protect human health were specific to whether the endpoint was cancer or noncancer. When using cancer as the critical risk assessment endpoint (which had been assumed not to have a threshold), the AWQC were presented as a range of concentrations associated with specified incremental lifetime risk

levels[1]. When using noncancer effects as the critical endpoint, the AWQC reflected an assessment of a "no-effect" level, since noncancer effects were assumed to have a threshold. The key features of each procedure are described briefly in the following paragraphs.

Cancer effects. If human or animal studies on a contaminant indicated that it induced a statistically significant carcinogenic response, the 1980 AWQC National Guidelines treated the contaminant as a carcinogen and derived a low-dose cancer potency factor from available animal data using the linearized multistage model (LMS). The LMS, which uses a linear, nonthreshold assumption for low-dose risk, was used by the Agency as a science policy choice in protecting public health, and represented a plausible upper limit for low-dose risk. The cancer potency factor, which expresses incremental, lifetime risk as a function of the rate of intake of the contaminant, was then combined with exposure assumptions to express that risk in terms of an ambient water concentration. In the 1980 AWQC National Guidelines, the Agency presented a range of contaminant concentrations corresponding to incremental cancer risks of 10^{-7} to 10^{-5} (that is, a risk of one additional case of cancer in a population of ten million to one additional cancer case in a population of one hundred thousand, respectively).

Noncancer effects. If the pollutant was not considered to have the potential for causing cancer in humans (later defined as a known, probable, or possible human carcinogen by the 1986 *Guidelines for Carcinogen Risk Assessment,* USEPA, 1986d), the 1980 AWQC National Guidelines treated the contaminant as a noncarcinogen; a criterion was derived using a threshold concentration for noncancer adverse effects. The criteria derived from noncancer data were based on the Acceptable Daily Intake (ADI) (now termed the reference dose [RfD]). ADI values were generally derived using a no-observed-adverse-effect level (NOAEL) from animal studies, although human data were used whenever available. The ADI was calculated by dividing the NOAEL by an uncertainty factor to account for uncertainties inherent in extrapolating limited toxicological data to humans. In accordance with the National Research Council recommendations of 1977 (NRC, 1977), safety factors (SFs) (later redefined as uncertainty factors) of 10, 100, or 1,000 were used, depending on the quality of the data.

Organoleptic effects. Organoleptic characteristics were also used in developing criteria for some contaminants to control undesirable taste and/or odor imparted by them to ambient water. In some cases, a water quality criterion based on organoleptic effects would be more stringent than a criterion based on toxicologic endpoints. The 1980 AWQC National Guidelines emphasized that criteria derived for organoleptic endpoints are not based on toxicological information, have no direct relationship to adverse human health effects and, therefore, do not necessarily represent approximations of acceptable risk levels for humans.

[1]Throughout this document, the term "risk level" regarding a cancer assessment using linear approach refers to an upper-bound estimate of excess lifetime cancer risk.

1.4 RELATIONSHIP OF WATER QUALITY STANDARDS TO AWQC

Under Section 303(c) of the CWA, States have the primary responsibility for establishing water quality standards, defined under the Act as designated beneficial uses of a water segment and the water quality criteria necessary to support those uses. Additionally, Native American Tribes authorized to administer the water quality standards program under 40 CFR 131.8 establish water quality standards for waters within their jurisdictions. This statutory framework allows States and authorized Tribes to work with local communities to adopt appropriate designated uses and to adopt criteria to protect those designated uses. Section 303(c) provides for EPA review of water quality standards and for promulgation of a superseding Federal rule in cases where State or Tribal standards are not consistent with the applicable requirements of the CWA and the implementing Federal regulations, or where the Agency determines Federal standards are necessary to meet the requirements of the Act. Section 303(c)(2)(B) specifically requires States and authorized Tribes to adopt water quality criteria for toxics for which EPA has published criteria under Section 304(a) and for which the discharge or presence could reasonably be expected to interfere with the designated use adopted by the State or Tribe. In adopting such criteria, States and authorized Tribes must establish numerical values based on one of the following: (1) 304(a) criteria; (2) 304(a) criteria modified to reflect site-specific conditions; or, (3) other scientifically defensible methods. In addition, States and authorized Tribes can establish narrative criteria where numeric criteria cannot be determined.

It must be recognized that the Act uses the term "criteria" in two different ways. In Section 303(c), the term is part of the definition of a water quality standard. Specifically, a water quality standard is composed of designated uses and the criteria necessary to protect those uses. Thus, States and authorized Tribes are required to adopt regulations which contain legally enforceable criteria. However, in Section 304(a) the term criteria is used to describe the scientific information that EPA develops to be used as guidance by States, authorized Tribes and EPA when establishing water quality standards pursuant to 303(c). Thus, two distinct purposes are served by the 304(a) criteria. The first is as guidance to the States and authorized Tribes in the development and adoption of water quality criteria which will protect designated uses, and the second is as the basis for promulgation of a superseding Federal rule when such action is necessary.

1.5 NEED FOR THE AWQC METHODOLOGY REVISIONS

Since 1980, EPA risk assessment practices have evolved significantly in all of the major Methodology areas: that is, cancer and noncancer risk assessments, exposure assessments, and bioaccumulation. When the 1980 Methodology was developed, EPA had not yet developed formal cancer or noncancer risk assessment guidelines. Since then, EPA has published several risk assessment guidelines. In cancer risk assessment, there have been advances in the use of mode of action (MOA) information to support both the identification of potential human carcinogens and the selection of procedures to characterize risk at low, environmentally relevant exposure levels. EPA published *Proposed Guidelines for Carcinogen Risk Assessment* (USEPA, 1996a, hereafter the "1996 proposed cancer guidelines"). These guidelines presented revised procedures to quantify cancer risk at low doses, replacing the current default use of the LMS model. Following review by the Agency's Science Advisory Board (SAB), EPA published the

revised *Guidelines for Carcinogen Risk Assessment–Review Draft* in July 1999 (USEPA, 1999a, hereafter the "1999 draft revised cancer guidelines"). In noncancer risk assessment, the Agency is moving toward the use of the benchmark dose (BMD) and other dose-response approaches in place of the traditional NOAEL approach to estimate an RfD or Reference Concentration (RfC). *Guidelines for Mutagenicity Risk Assessment* were published in 1986 (USEPA, 1986b). In 1991, the Agency published *Guidelines for Developmental Toxicity Risk Assessment* (USEPA, 1991), and it issued *Guidelines for Reproductive Toxicity Risk Assessment* in 1996 (USEPA, 1996b). In 1998, EPA published final *Guidelines for Neurotoxicity Risk Assessment* (USEPA, 1998), and in 1999 it issued the draft *Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (USEPA, 1999b).

In 1986, the Agency made available to the public the Integrated Risk Information System (IRIS). IRIS is a database that contains risk information on the cancer and noncancer effects of chemicals. The IRIS assessments are peer reviewed and represent EPA consensus positions across the Agency's program and regional offices.

New studies have addressed water consumption and fish tissue consumption. These studies provide a more current and comprehensive description of national, regional, and special-population consumption patterns that EPA has reflected in the 2000 Human Health Methodology. In addition, more formalized procedures are now available to account for human exposure from multiple sources when setting health goals such as AWQC that address only one exposure source. In 1986, the Agency published the *Total Exposure Assessment Methodology (TEAM) Study: Summary and Analysis, Volume I, Final Report* (USEPA, 1986c), which presents a process for conducting comprehensive evaluation of human exposures. In 1992, EPA published the revised *Guidelines for Exposure Assessment* (USEPA, 1992), which describe general concepts of exposure assessment, including definitions and associated units, and provide guidance on planning and conducting an exposure assessment. The *Exposure Factors Handbook* was updated in 1997 (USEPA, 1997a). Also in 1997, EPA developed *Guiding Principles for Monte Carlo Analysis* (USEPA, 1997b) and published its *Policy for Use of Probabilistic Analysis in Risk Assessment* (see http://www.epa.gov/ncea/mcpolicy.htm). The Monte Carlo guidance can be applied to exposure assessments and risk assessments. The Agency has recently developed the Relative Source Contribution (RSC) Policy for assessing total human exposure to a contaminant and apportioning the RfD among the media of concern, published for the first time in this Methodology.

The Agency has moved toward the use of a bioaccumulation factor (BAF) to reflect the uptake of a contaminant from all sources (e.g., ingestion, sediment) by fish and shellfish, rather than just from the water column as reflected by the use of a bioconcentration factor (BCF) in the 1980 Methodology. The Agency has also developed detailed procedures and guidelines for estimating BAF values.

Another reason for the 2000 Human Health Methodology is the need to bridge the gap between the differences in the risk assessment and risk management approaches used by EPA's Office of Water for the derivation of AWQC under the authority of the CWA and Maximum Contaminant Level Goals (MCLGs) under the Safe Drinking Water Act (SDWA). Three notable differences are the treatment of chemicals designated as Group C, possible human carcinogens

under the 1996 proposed cancer guidelines, the consideration of non-water sources of exposure when setting an AWQC or MCLG for a noncarcinogen, and cancer risk ranges. Those three differences are described in the three subsections below, respectively.

1.5.1 Group C Chemicals

Chemicals were typically classified as Group C–i.e., possible human carcinogens–under the existing (1986) EPA cancer classification scheme for any of the following reasons:

1) Carcinogenicity has been documented in only one test species and/or only one cancer bioassay and the results do not meet the requirements of "sufficient evidence."

2) Tumor response is of marginal statistical significance due to inadequate design or reporting.

3) Benign, but not malignant, tumors occur with an agent showing no response in a variety of short-term tests for mutagenicity.

4) There are responses of marginal statistical significance in a tissue known to have a high or variable background rate.

The 1986 *Guidelines for Carcinogen Risk Assessment* (hereafter the "1986 cancer guidelines") specifically recognized the need for flexibility with respect to quantifying the risk of Group C, possible human carcinogens. The 1986 cancer guidelines noted that agents judged to be in Group C, possible human carcinogens, may generally be regarded as suitable for quantitative risk assessment, but that case-by-case judgments may be made in this regard.

The EPA Office of Water has historically treated Group C chemicals differently under the CWA and the SDWA. It is important to note that the 1980 AWQC National Guidelines for setting AWQC under the CWA predated EPA's carcinogen classification system, which was proposed in 1984 (USEPA, 1984) and finalized in 1986 (USEPA, 1986a). The 1980 AWQC National Guidelines did not explicitly differentiate among agents with respect to the weight of evidence for characterizing them as likely to be carcinogenic to humans. For all pollutants judged as having adequate data for quantifying carcinogenic risk–including those now classified as Group C–AWQC were derived based on data on cancer incidence. In the1980 AWQC National Guidelines, EPA emphasized that the AWQC for carcinogens should state that the recommended concentration for maximum protection of human health is zero. At the same time, the criteria published for specific carcinogens presented water concentrations for these pollutants corresponding to individual lifetime excess cancer risk levels in the range of 10^{-7} to 10^{-5}.

In the development of national primary drinking water regulations under the SDWA, EPA is required to promulgate a health-based MCLG for each contaminant. The Agency policy has been to set the MCLG at zero for chemicals with strong evidence of carcinogenicity associated with exposure from water. For chemicals with limited evidence of carcinogenicity, including many Group C agents, the MCLG was usually obtained using an RfD based on the

pollutant's noncancer effects with the application of an additional uncertainty factor of 1 to 10 to account for carcinogenic potential of the chemical. If valid noncancer data for a Group C agent were not available to establish an RfD but adequate data are available to quantify the cancer risk, then the MCLG was based upon a nominal lifetime excess cancer risk in the range of 10^{-6} to10^{-5} (ranging from one case in a population of one million to one case in a population of one hundred thousand). Even in those cases where the RfD approach has been used for the derivation of the MCLG for a Group C agent, the drinking water concentrations associated with excess cancer risks in the range of 10^{-6} to 10^{-5} were also provided for comparison.

It should also be noted that EPA's pesticides program has applied both of the previously described methods for addressing Group C chemicals in actions taken under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and finds both methods applicable on a case-by-case basis. Unlike the drinking water program, however, the pesticides program does not add an extra uncertainty factor to account for potential carcinogenicity when using the RfD approach.

In the 1999 draft revised cancer guidelines, there are no more alphanumeric categories. Instead, there will be longer narratives for hazard characterization that will use consistent descriptive terms when assessing cancer risk.

1.5.2 Consideration of Non-water Sources of Exposure

The 1980 AWQC National Guidelines recommended that contributions from non-water sources, namely air and non-fish dietary intake, be subtracted from the Acceptable Daily Intake (ADI), thus reducing the amount of the ADI "available" for water-related sources of intake. In practice, however, when calculating human health criteria, these other exposures were generally not considered because reliable data on these exposure pathways were not available. Consequently, the AWQC were usually derived such that drinking water and fish ingestion accounted for the entire ADI (now called RfD).

In the drinking water program, a similar "subtraction" method was used in the derivation of MCLGs proposed and promulgated in drinking water regulations through the mid-1980s. More recently, the drinking water program has used a "percentage" method in the derivation of MCLGs for noncarcinogens. In this approach, the percentage of total exposure typically accounted for by drinking water, referred to as the relative source contribution (RSC), is applied to the RfD to determine the maximum amount of the RfD "apportioned" to drinking water reflected by the MCLG value. In using this percentage procedure, the drinking water program also applies a ceiling level of 80 percent of the RfD and a floor level of 20 percent of the RfD. That is, the MCLG cannot account for more than 80 percent of the RfD, nor less than 20 percent of the RfD.

The drinking water program usually takes a conservative approach to public health by applying an RSC factor of 20 percent to the RfD when adequate exposure data do not exist, assuming that the major portion (80 percent) of the total exposure comes from other sources, such as diet.

In the 2000 Human Health Methodology, guidance for the routine consideration of non-water sources of exposure [both ingestion exposures (e.g., food) and exposures other than the oral route (e.g., inhalation)] is presented. The approach is called the Exposure Decision Tree. Relative source contribution estimates will be made by EPA using this approach, which allows for use of either the subtraction or percentage methods, depending on chemical-specific circumstances, within the 20 to 80 percent range described above.

1.5.3 Cancer Risk Ranges

In addition to the different risk assessment approaches discussed above for deriving AWQC and MCLGs for Group C agents, there have been different risk management approaches by the drinking water and surface water programs on lifetime excess risk values when setting health-based criteria for carcinogens. The surface water program has derived AWQC for carcinogens that generally corresponded to lifetime excess cancer risk levels of 10^{-7} to 10^{-5}. The drinking water program has set MCLGs for Group C agents based on a slightly less stringent risk range of 10^{-6} to 10^{-5}, while MCLGs for chemicals with strong evidence of carcinogenicity (that is, classified as Group A, known, or B probable, human carcinogen) are set at zero. The drinking water program is now following the principles of the 1999 draft revised cancer guidelines to determine the type of low-dose extrapolation based on mode of action.

It is also important to note that under the drinking water program, for those substances having an MCLG of zero, enforceable Maximum Contaminant Levels (MCLs) have generally been promulgated to correspond with cancer risk levels ranging from 10^{-6} to 10^{-4}. Unlike AWQC and MCLGs which are strictly health-based criteria, MCLs are developed with consideration given to the costs and technological feasibility of reducing contaminant levels in water to meet those standards.

With the 2000 Human Health Methodology, EPA will publish its national 304(a) water quality criteria at a 10^{-6} risk level, which EPA considers appropriate for the general population. EPA is increasing the degree of consistency between the drinking water and ambient water programs, given the somewhat different requirements of the CWA and SDWA.

1.6 OVERVIEW OF THE AWQC METHODOLOGY REVISIONS

The following equations for deriving AWQC include toxicological and exposure assessment parameters which are derived from scientific analysis, science policy, and risk management decisions. For example, values for parameters such as a field-measured BAF or a point of departure from an animal study [in the form of a lowest-observed-adverse-effect level (LOAEL)/no-observed -adverse-effect level (NOAEL)/lower 95 percent confidence limit on a dose associated with a 10 percent extra risk (LED_{10})] are empirically measured using scientific methods. By contrast, the decision to use animal effects as surrogates for human effects involves judgment on the part of the EPA (and similarly, by other agencies) as to the best practice to follow when human data are lacking. Such a decision is, therefore, a matter of science policy. The choice of default fish consumption rates for protection of a certain percentage (i.e., the 90th percentile) of the general population is clearly a risk management decision. In many cases, the Agency has selected parameter values using its best judgment regarding the overall protection afforded by the resulting AWQC when all parameters are combined. For a longer discussion of the differences between science, science policy, and risk management, please refer to Section 2 of this document. Section 2 also provides further details with regard to risk characterization for this Methodology, with emphasis placed on explaining the uncertainties in the overall risk assessment.

The generalized equations for deriving AWQC based on noncancer effects are:

Noncancer Effects[2]

$$AWQC = RfD \cdot RSC \cdot \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \cdot BAF_i)} \right) \qquad \text{(Equation 1-1)}$$

Cancer Effects: Nonlinear Low-Dose Extrapolation

$$AWQC = \frac{POD}{UF} \cdot RSC \cdot \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \cdot BAF_i)} \right) \qquad \text{(Equation 1-2)}$$

[2] Although appearing in this equation as a factor to be multiplied, the RSC can also be an amount subtracted. Refer to the explanation key below the equations.

Cancer Effects: Linear Low-Dose Extrapolation

$$AWQC = RSD \cdot \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \cdot BAF_i)} \right) \qquad \text{(Equation 1-3)}$$

where:

AWQC	=	Ambient Water Quality Criterion (mg/L)
RfD	=	Reference dose for noncancer effects (mg/kg-day)
POD	=	Point of departure for carcinogens based on a nonlinear low-dose extrapolation (mg/kg-day), usually a LOAEL, NOAEL, or LED_{10}
UF	=	Uncertainty Factor for carcinogens based on a nonlinear low-dose extrapolation (unitless)
RSD	=	Risk-specific dose for carcinogens based on a linear low-dose extrapolation (mg/kg-day) (dose associated with a target risk, such as 10^{-6})
RSC	=	Relative source contribution factor to account for non-water sources of exposure. (Not used for linear carcinogens.) May be either a percentage (multiplied) or amount subtracted, depending on whether multiple criteria are relevant to the chemical.
BW	=	Human body weight (default = 70 kg for adults)
DI	=	Drinking water intake (default = 2 L/day for adults)
FI_i	=	Fish intake at trophic level (TL) I (I = 2, 3, and 4) (defaults for total intake = 0.0175 kg/day for general adult population and sport anglers, and 0.1424 kg/day for subsistence fishers). Trophic level breakouts for the general adult population and sport anglers are: TL2 = 0.0038 kg/day; TL3 = 0.0080 kg/day; and TL4 = 0.0057 kg/day.
BAF_i	=	Bioaccumulation factor at trophic level I (I=2, 3 and 4), lipid normalized (L/kg)

For highly bioaccumulative chemicals where ingestion from water might be considered negligible, EPA is currently evaluating the feasibility of developing and implementing AWQCs that are expressed in terms of concentrations in tissues of aquatic organisms. Such tissue residue criteria might be used as an alternative to AWQCs which are expressed as concentrations in water, particularly in situations where AWQCs are at or below the practical limits for quantifying a chemical in water. Even though tissue residue criteria would not require the use of a BAF in their derivation, implementing such criteria would still require a mechanism for relating chemical loads and concentrations in water and sediment to concentrations in tissues of appropriate fish and shellfish (e.g., a BAF or bioaccumulation model). At this time, no revisions are planned to the Methodology to provide specific guidance on developing fish tissue-based water quality criteria. However, guidance may be provided in the future either as a separate document or integrated in a specific 304(a) water quality criteria document for a chemical that warrants such an approach.

AWQC for the protection of human health are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters. The Agency is not recommending the development of additional water quality criteria similar to the "drinking water health advisories" that focus on acute or short-term effects; these are not seen as routinely having a meaningful role in the water quality criteria and standards program. However, as discussed below, there may be some instances where the consideration of acute or short-term toxicity and exposure in the derivation of AWQC is warranted.

Although the AWQC are based on chronic health effects data (both cancer and noncancer effects), the criteria are intended to also be protective against adverse effects that may reasonably be expected to occur as a result of elevated acute or short-term exposures. That is, through the use of conservative assumptions with respect to both toxicity and exposure parameters, the resulting AWQC should provide adequate protection not only for the general population over a lifetime of exposure, but also for special subpopulations who, because of high water- or fish-intake rates, or because of biological sensitivities, have an increased risk of receiving a dose that would elicit adverse effects. The Agency recognizes that there may be some cases where the AWQC based on chronic toxicity may not provide adequate protection for a subpopulation at special risk from shorter-term exposures. The Agency encourages States, Tribes, and others employing the 2000 Human Health Methodology to give consideration to such circumstances in deriving criteria to ensure that adequate protection is afforded to all identifiable subpopulations. (See Section 4.3, Factors Used in the AWQC Computation, for additional discussion of these subpopulations.)

The EPA is in the process of revising its cancer guidelines, including its descriptions of human carcinogenic potential. Once final guidelines are published, they will be the basis for assessment under this methodology. In the meanwhile, the 1986 guidelines are used and extended with principles discussed in EPA's 1999 *Guidelines for Carcinogen Risk Assessment - Review Draft* (hereafter "1999 draft revised cancer guidelines"). These principles arise from new science about cancer discovered in the last 15 years and from EPA policy of recent years supporting full characterization of hazard and risk both for the general population and potentially sensitive groups such as children. These principles are incorporated in recent and ongoing assessments such as the reassessment of dioxin, consistent with the 1986 guidelines. Until final guidelines are published, information is presented to describe risk under both the old guidelines and draft revisions. Dose-response assessment under the 1986 guidelines employs a linearized multistage model to extrapolate tumor dose-response observed in animal or human studies down to zero dose, zero extra risk. The dose-response assessment under EPA's 1999 draft revised cancer guidelines is a two-step process. In the first step, the response data are modeled in the range of empirical observation. Modeling in the observed range is done with biologically based or appropriate curve-fitting modeling. In the second step, extrapolation below the range of observation is accomplished by biologically based modeling if there are sufficient data or by a default procedure (linear, nonlinear, or both). A point of departure (POD) for extrapolation is estimated from modeling observed data. The lower 95 percent confidence limit on a dose associated with 10 percent extra risk (LED_{10}) is the standard POD for low-dose extrapolation. The linear default procedure is a straight line extrapolation to the origin (i.e., zero dose, zero extra risk) from the POD, which is the LED_{10} identified in the observable response

range. The result of this procedure is generally comparable (within 2-fold) to that of using a linearized multistage model under existing, 1986 guidelines. The linear low-dose extrapolation applies to agents that are best characterized by the assumption of linearity (e.g., direct DNA reactive mutagens) for their MOA. A linear approach would also be applied when inadequate or no information is available to explain the carcinogenic MOA; this is a science policy choice in the interest of public health. If it is determined that the MOA understanding fully supports a nonlinear extrapolation, the AWQC is derived using the nonlinear default which is based on a margin of exposure (MOE) analysis using the LED_{10} as the POD and applying uncertainty factors (UFs) to arrive at an acceptable MOE. There may be situations where it is appropriate to apply both the linear and nonlinear default procedures (e.g., for an agent that is both DNA reactive and active as a promoter at higher doses).

For substances that are carcinogenic, particularly those for which the MOA suggests nonlinearity at low doses, the Agency recommends that an integrated approach be taken in looking at cancer and noncancer effects. If one effect does not predominate, AWQC values should be determined for both carcinogenic and noncarcinogenic endpoints. The lower of the resulting values should be used for the AWQC.

When deriving AWQC for noncarcinogens and carcinogens based on a nonlinear low-dose extrapolation, a factor is included to account for other non-water exposure sources [both ingestion exposures (e.g., food) and exposures other than the oral route (e.g., inhalation)] so that the entire RfD, or POD/UF, is not apportioned to drinking water and fish consumption alone. Guidance is provided in the 2000 Human Health Methodology for determining the factor (i.e., the RSC) to be used for a particular chemical. The Agency is recommending the use of an Exposure Decision Tree procedure to support the determination of the appropriate RSC value for a given water contaminant. In the absence of data, the Agency intends to use 20 percent of the RfD (or POD/UF) as the default RSC in calculating 304(a) criteria or promulgating State or Tribal water quality standards under Section 303(c).

With AWQC derived for carcinogens based on a linear low-dose extrapolation, the Agency will publish recommended criteria values at a 10^{-6} risk level. States and authorized Tribes can always choose a more stringent risk level, such as 10^{-7}. EPA also believes that criteria based on a 10^{-5} risk level are acceptable for the general population as long as States and authorized Tribes ensure that the risk to more highly exposed subgroups (sportfishers or subsistence fishers) does not exceed the 10^{-4} level. Clarification on this risk management decision is provided in Section 2 of this document.

The default fish consumption value for the general adult population in the 2000 Human Health Methodology is 17.5 grams/day, which represents an estimate of the 90^{th} percentile consumption rate for the U.S. adult population based on the U.S. Department of Agriculture's (USDA's) Continuing Survey of Food Intake by Individuals (CSFII) 1994-96 data (USDA, 1998). EPA will use this default intake rate with future national 304(a) criteria derivations or revisions. This default value is chosen to be protective of the majority of the general population. However, States and authorized Tribes are urged to use a fish intake level derived from local data on fish consumption in place of this default value when deriving AWQC, ensuring that the fish intake level chosen is protective of highly exposed individuals in the population. EPA has

provided default values for States and authorized Tribes that do not have adequate information on local or regional consumption patterns, based on numerous studies that EPA has reviewed on sport anglers and subsistence fishers. EPA's defaults for these population groups are estimates of their average consumption. EPA recommends a default of 17.5 grams/day for sport anglers as an approximation of their average consumption and 142.4 grams/day for subsistence fishers, which falls within the range of averages for this group. Consumption rates for women of childbearing age and children younger than 14 are also provided to maximize protection in those cases where these subpopulations may be at greatest risk.

In the 2000 Human Health Methodology, criteria are derived using a BAF rather than a BCF. To derive the BAF, States and authorized Tribes may use EPA's Methodology or any method consistent with this Methodology. EPA's highest preference in developing BAFs are BAFs based on field-measured data from local/regional fish.

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2. CLARIFICATIONS ON THE METHODOLOGY, RISK CHARACTERIZATION, AND OTHER ISSUES FOR DEVELOPING CRITERIA

2.1 IDENTIFYING THE POPULATION SUBGROUP THAT THE AWQC SHOULD PROTECT

Water quality criteria are derived to establish ambient concentrations of pollutants which, if not exceeded, will protect the general population from adverse health impacts from those pollutants due to consumption of aquatic organisms and water, including incidental water consumption related to recreational activities. For each pollutant, chronic criteria are derived to reflect long-term consumption of food and water. An important decision to make when setting AWQC is the choice of the particular population to protect. For instance, criteria could be set to protect those individuals who have average or "typical" exposures, or the criteria could be set so that they offer greater protection to those individuals who are more highly exposed. EPA has selected default parameter values that are representative of several defined populations: adults in the general population; sport (recreational) fishers; subsistence fishers; women of childbearing age (defined as ages 15-44); and children (up to the age of 14). In deciding on default parameter values, EPA is aware that multiple parameters are used in combination when calculating AWQC (e.g., intake rates and body weight). EPA describes the estimated population percentiles that are represented by each of the default exposure parameter values in Section 4.

EPA's national 304(a) criteria are usually derived to protect the majority of the general population from chronic adverse health effects. EPA has used a combination of median values, mean values, and percentile estimates for the parameter value defaults to calculate its national 304(a) criteria. EPA believes that its assumptions afford an overall level of protection targeted at the high end of the general population (i.e., the target population or the criteria-basis population). EPA also believes that this is reasonably conservative and appropriate to meet the goals of the CWA and the 304(a) criteria program. EPA considers that its target protection goal is satisfied if the population as a whole will be adequately protected by the human health criteria when the criteria are met in ambient water. However, associating the derived criteria with a specific population percentile is far more difficult, and such a quantitative descriptor typically requires detailed distributional exposure and dose information. EPA's *Guidelines For Exposure Assessment* (USEPA, 1992) describes the extreme difficulty in making accurate estimates of exposures and indicates that uncertainties at the more extreme ends of the distribution increase greatly. On quantifying population exposures/risks, the guidelines specifically state:

> *In practice, it is difficult even to establish an accurate mean health effect risk for a population. This is due to many complications, including uncertainties in using animal data for human dose-response relationships, nonlinearities in the dose-response curve, projecting incidence data from one group to another dissimilar group, etc. Although it has been common practice to estimate the number of cases of disease, especially cancer, for populations exposed to chemicals, it should be understood that these estimates are not meant to be accurate estimates of real (or actuarial) cases of disease. The estimate's value lies in framing*

hypothetical risk in an understandable way rather than in any literal interpretation of the term "cases."

Although it is not possible to subject the estimates to such a rigorous analysis (say, for example, to determine what criterion value provides protection of exactly the 90th percentile of the population), EPA believes that the combination of parameter value assumptions achieves its target goal, without being inordinately conservative. The standard assumptions made for the national 304(a) criteria are as follows. The assumed body weight value used is an arithmetic mean, as are the RSC intake estimates of other exposures (e.g., non-fish dietary), when data are available. The BAF component data (e.g., for lipid values, for particulate and dissolved organic carbon) are based on median (i.e., 50th percentile) values. The drinking water intake values are approximately 90th percentile estimates and fish intake values are 90th percentile estimates. EPA believes the use of these values will result in 304(a) criteria that are protective of a majority of the population; this is EPA's goal.

However, EPA also strongly believes that States and authorized Tribes should have the flexibility to develop criteria, on a site-specific basis, that provide additional protection appropriate for highly exposed populations. EPA is aware that exposure patterns in general, and fish consumption in particular, vary substantially. EPA understands that highly exposed populations may be widely distributed geographically throughout a given State or Tribal area. EPA recommends that priority be given to identifying and adequately protecting the most highly exposed population. Thus, if the State or Tribe determines that a highly exposed population is at greater risk and would not be adequately protected by criteria based on the general population, and by the national 304(a) criteria in particular, EPA recommends that the State or Tribe adopt more stringent criteria using alternative exposure assumptions.

EPA has provided recommended default intake rates for various population groups for State and Tribal consideration. EPA does not intend for these alternative default values to be prescriptive. EPA strongly emphasizes its preference that States and Tribes use local or regional data over EPA's defaults, if they so choose, as being more representative of their population groups of concern.

In the course of updating the 2000 Human Health Methodology, EPA received some questions regarding the population groups for which the criteria would be developed. EPA does not intend to derive multiple 304(a) criteria for all subpopulation groups for every chemical. As stated above, criteria that address chronic adverse health effects are most applicable to the CWA Section 304(a) criteria program and the chemicals evaluated for this program. If EPA determined that pregnant women/fetuses or young children were the target population (or criteria basis population) of a chemical's RfD or POD/UF, then the 304(a) criteria would be developed using exposure parameters for that subgroup. This would only be relevant for acute or subchronic toxicity situations. This does not conflict with the fact that chronic health effects potentially reflect a person's exposure during both childhood and adult years.

For RfD-based and POD/UF-based chemicals, EPA's policy is that, in general, the RfD (or POD/UF) should not be exceeded and the exposure assumptions used should reflect the population of concern. It is recommended that when a State or authorized Tribe sets a

waterbody-specific AWQC, they consider the populations most exposed via water and fish. EPA's policy on cancer risk management goals is discussed in Section 2.4.

Health Risks to Children

In recognition that children have a special vulnerability to many toxic substances, EPA's Administrator directed the Agency in 1995 to explicitly and consistently take into account environmental health risks to infants and children in all risk assessments, risk characterizations, and public health standards set for the United States. In April 1997, President Clinton signed Executive Order 13045 on the protection of children from environmental health risks, which assigned a high priority to addressing risks to children. In May 1997, EPA established the Office of Children's Health Protection to ensure the implementation of the President's Executive Order. EPA has increased efforts to ensure its guidance and regulations take into account risks to children. Circumstances where risks to children should be considered in the context of the 2000 Human Health Methodology are discussed in the Section 3.2, Noncancer Effects (in terms of developmental and reproductive toxicity) and in Section 4, Exposure (for appropriate exposure intake parameters).

Details on risk characterization and the guiding principles stated above are included in EPA's March 21, 1995 policy statement and the discussion of risk characterization (USEPA, 1995) and the 1999 *Guidelines for Carcinogen Risk Assessment. Review Draft* (USEPA, 1999a) and the *Reproductive and Toxicity Risk Assessment Guidelines* of 1996 (USEPA, 1996b).

2.2 SCIENCE, SCIENCE POLICY, AND RISK MANAGEMENT

An important part of risk characterization, as described later in Section 2.7, is to make risk assessments transparent. This means that conclusions drawn from the science are identified separately from policy judgments and risk management decisions, and that the use of default values or methods, as well as the use of assumptions in risk assessments, are clearly articulated. In this Methodology, EPA has attempted to separate scientific analysis from science policy and risk management decisions for clarity. This should allow States and Tribes (who are also prospective users of this Methodology) to understand the elements of the Methodology accurately and clearly, and to easily separate out the scientific decisions from the science policy and risk management decisions. This is important so that when questions are asked regarding the scientific merit, validity, or apparent stringency or leniency of AWQC, the implementer of the criteria can clearly explain what judgments were made to develop the criterion in question and to what degree these judgments were based on science, science policy, or risk management. To some extent this process will also be displayed in future AWQC documents.

When EPA speaks of science or scientific analysis, it is referring to the extraction of data from toxicological or exposure studies and surveys with a minimum of judgment being used to make inferences from the available evidence. For example, if EPA is describing a POD from an animal study (e.g., a LOAEL), this is usually determined as a lowest dose that produces an observable adverse effect. This would constitute a scientific determination. Judgments applying science policy, however, may enter this determination. For example, several scientists may differ in their opinion of what is adverse, and this in turn can influence the selection of a LOAEL

in a given study. The use of an animal study to predict effects in a human in the absence of human data is an inherent science policy decision. The selection of specific UFs when developing an RfD is another example of science policy. In any risk assessment, a number of decision points occur where risk to humans can only be inferred from the available evidence. Both scientific judgments and policy choices may be involved in selecting from among several possible inferences when conducting a risk assessment.

Risk management is the process of selecting the most appropriate guidance or regulatory actions by integrating the results of risk assessment with engineering data and with social, economic, and political concerns to reach a decision. In this Methodology, the choice of a default fish consumption rate which is protective of 90 percent of the general population is a risk management decision. The choice of an acceptable cancer risk by a State or Tribe is a risk management decision.

Many of the components in the 2000 Human Health Methodology are an amalgam of science, science policy, and/or risk management. For example, most of the default values chosen by EPA are based on examination of scientific data and application of either science policy or risk management. This includes the default assumption of 2 liters a day of drinking water; the assumption of 70 kilograms for an adult body weight; the use of default percent lipid and particulate organic carbon/dissolved organic carbon (POC/DOC) for developing national BAFs; the default fish consumption rates for the general population and sport and subsistence anglers; and the choice of a default cancer risk level. Some decisions are more grounded in science and science policy (such as the choice of default BAFs) and others are more obviously risk management decisions (such as the determination of default fish consumption rates and cancer risk levels). Throughout the 2000 Human Health Methodology, EPA has identified the kind of decision necessary to develop defaults and what the basis for the decision was. More details on the concepts of science analysis, science policy, risk management, and how they are introduced into risk assessments are included in *Risk Assessment in the Federal Government: Managing the Process* (NRC, 1983).

2.3 SETTING CRITERIA TO PROTECT AGAINST MULTIPLE EXPOSURES FROM MULTIPLE CHEMICALS (CUMULATIVE RISK)

EPA is very much aware of the complex issues and implications of cumulative risk and has endeavored to begin developing an overall approach at the Agency-wide level. Assuming that multiple exposures to multiple chemicals are additive is scientifically sound if they exhibit the same toxic endpoints and modes of action. There are numerous publications relevant to cumulative risk that can assist States and Tribes in understanding the complex issues associated with cumulative risk. These include the following:

- Durkin, P.R., R.C. Hertzberg, W. Stiteler, and M. Mumtaz. 1995. The identification and testing of interaction patterns. *Toxicol. Letters* 79:251-264.

- Hertzberg, R.C., G. Rice, and L.K. Teuschler. 1999. Methods for health risk assessment of combustion mixtures. In: *Hazardous Waste Incineration: Evaluating the Human*

Health and Environmental Risks. S. Roberts, C. Teaf and J. Bean, (eds). CRC Press LLC, Boca Raton, FL. Pp. 105-148.

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- USEPA. 1996. PCBs: *Cancer Dose-Response Assessment and Application to Environmental Mixtures*. National Center for Environmental Assessment. Washington, DC. EPA/600/P-96/001F.

- USEPA. 1993. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Office of Health and Environmental Assessment, Office of Research and Development. Washington, DC. EPA/600/AP-93/003. November.

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The Agency's program offices are also engaged in on-going discussions of the great complexities, methodological challenges, data adequacy needs and other information gaps, as well as the science policy and risk management decisions that will need to be made, as they pursue developing a sound strategy and, eventually, specific guidance for addressing cumulative

risks. As a matter of internal policy, EPA is committed to refining the Methodology as advances in relevant aspects of the science improve, as part of the water quality criteria program.

2.4 CANCER RISK RANGE

For deriving 304(a) criteria or promulgating water quality criteria for States and Tribes under Section 303(c) based on the 2000 Human Health Methodology, EPA intends to use the 10^{-6} risk level, which the Agency believes reflects an appropriate risk for the general population. EPA's program office guidance and regulatory actions have evolved in recent years to target a 10^{-6} risk level as an appropriate risk for the general population. EPA has recently reviewed the policies and regulatory language of other Agency mandates (e.g., the Clean Air Act Amendments of 1990, the Food Quality Protection Act) and believes the target of a 10^{-6} risk level is consistent with Agency-wide practice.

EPA believes that both 10^{-6} and 10^{-5} may be acceptable for the general population and that highly exposed populations should not exceed a 10^{-4} risk level. States or Tribes that have adopted standards based on criteria at the 10^{-5} risk level can continue to do so, if the highly exposed groups would at least be protected at the 10^{-4} risk level. However, EPA is not automatically assuming that 10^{-5} will protect "the highest consumers" at the 10^{-4} risk level. Nor is EPA advocating that States and Tribes automatically set criteria based on assumptions for highly exposed population groups at the 10^{-4} risk level. The Agency is simply endeavoring to add that a specific determination should be made to ensure that highly exposed groups do not exceed a 10^{-4} risk level. EPA understands that fish consumption rates vary considerably, especially among subsistence populations, and it is such great variation among these population groups that may make either 10^{-6} or 10^{-5} protective of those groups at a 10^{-4} risk level. Therefore, depending on the consumption patterns in a given State or Tribal jurisdiction, a 10^{-6} or 10^{-5} risk level could be appropriate. In cases where fish consumption among highly exposed population groups is of a magnitude that a 10^{-4} risk level would be exceeded, a more protective risk level should be chosen. Such determinations should be made by the State or Tribal authorities and are subject to EPA's review and approval or disapproval under Section 303(c) of the CWA.

Adoption of a 10^{-6} or 10^{-5} risk level, both of which States and authorized Tribes have chosen in adopting water quality standards to date, represents a generally acceptable risk management decision, and EPA intends to continue providing this flexibility to States and Tribes. EPA believes that such State or Tribal decisions are consistent with Section 303(c) if the State or authorized Tribe has identified the most highly exposed subpopulation, has demonstrated that the chosen risk level is adequately protective of the most highly exposed subpopulation, and has completed all necessary public participation. States and authorized Tribes also have flexibility in how they demonstrate this protectiveness and obtain such information. A State or authorized Tribe may use existing information as well as collect new information in making this determination. In addition, if a State or authorized Tribe does not believe that the 10^{-6} risk level adequately protects the exposed subpopulations, water quality criteria based on a more stringent risk level may be adopted. This discretion includes combining the 10^{-6} risk level with fish consumption rates for highly exposed population groups.

It is important to understand that criteria for carcinogens are based on chosen risk levels that inherently reflect, in part, the exposure parameters used to derive those values. Therefore, changing the exposure parameters also changes the risk. Specifically, the incremental cancer risk levels are *relative*, meaning that any given criterion associated with a particular cancer risk level is also associated with specific exposure parameter assumptions (e.g., intake rates, body weights). When these exposure parameter values change, so does the relative risk. For a criterion derived on the basis of a cancer risk level of 10^{-6}, individuals consuming up to 10 times the assumed fish intake rate would not exceed a 10^{-5} risk level. Similarly, individuals consuming up to 100 times the assumed rate would not exceed a 10^{-4} risk level. Thus, for a criterion based on EPA's default fish intake rate (17.5 gm/day) and a risk level of 10^{-6}, those consuming a pound per day (i.e., 454 grams/day) would potentially experience between a 10^{-5} and a 10^{-4} risk level (closer to a 10^{-5} risk level). (Note: Fish consumers of up to 1,750 gm/day would not exceed the 10^{-4} risk level.) If a criterion were based on high-end intake rates and the relative risk of 10^{-6}, then an average fish consumer would be protected at a cancer risk level of approximately 10^{-8}. The point is that the risks for different population groups are not the same.

2.5 MICROBIOLOGICAL AMBIENT WATER QUALITY CRITERIA

Guidance for deriving microbiological AWQC is not a part of this Methodology. In 1986, EPA published *Ambient Water Quality Criteria for Bacteria - 1986* (USEPA, 1986a), which updated and revised bacteriological criteria previously published in 1976 in *Quality Criteria for Water* (USEPA, 1976). The inclusion of guidance for deriving microbiological AWQC was considered in the 1992 national workshop that initiated the effort to revise the 1980 Methodology and was recommended by the SAB in 1993. Since that time, however, efforts separate from these Methodology revisions have addressed microbiological AWQC concerns. The purpose of this section is to briefly describe EPA's current recommendations and activities.

EPA's *Ambient Water Quality Criteria for Bacteria - 1986* recommends the use of *Escherichia coli* and enterococci rather than fecal coliforms (USEPA, 1986a). EPA's criteria recommendations are:

- Fresh water: *E. coli* not to exceed 126/100 ml or enterococci not to exceed 33/100 ml; and

- Marine water: enterococci not to exceed 35/100 ml.

These criteria should be calculated as the geometric mean based on five equally spaced samples taken over a 30-day period.

In addition, EPA recommends that States adopt a single sample maximum, based on the expected frequency of use. No sample taken should exceed this value. EPA specifies appropriate single sample maximum values in the 1986 criteria document.

<u>Current Activities and Plans for Future Work</u>

EPA has identified development of microbial water quality criteria as part of its strategy to control waterborne microbial disease, by controlling pathogens in waterbodies and by protecting designated uses, such as recreation and public water supplies. The program fosters an integrated approach to protect both ground-water and surface water sources. EPA plans to conduct additional monitoring for *Cryptosporidium parvum* and *E. coli*, and determine action plans in accordance with the results of this monitoring.

EPA recommends no change at this time in the stringency of its bacterial criteria for recreational waters; existing criteria and methodologies from 1986 will still apply. The recommended methods for *E. coli* and enterococci have been improved. As outlined in the *Action Plan for Beaches and Recreational Waters* (Beach Action Plan, see below), the Agency plans to conduct national studies on improving indicators together with epidemiology studies for new criteria development (USEPA, 1999b). The Agency is also planning to establish improved temporal and spatial monitoring protocols.

In the Beach Action Plan, EPA identifies a multi-year strategy for monitoring recreational water quality and communicating public health risks associated with potentially pathogen-contaminated recreational rivers, lakes, and ocean beaches. It articulates the Agency's rationale and goals in addressing specific problems and integrates all associated program, policy, and research needs and directions. The Beach Action Plan also provides information on timing, products and lead organization for each activity. These include activities and products in the areas of program development, risk communication, water quality indicator research, modeling and monitoring research, and exposure and health effects research.

Recently, EPA approved new 24-hour *E. coli* and enterococcus tests for recreational waters that may be used as an alternative to the 48-hour test (USEPA, 1997). EPA anticipates proposing these methods for inclusion in the 40 CRF 136 in the Fall of 2000. EPA has also published a video with accompanying manual on the original and newer methods for enterococci and *E. coli* (USEPA, 2000).

As part of the Beach Action Plan, EPA made the following recommendations for further Agency study:

- Future criteria development should consider the risk of diseases other than gastroenteritis. EPA intends to consider and evaluate such water-related exposure routes as inhalation and dermal absorption when addressing microbial health effects. The nature and significance of other than the classical waterborne pathogens are to some degree tied to the particular type of waste sources.

- A new set of indicator organisms may need to be developed for tropical water if it is proven that the current fecal indicators can maintain viable cell populations in the soil and water for significant periods of time in uniform tropical conditions. Some potential alternative indicators to be fully explored are coliphage, other bacteriophage, and *Clostridium perfringens*.

- Because animal sources of pathogens of concern for human infection such as *Giardia lamblia*, *Cryptosporidium parvum*, and *Escherichia coli* 0157:H7 may be waterborne or washed into water and thus become a potential source for infection, they should not be ignored in risk assessment. A likely approach would be phylogenetic differentiation; that is, indicators that are specific to, or can discriminate among, animal sources.

- EPA intends to develop additional data on secondary infection routes and infection rates from prospective epidemiology studies and outbreaks from various types of exposure (e.g., shellfish consumption, drinking water, recreational exposure).

- EPA needs to improve sampling strategies for recreational water monitoring including consideration of rainfall and pollution events to trigger sampling.

2.6 RISK CHARACTERIZATION CONSIDERATIONS

On March 21, 1995, EPA's Administrator issued the *EPA Risk Characterization Policy and Guidance* (USEPA, 1995). This policy and guidance is intended to ensure that characterization information from each stage of a risk assessment is used in forming conclusions about risk and that this information is communicated from risk assessors to risk managers, and from EPA to the public. The policy also provides the basis for greater clarity, transparency, reasonableness, and consistency in risk assessments across EPA programs. The fundamental principles which form the basis for a risk characterization are as follows:

- Risk assessments should be transparent, in that the conclusions drawn from the science are identified separately from policy judgments, and the use of default values or methods and the use of assumptions in the risk assessment are clearly articulated.

- Risk characterizations should include a summary of the key issues and conclusions of each of the other components of the risk assessments, as well as describe the likelihood of harm. The summary should include a description of the overall strengths and limitations (including uncertainties) of the assessment and conclusions.

- Risk characterizations should be consistent in general format, but recognize the unique characteristics of each specific situation.

- Risk characterizations should include, at least in a qualitative sense, a discussion of how a specific risk and its context compares with similar risks. This may be accomplished by comparisons with other pollutants or situations on which the Agency has decided to act, or other situations with which the public may be familiar. The discussion should highlight the limitations of such comparisons.

- Risk characterization is a key component of risk communication, which is an interactive process involving exchange of information and expert opinion among individuals, groups, and institutions.

Additional guiding principles include:

- The risk characterization integrates the information from the hazard identification, dose-response, and exposure assessments, using a combination of qualitative information, quantitative information, and information regarding uncertainties.

- The risk characterization includes a discussion of uncertainty and variability in the risk assessment.

- Well-balanced risk characterizations present conclusions and information regarding the strengths and limitations of the assessment for other risk assessors, EPA decision-makers, and the public.

In developing the methodology presented here, EPA has closely followed the risk characterization guiding principles listed above. As States and Tribes adopt criteria using the 2000 Human Health Methodology, they are strongly encouraged to follow EPA's risk characterization guidance. There are a number of areas within the Methodology and criteria development process where risk characterization principles apply:

- Integration of cancer and noncancer assessments with exposure assessments, including bioaccumulation potential determinations, in essence, weighing the strengths and weaknesses of the risk assessment as a whole when developing a criterion.

- Selecting a fish consumption rate, either locally derived or the national default value, within the context of a target population (e.g., sensitive subpopulations) as compared to the general population.

- Presenting cancer and/or noncancer risk assessment options.

- Describing the uncertainty and variability in the hazard identification, the dose-response, and the exposure assessment.

2.7 DISCUSSION OF UNCERTAINTY

2.7.1 Observed Range of Toxicity Versus Range of Environmental Exposure

When characterizing a risk assessment, an important distinction to make is between the observed range of adverse effects (from an epidemiology or animal study) and the environmentally observed range of exposure (or anticipated human exposure) to the contaminant. In many cases, EPA intends to apply default factors to account for uncertainties or incomplete knowledge in developing RfDs or cancer risk assessments using nonlinear low-dose extrapolation to provide a margin of protection. In reality, the actual effect level and the environmental exposure levels may be separated by several orders of magnitude. The difference between the dose causing some observed response and the anticipated human exposure should be described by risk assessors and managers, especially when comparing criteria to environmental levels of a contaminant.

2.7.2 Continuum of Preferred Data/Use of Defaults

In both toxicological and exposure assessments, EPA has defined a continuum of preferred data for toxicological assessments ranging from a highest preference for chronic human data (e.g., studies that examine a long-term exposure of humans to a chemical, usually from occupational and/or residential exposure) and actual field data for many of the exposure parameter values (e.g., locally derived fish consumption rates, waterbody-specific bioaccumulation rates), to default values which are at the lower end of the preference continuum. EPA has supplied default values for all of the risk assessment parameters in the 2000 Human Health Methodology; however, it is important to note that when default values are used, the uncertainty in the final risk assessment may be higher, and the final resulting criterion may not be as applicable to local conditions, than is a risk assessment derived from human/field data. Using defaults assumes generalized conditions and may not capture the actual variability in the population (e.g., sensitive subpopulations/high-end consumers). If defaults are chosen as the basis for criteria, these inherent uncertainties should be communicated to the risk manager and the public. While this continuum is an expression of preference on the part of EPA, it does not imply in any way that any of the choices are unacceptable or scientifically indefensible.

2.7.3 Significant Figures

The number of significant figures in a numeric value is the number of certain digits plus one estimated digit. Digits should not be confused with decimal places. For example, 15.1, 0.0151, and 0.0150 all have 3 significant figures. Decimal places may have been used to maintain the correct number of significant figures, but in themselves they do not indicate significant figures (Brinker, 1984). Since the number of significant figures must include only one estimated digit, the sources of input parameters (e.g., fish consumption and water consumption rates) should be checked to determine the number of significant figures associated with data they provide. However, the original measured values may not be available to determine the number of significant figures in the input parameters. In these situations, EPA recommends utilizing the data as presented.

When developing criteria, EPA recommends rounding the number of significant figures at the end of the criterion calculation to the same number of significant figures in the least precise parameter. This is a generally accepted practice which can be found described in greater detail in APHA (1992) and Brinker (1984). The general rule is that for multiplication or division, the resulting value should not possess any more significant figures than is associated with the factor in the calculation with the least precision. When numbers are added or subtracted, the number that has the fewest decimal places, not necessarily the fewest significant figures, puts the limit on the number of places that justifiably may be carried in the sum or difference. Rounding off a number is the process of dropping one or more digits so that the value contains only those digits that are significant or necessary in subsequent computations (Brinker, 1984). The following rounding procedures are recommended: (1) if the digit 6, 7, 8, or 9 is dropped, increase the preceding digit by one unit; (2) if the digit 0, 1, 2, 3, or 4 is dropped, do not alter the preceding digit; and (3) if the digit 5 is dropped, round off the preceding digit to the nearest even number (e.g., 2.25 becomes 2.2 and 2.35 becomes 2.4) (APHA, 1992; Brinker, 1984).

EPA recommends that calculations of water quality criteria be performed without rounding of intermediate step values. The resulting criterion may be rounded to a manageable number of decimal places. However, in no case should the number of digits presented exceed the number of significant figures implied in the data and calculations performed on them. The term "intermediate step values" refers to values of the parameters in Equations 1-1 through 1-3. The final step is considered the resulting AWQC. Although AWQC are, in turn, used for purposes of establishing water quality-based effluent limits (WQBELs) in National Pollutant Discharge Elimination System (NPDES) permits, calculating total maximum daily loads (TMDLs), and applicable or relevant and appropriate requirements (ARARs) for Superfund, they are considered the final step of this Methodology and, for the purpose of this discussion, where the rounding should occur.

The determination of appropriate significant figures inevitably involves some judgment given that some of the equation parameters are adopted default exposure values. Specifically, the default drinking water intake rate of 2 L/day is a value adopted to represent a majority of the population over the course of a lifetime. Although supported by drinking water consumption survey data, this value was adopted as a policy decision and, as such, does not have to be considered in determining the parameter with the least precision. That is, the resulting AWQC need not always be reduced to one significant digit. Similarly, the 70-kg adult body weight has been adopted Agency-wide and represents a default policy decision.

The following example with a simplified AWQC equation illustrates the rule described above. The example is for hexachlorobutadiene (HCBD), which EPA used to demonstrate the 1998 draft Methodology revisions (USEPA, 1998b). The parameters that were calculated (i.e., not policy adopted values) include values with significant figures of two (the POD and RSC), three (the UF), and four (the FI and BAF). Based on the 2000 Human Health Methodology, the final criterion should be rounded to two significant figures. The bold numbers in parentheses indicate the number of significant figures and those with asterisks also indicate Agency adopted policy values.

$$AWQC = \frac{POD}{UF} \cdot RSC \cdot \left(\frac{BW}{DI + (FI \cdot BAF)} \right) \qquad \text{(Equation 2-1)}$$

Example [Refer to draft HCBD document for details on the POD/UF, RSC and BAF data (EPA 822-R-98-004). Also note that the fish intake rate in this example is the revised value.]:

$$AWQC = \left(\frac{0.054\mathbf{(2)}}{300\mathbf{(3)}} - 1.2 \times 10^{-4}\mathbf{(2)} \right) \times \left(\frac{70\mathbf{(2^*)}}{2\mathbf{(1^*)} + (0.01750\mathbf{(4)} \times 3{,}180\mathbf{(4)})} \right)$$

AWQC = 7.3×10^{-5} mg/L (0.073 µg/L, rounded from 7.285×10^{-2} µg/L)
* represents Agency adopted policy value

A number of the values used in the equation may result in intermediate step values that have more than four figures past the decimal place and may be carried throughout the calculation. However, carrying more than four figures past the decimal place (equivalent to the most precise parameter) is unnecessary as it has no effect on the resulting criterion value.

2.8 OTHER CONSIDERATIONS

2.8.1 Minimum Data Considerations

For many of the preceding technical areas, considerations have been presented for data quality in developing toxicological and exposure assessments. For greater detail and discussion of minimum data recommendations, the reader is referred to the specific sections in the Methodology on cancer and noncancer risk assessments (and especially to the referenced EPA risk assessment guidelines documents), exposure assessment, and bioaccumulation assessment, in addition to the TSD volumes for each.

2.8.2 Site-Specific Criterion Calculation

The 2000 Human Health Methodology allows for site-specific modifications by States and Tribes to reflect local environmental conditions and human exposure patterns. "Local" may refer to any appropriate geographic area where common aquatic environmental or exposure patterns exist. Thus "local" may signify Statewide, regional, a river reach, or an entire river.

Such site-specific criteria may be developed as long as the site-specific data, either toxicological or exposure-related, is justifiable. For example, when using a site-specific fish consumption rate, a State should use a value that represents at least the central tendency of the population surveyed (either sport or subsistence, or both). If a site-specific fish consumption rate for sport anglers or subsistence anglers is lower than an EPA default value, it may be used in calculating AWQC. However, to justify such a level (either higher or lower than EPA defaults), the State should assemble appropriate survey data to arrive at a defensible site-specific fish consumption rate.

Such data must also be submitted to EPA for its review when approving or disapproving State or Tribal water quality standards under Section 303(c). The same conditions apply to site-specific calculations of BAF, percent fish lipid, or the RSC. In the case of deviations from toxicological values (i.e., IRIS values: verified noncancer and cancer assessments), EPA strongly recommends that the data upon which the deviation is based be presented to and approved by the Agency before a criterion is developed.

Additional guidance on site-specific modifications to the 2000 Human Health Methodology is provided in each of the three TSD volumes.

2.8.3 Organoleptic Criteria

Organoleptic criteria define concentrations of chemicals or materials which impart undesirable taste and/or odor to water. Organoleptic effects, while significant from an aesthetic standpoint, are not a significant health concern. In developing and utilizing such criteria, two factors must be appreciated: (1) the limitations of most organoleptic data; and (2) the human health significance of organoleptic properties. In the past, EPA has developed organoleptic criteria if organoleptic data were available for a specific contaminant. The 1980 AWQC National Guidelines made a clear distinction that organoleptic criteria and toxicity-based criteria are derived from completely different endpoints, and that organoleptic criteria have no demonstrated relationship to potential adverse human health effects because there is no toxicological basis. EPA acknowledges that if organoleptic effects (i.e., objectionable taste and odor) cause people to reject the water and its designated uses, then the public is effectively deprived of the natural resource. It is also possible that intense organoleptic characteristics could result in depressed fluid intake which, in turn, might lead to an indirect human health effect via decreased fluid consumption. Although EPA has developed organoleptic criteria in the past and may potentially do so in the future, this will not be a significant part of the water quality criteria program. EPA encourages the development of organoleptic criteria when States and Tribes believe they are needed. However, EPA cautions States and Tribes that the quality of organoleptic data is often significantly less than that of toxicologic data used in establishing health-based criteria. Therefore, a comprehensive evaluation of available organoleptic data should be made, and the selection of the most appropriate database for the criterion should be based on sound scientific judgment.

In 1980, EPA provided recommended criteria summary language when both types of data are available. The following format was used and is repeated here:

> *For comparison purposes, two approaches were used to derive criterion levels for ____. Based on available toxicity data, for the protection of public health the derived level is ____. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water the estimated level is ____. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have no demonstrated relationship to potential adverse human health effects.*

Similarly, the 1980 Methodology recommended that in those instances where a level to limit toxicity cannot be derived, the following statement should be provided:

> *Sufficient data are not available for ____ to derive a level which would protect against the potential toxicity of this compound.*

2.8.4 Criteria for Chemical Classes

The 2000 Human Health Methodology also allows for the development of a criterion for classes of chemicals, as long as a justification is provided through the analysis of mechanistic data, toxicokinetic data, structure-activity relationship data, and limited acute and chronic toxicity data. When potency differences between members of a class is great (such as in the case

of chlorinated dioxins and furans), toxicity equivalency factors (TEFs) may be more appropriately developed than one class criterion.

A chemical class is defined as any group of chemical compounds which are similar in chemical structure and biological activity, and which frequently occur together in the environment usually because they are generated by the same commercial process. In criterion development, isomers should be regarded as part of a chemical class rather than as a single compound. A class criterion, therefore, is an estimate of risk/safety which applies to more than one member of a class. It involves the use of available data on one or more chemicals of a class to derive criteria for other compounds of the same class in the event that there are insufficient data available to derive compound-specific criteria. The health-based criterion may apply to the water concentration of each member of the class, or may apply to the sum of the water concentrations of the compounds within the class. Because relatively minor structural changes within the class of compounds can have pronounced effects on their biological activities, reliance on class criteria should be minimized depending on the data available.

The following guidance should also be followed when considering the development of a class criterion.

- A detailed review of the chemical and physical properties of the chemicals within the group should be made. A close relationship within the class with respect to chemical activity would suggest a similar potential to reach common biological sites within tissues. Likewise, similar lipid solubilities would suggest the possibility of comparable absorption and distribution.

- Qualitative and quantitative toxicological data for chemicals within the group should be examined. Adequate toxicological data on a number of compounds within a group provides a more reasonable basis for extrapolation to other chemicals of the same class than minimal data on one chemical or a few chemicals within the group.

- Similarities in the nature of the toxicological response to chemicals in the class provides additional support for the prediction that the response to other members of the class may be similar. In contrast, where the biological response has been shown to differ markedly on a qualitative and quantitative basis for chemicals within a class, the extrapolation of a criterion to other members is not appropriate.

- Additional support for the validity of extrapolation of a criterion to other members of a class could be provided by evidence of similar metabolic and toxicokinetic data for some members of the class.

Additional guidance is described in the *Technical Support Document on Health Risk Assessment of Chemical Mixtures* (USEPA, 1990).

2.9.5 Criteria for Essential Elements

Developing criteria for essential elements, particularly metals, must be a balancing act between toxicity and the requirement for good health. The AWQC must consider essentiality and cannot be established at levels that would result in deficiency of the element in the human population. The difference between the recommended daily allowance (RDA) and the daily doses causing a specified risk level for carcinogens or the RfDs for noncarcinogens defines the spread of daily doses within which the criterion may be derived. Because errors are inherent in defining both essential and adverse-effect levels, the criterion is derived from a dose level near the center of such dose ranges.

The process for developing criteria for essential elements should be similar to that used for any other chemical with minor modifications. The RfD represents concern for one end of the exposure spectrum (toxicity), whereas the RDA represents the other end (minimum essentiality). While the RDA and RfD values might occasionally appear to be similar in magnitude to one another, it does not imply incompatibility of the two methodological approaches, nor does it imply inaccuracy or error in either calculation.

2.9 REFERENCES

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3. RISK ASSESSMENT

This section describes the methods used to estimate ambient water quality criteria (AWQC) for the protection of human health for carcinogenic chemicals (Section 3.1) and for noncarcinogenic chemicals (Section 3.2).

3.1 CANCER EFFECTS

3.1.1 Background on EPA Cancer Risk Assessment Guidelines

The current EPA *Guidelines for Carcinogen Risk Assessment* were published in 1986 (USEPA, 1986a, hereafter the "1986 cancer guidelines"). The 1986 cancer guidelines categorize chemicals into alpha-numerical Groups: A, known human carcinogen (sufficient evidence from epidemiological studies or other human studies); B, probable human carcinogen (sufficient evidence in animals and limited or inadequate evidence in humans); C, possible human carcinogen (limited evidence of carcinogenicity in animals in the absence of human data); D, not classifiable (inadequate or no animal evidence of carcinogenicity); and E, evidence of noncarcinogenicity for humans (no evidence of carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiological and animal studies). Within Group B there are two subgroups, Groups B1 and B2. Group B1 is reserved for agents for which there is limited evidence of carcinogenicity from epidemiological studies. Group B2 is generally for agents for which there is sufficient evidence from animal studies and for which there is inadequate evidence or no data from epidemiological studies (USEPA, 1986). The system was similar to that used by the International Agency for Research on Cancer (IARC).

The 1986 cancer guidelines include guidance on what constitutes sufficient, limited, or inadequate evidence. In epidemiological studies, sufficient evidence indicates a causal relationship between the agent and human cancer; limited evidence indicates that a causal relationship is credible, but that alternative explanations, such as chance, bias, or confounding, could not adequately be excluded; inadequate evidence indicates either lack of pertinent data, or a causal interpretation is not credible. In general, although a single study may be indicative of a cause-effect relationship, confidence in inferring a causal association is increased when several independent studies are concordant in showing the association. In animal studies, sufficient evidence includes an increased incidence of malignant tumors or combined malignant and benign tumors:

- In multiple species or strains;
- In multiple experiments (e.g., with different routes of administration or using different dose levels);
- To an unusual degree in a single experiment with regard to high incidence, unusual site or type of tumor, or early age at onset;
- Additional data on dose-response, short-term tests, or structural activity relationships.

In the 1986 cancer guidelines, hazard identification and the weight-of-evidence process focus on tumor findings. The weight-of-evidence approach for making judgments about cancer hazard analyzes human and animal tumor data separately, then combines them to make the overall conclusion about potential human carcinogenicity. The next step of the hazard analysis is an evaluation of supporting evidence (e.g., mutagenicity, cell transformation) to determine whether the overall weight-of-evidence conclusion should be modified.

For cancer risk quantification, the 1986 cancer guidelines recommend the use of linearized multistage model (LMS) as the only default approach. The 1986 cancer guidelines also mention that a low-dose extrapolation model other than the LMS might be considered more appropriate based on biological grounds. However, no guidance is given in choosing other approaches. The 1986 cancer guidelines recommended the use of body weight raised to the 2/3 power ($BW^{2/3}$) as a dose scaling factor between species.

3.1.2 EPA's Proposed Guidelines for Carcinogen Risk Assessment and the Subsequent July, 1999 Draft Revised Cancer Guidelines

In 1996, EPA published *Proposed Guidelines for Carcinogen Risk Assessment* (USEPA, 1996a, hereafter the "1996 proposed cancer guidelines"). After the publication of the 1996 proposed cancer guidelines and a February, 1997 and January, 1999 Science Advisory Board (SAB) review, a revision was made in July, 1999 *Guidelines for Carcinogen Risk Assessment - Review Draft* (hereafter the "1999 draft revised cancer guidelines"; USEPA, 1999a), and an SAB meeting was convened to review this revised document. When final guidelines are published, they will replace the 1986 cancer guidelines. These revisions are designed to ensure that the Agency's cancer risk assessment methods reflect the most current scientific information and advances in risk assessment methodology.

In the meanwhile, the 1986 guidelines are used and extended with principles discussed in the 1999 draft revised cancer guidelines. These principles arise from scientific discoveries concerning cancer made in the last 15 years and from EPA policy of recent years supporting full characterization of hazard and risk both for the general population and potentially sensitive groups such as children. These principles are incorporated in recent and ongoing assessments such as the reassessment of dioxin, consistent with the 1986 guidelines. Until final guidelines are published, information is presented to describe risk under both the 1986 guidelines and 1999 draft revisions.

The 1999 draft revised cancer guidelines call for the full use of all relevant information to convey the circumstances or conditions under which a particular hazard is expressed (e.g., route, duration, pattern, or magnitude of exposure). They emphasize understanding the mode of action (MOA) whereby the agent induces tumors. The MOA underlies the hazard assessment and provides the rationale for dose-response assessments.

The key principles in the 1999 draft revised cancer guidelines include:

a) Hazard assessment is based on the analysis of all biological information rather than just tumor findings.

b) An agent's MOA in causing tumors is emphasized to reduce the uncertainty in describing the likelihood of harm and in determining the dose-response approach(es).

c) The 1999 draft revised cancer guidelines emphasize the conditions under which the hazard may be expressed (e.g., route, pattern, duration and magnitude of exposure). Further, the guidelines call for a *hazard characterization* to integrate the data analysis of all relevant studies into a weight-of-evidence conclusion of hazard and to develop a working conclusion regarding the agent's mode of action in leading to tumor development.

d) A weight-of-evidence narrative with accompanying descriptors (listed in Section 3.1.3.1 below) would replace the current alphanumeric classification system. The narrative summarizes the key evidence for carcinogenicity, describes the agent's MOA, characterizes the conditions of hazard expression, including route of exposure, describes any disproportionate effects on subgroups of the human population (e.g., children), and recommends appropriate dose-response approach(es). Significant strengths, weaknesses, and uncertainties of contributing evidence are also highlighted.

e) Biologically based extrapolation models are the preferred approach for quantifying risk. These models integrate data and conclusions about events in the carcinogenic process throughout the dose-response range from high to low doses. It is anticipated, however, that the necessary data for the parameters used in such models will not be available for most chemicals. The 1999 draft revised cancer guidelines allow for alternative quantitative methods, including several default approaches.

f) Dose-response assessment is a two-step process. In the first step, response data are modeled in the observable range of data and a determination is made of the point of departure (POD) from the observed range to extrapolate to low doses. The second step is extrapolation from the POD to estimate dose-response at lower doses. In addition to modeling tumor data, the 1999 draft revised cancer guidelines call for the use and modeling of other kinds of responses if they are considered to be more informed measures of carcinogenic risk. Nominally, these responses reflect key events in the carcinogenic process integral to the MOA of the agent.

g) Three default approaches are provided–linear, nonlinear, or both when adequate data are unavailable to generate a biologically based model. As the first step for all approaches, curve fitting in the observed range is used to determine a POD. A standard POD is the effective dose corresponding to the lower 95 percent limit on

a dose associated with 10 percent extra risk (LED_{10}).[3] *Linear*: The linear default is a straight line extrapolation from the response at LED_{10} to the origin (zero dose, zero extra risk). *Nonlinear*: The nonlinear default begins with the identified POD and provides a margin of exposure (MOE) analysis rather than estimating the probability of effects at low doses. The MOE analysis is used to determine the appropriate margin between the POD and the exposure level of interest, in this Methodology, the AWQC. The key objective of the MOE analysis is to describe for the risk manager how rapidly responses may decline with dose. Other factors are also considered in the MOE analysis (i.e., nature of the response, slope of the dose-response curve, human sensitivity compared with experimental animals, nature and extent of human variability in sensitivity and human exposure). *Linear and nonlinear*: Section 3.1.3.4E describes the situations when both linear and nonlinear defaults are used.

h) The approach used to calculate an oral human equivalent dose when assessments are based on animal bioassays has been refined and includes a change in the default assumption for interspecies dose scaling. The 1999 draft revised cancer guidelines use body weight raised to the 3/4 power.

EPA health risk assessment practices for both cancer and noncancer endpoints are beginning to come together with recent proposals to emphasize MOA understanding in risk assessment and to model response data in the observable range to derive PODs for data sets and benchmark doses (BMDs) for individual studies. The modeling of observed response data to identify PODs in a standard way will help to harmonize cancer and noncancer dose-response approaches and permit comparisons of cancer and noncancer risk estimates.

3.1.3 Methodology for Deriving AWQC[4] by the 1999 Draft Revised Cancer Guidelines

Following the publication of the *Draft Water Quality Criteria Methodology: Human Health* (USEPA, 1998a) and the accompanying TSD (USEPA, 1998b), EPA received comments from the public. EPA also held an external peer review of the draft Methodology. Both the peer reviewers and the public recommended that EPA incorporate the new approaches into the AWQC Methodology.

Until new guidelines are published, the 1986 cancer guidelines will be used along with principles of the 1999 draft revised cancer guidelines. The 1986 guidelines are the basis for IRIS risk numbers which were used to derive the current AWQC. Each new assessment applying the principles of the 1999 draft revised cancer guidelines will be subject to peer review before being used as the basis of AWQC.

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[3] Use of the LED_{10} as the point of departure is recommended with this Methodology, as it is with the 1999 draft revised cancer guidelines.

[4] Additional information regarding the revised method for assessing carcinogens may be found in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). Technical Support Document, Volume 1: Risk Assessment* (USEPA, 2000).

The remainder of Section 3 illustrates the methodology for deriving numerical AWQC for carcinogens applying the 1999 draft revised cancer guidelines (USEPA, 1999a). This discussion of the revised methodology for carcinogens focuses primarily on the quantitative aspects of deriving numerical AWQC values. It is important to note that the cancer risk assessment process outlined in the 1999 draft revised cancer guidelines is not limited to the quantitative aspects. A numerical AWQC value derived for a carcinogen is to be based on appropriate hazard characterization and accompanied by risk characterization information.

This section contains a discussion of the weight-of-evidence narrative, that describes all information relevant to a cancer risk evaluation, followed by a discussion of the quantitative aspects of deriving numerical AWQC values for carcinogens. It is assumed that data from an appropriately conducted animal bioassay or human epidemiological study provide the underlying basis for deriving the AWQC value. The discussion focuses on the following: (1) the weight-of-evidence narrative; (2) general considerations and framework for analysis of the MOA; (3) dose estimation; (4) characterizing dose-response relationships in the range of observation and at low, environmentally relevant doses; (5) calculating the AWQC value; (6) risk characterization; and (7) use of Toxicity Equivalent Factors (TEF) and Relative Potency Estimates. The first three topics encompass the quantitative aspects of deriving AWQC for carcinogens.

3.1.3.1 Weight-of-Evidence Narrative[5]

The 1999 draft revised cancer guidelines include a weight-of-evidence narrative that is based on an overall judgment of biological and chemical/physical considerations. Hazard assessment information accompanying an AWQC value for a carcinogen in the form of a weight-of-evidence narrative is described in the footnote. Of particular importance is that the weight-of-evidence narrative explicitly provides adequate support based on human studies, animal bioassays, and other key evidence for the conclusion whether the substance is or is likely to be carcinogenic to humans from exposures through drinking water and/or fish ingestion. The Agency emphasizes the importance of providing an explicit discussion of the MOA for the substance in the weight-of-evidence narrative if data are available, including a discussion that relates the MOA to the quantitative procedures used in the derivation of the AWQC.

3.1.3.2 Mode of Action - General Considerations and Framework for Analysis

[5] The weight-of-evidence narrative is intended for the risk manager, and thus explains in nontechnical language the key data and conclusions, as well as the conditions for hazard expression. Conclusions about potential human carcinogenicity are presented by route of exposure. Contained within this narrative are simple likelihood descriptors that essentially distinguish whether there is enough evidence to make a projection about human hazard (i.e., Carcinogenic to humans; Likely to be carcinogenic to humans; Suggestive evidence of carcinogenicity but not sufficient to assess human carcinogenic potential; Data are inadequate for an assessment of human carcinogenic potential; and Not likely to be carcinogenic to humans). Because one encounters a variety of data sets on agents, these descriptors are not meant to stand alone; rather, the context of the weight-of-evidence narrative is intended to provide a transparent explanation of the biological evidence and how the conclusions were derived. Moreover, these descriptors should not be viewed as classification categories (like the alphameric system), which often obscure key scientific differences among chemicals. The new weight-of-evidence narrative also presents conclusions about how the agent induces tumors and the relevance of the mode of action to humans, and recommends a dose-response approach based on the MOA understanding (USEPA, 1996a, 1999a).

An MOA is composed of key events and processes starting with the interaction of an agent with a cell, through operational and anatomical changes, resulting in cancer formation. "Mode" of action is contrasted with "mechanism" of action, which implies a more detailed, molecular description of events than is meant by MOA.

Mode of action analysis is based on physical, chemical, and biological information that helps to explain key events[6] in an agent's influence on development of tumors. Inputs to MOA analysis include tumor data in humans, animals, and among structural analogues as well as the other key data.

There are many examples of possible modes of carcinogenic action, such as mutagenicity, mitogenesis, inhibition of cell death, cytotoxicity with reparative cell proliferation, and immune suppression. All pertinent studies are reviewed in analyzing an MOA, and an overall weighing of evidence is performed, laying out the strengths, weaknesses, and uncertainties of the case as well as potential alternative positions and rationales. Identifying data gaps and research needs is also part of the assessment.

Mode of action conclusions are used to address the question of human relevance of animal tumor responses, to address differences in anticipated response among humans such as between children and adults or men and women, and as the basis of decisions about the anticipated shape of the dose-response relationship.

In reaching conclusions, the question of "general acceptance" of an MOA will be tested as part of the independent peer review that EPA obtains for its assessment and conclusions.

Framework for Evaluating a Postulated Carcinogenic Mode(s) of Action

The framework is intended to be an analytic tool for judging whether available data support a mode of carcinogenic action postulated for an agent and includes nine elements:

1. Summary description of postulated MOA
2. Identification of key events
3. Strength, consistency, specificity of association
4. Dose-response relationship
5. Temporal relationship
6. Biological plausibility and coherence
7. Other modes of action
8. Conclusion
9. Human relevance, including subpopulations

3.1.3.3 Dose Estimation

[6]A "key event" is an empirically observable, precursor step that is itself a necessary element of the mode of action, or is a marker for such an element.

A. Determining the Human Equivalent Dose by the Oral Route

An important objective in the dose-response assessment is to use a measure of internal or delivered dose at the target site where possible. This is particularly important in those cases where the carcinogenic response information is being extrapolated to humans from animal studies. Generally, by the oral exposure route, the measure of a dose provided in the underlying human studies or animal bioassays is the applied dose, typically given in terms of unit mass per unit body weight per unit time, (e.g., mg/kg-day). When animal bioassay data are used, it is necessary to make adjustments to the applied dose values to account for differences in toxicokinetics between animals and humans that affect the relationship between applied dose and delivered dose at the target organ.

In the estimation of a human equivalent dose, the 1999 draft revised cancer guidelines recommend that when adequate data are available, the doses used in animal studies can be adjusted to equivalent human doses using toxicokinetic information on the particular agent. However, in most cases, there are insufficient data available to compare dose between species. In these cases, the estimate of a human equivalent dose is based on science policy default assumptions. To derive an equivalent human oral dose from animal data, the default procedure in the 1999 draft revised cancer guidelines is to scale daily applied oral doses experienced for a lifetime in proportion to body weight raised to the 3/4 power ($BW^{3/4}$). The adjustment factor is used because metabolic rates, as well as most rates of physiological processes that determine the disposition of dose, scale this way. Thus, the rationale for this factor rests on the empirical observation that rates of physiological processes consistently tend to maintain proportionality with body weight raised to 3/4 power (USEPA, 1992a, 1999a).

The use of $BW^{3/4}$ is a departure from the scaling factor of $BW^{2/3}$ that was based on surface area adjustment and was included in the 1980 AWQC National Guidelines as well as the 1986 cancer guidelines.

B. Dose-Response Analysis

If data on the agent are sufficient to support the parameters of a biologically based model and the purpose of the assessment is such as to justify investing resources supporting its use, this is the preferred approach for both the observed tumor and related response data and for extrapolation below the range of observed data in either animal or human studies.

3.1.3.4 Characterizing Dose-Response Relationships in the Range of Observation and at Low Environmentally Relevant Doses

The first quantitative component in the derivation of AWQC for carcinogens is the dose-response assessment in the range of observation. For most agents, in the absence of adequate data to generate a biologically based model, dose-response relationships in the observed range can be addressed through curve-fitting procedures for response data. It should be noted that the 1999 draft revised cancer guidelines call for modeling of not only tumor data in the observable range, but also other responses thought to be important events preceding tumor development (e.g., DNA adducts, cellular proliferation, receptor binding, hormonal changes). The modeling of

these data is intended to better inform the dose-response assessment by providing insights into the relationships of exposure (or dose) below the observable range for tumor response. These non-tumor response data can only play a role in the dose-response assessment if the agent's carcinogenic mode of action is reasonably understood, as well as the role of that precursor event.

The 1999 draft revised cancer guidelines recommend calculating the lower 95 percent confidence limit on a dose associated with an estimated 10 percent increased tumor or relevant non-tumor response (LED_{10}) for quantitative modeling of dose-response relationships in the observed range. The estimate of the LED_{10} is used as the POD for low-dose extrapolations discussed below. This standard point of departure (LED_{10}) is adopted as a matter of science policy to remain as consistent and comparable from case to case as possible. It is also a convenient comparison point for noncancer endpoints. The rationale supporting use of the LED_{10} is that a 10 percent response is at or just below the limit of sensitivity for discerning a statistically significant tumor response in most long-term rodent studies and is within the observed range for other toxicity studies. Use of lower limit takes experimental variability and sample size into account. The ED_{10} (central estimate) is also presented as a reference for comparison uses, especially for use in relative hazard/potency ranking among agents for priority setting.

For some data sets, a choice of the POD other than the LED_{10} may be appropriate. The objective is to determine the lowest reliable part of the dose-response curve for the beginning of the second step of the dose-response assessment—determine the extrapolation range. Therefore, if the observed response is below the LED_{10}, then a lower point may be a better choice (e.g., LED_5). Human studies more often support a lower POD than animal studies because of greater sample size.

The POD may be a NOAEL when a margin of exposure analysis is the nonlinear dose-response approach. The kinds of data available and the circumstances of the assessment both contribute to deciding to use a NOAEL or LOAEL which is not as rigorous or as ideal as curve fitting, but can be appropriate. If several data sets for key events and tumor response are available for an agent, and they are a mixture of continuous and incidence data, the most practicable way to assess them together is often through a NOAEL/LOAEL approach.

When an LED value estimated from animal data is used as the POD, it is adjusted to the human equivalent dose using an interspecies dose adjustment or a toxicokinetic analysis as described in Section 3.1.3.3.

Analysis of human studies in the observed range is designed on a case-by-case basis depending on the type of study and how dose and response are measured in the study.

A. Extrapolation to Low, Environmentally Relevant Doses

In most cases, the derivation of an AWQC will require an evaluation of carcinogenic risk at environmental exposure levels substantially lower than those used in the underlying study. Various approaches are used to extrapolate risk outside the range of observed experimental data. In the 1999 draft revised cancer guidelines, the choice of extrapolation method is largely

dependent on the mode of action. It should be noted that the term "mode of action" (MOA) is deliberately chosen in the 1999 draft revised cancer guidelines in lieu of the term "mechanism" to indicate using knowledge that is sufficient to draw a reasonable working conclusion without having to know the processes in detail as the term mechanism might imply. The 1999 draft revised cancer guidelines favor the choice of a biologically based model, if the parameters of such models can be calculated from data sources independent of tumor data. It is anticipated that the necessary data for such parameters will not be available for most chemicals. Thus, the 1999 draft revised cancer guidelines allow for several default extrapolation approaches (low-dose linear, nonlinear, or both).

B. Biologically Based Modeling Approaches

If a biologically based approach has been used to characterize the dose-response relationships in the observed range, and the confidence in the model is high, it may be used to extrapolate the dose-response relationship to environmentally relevant doses. For the purposes of deriving AWQC, the environmentally relevant dose would be the risk-specific dose (RSD) associated with incremental lifetime cancer risks in the 10^{-6} to 10^{-4} range for carcinogens for which a linear extrapolation approach is applied.[7] The use of the RSD and the POD/UF to compute the AWQC is presented in Section 3.1.3.5, below. Although biologically-based approaches are appropriate both for characterizing observed dose-response relationships and extrapolating to environmentally relevant doses, it is not expected that adequate data will be available to support the use of such approaches for most substances. In the absence of such data, the default linear approach, the nonlinear (MOE) approach, or both linear and nonlinear approaches will be used.

[7] For discussion of the cancer risk range, see Section 2.4.

C. Default Linear Extrapolation Approach

The default linear approach replaces the LMS approach that has served as the default for EPA cancer risk assessments. Any of the following conclusions leads to selection of a linear dose-response assessment approach:

- There is an absence of sufficient tumor MOA information.
- The chemical has direct DNA mutagenic reactivity or other indications of DNA effects that are consistent with linearity.
- Human exposure or body burden is high and near doses associated with key events in the carcinogenic process (e.g., 2,3,7,8-tetrachlorodibenzo-p-dioxin).
- Mode of action analysis does not support direct DNA effects, but the dose-response relationship is expected to be linear (e.g., certain receptor-mediated effects).

The procedures for implementing the default linear approach begin with the estimation of a POD as described above. The point of departure, LED_{10}, reflects the interspecies conversion to the human equivalent dose and the other adjustments for less-than-lifetime experimental duration. In most cases, the extrapolation for estimating response rates at low, environmentally relevant exposures is accomplished by drawing a straight line between the POD and the origin (i.e., zero dose, zero extra risk). This is mathematically represented as:

$$y = mx + b \qquad \text{(Equation 3-1)}$$
$$b = 0$$

where:

y	=	Response or incidence
m	=	Slope of the line (cancer potency factor) = $\Delta y/\Delta x$
x	=	Dose
b	=	Slope intercept

The slope of the line, "m" (the estimated cancer potency factor at low doses), is computed as:

$$m = \frac{0.10}{LED_{10}} \qquad \text{(Equation 3-2)}$$

The RSD is then calculated for a specific incremental targeted lifetime cancer risk (in the range of 10^{-6} to 10^{-4}) as:

$$RSD = \frac{\text{Target Incremental Cancer Risk}}{m} \qquad \text{(Equation 3-3)}$$

where:

RSD	=	Risk-specific dose (mg/kg-day)
Target Incremental Cancer Risk[8]	=	Value in the range of 10^{-6} to10^{-4}
m	=	Cancer potency factor $(mg/kg\text{-}day)^{-1}$

The use of the RSD to compute the AWQC is described in Section 3.1.3.5 below.

D. Default Nonlinear Approach

As discussed in the 1999 draft revised cancer guidelines, any of the following conclusions leads to a selection of a nonlinear (MOE) approach to dose-response assessment:

- A tumor MOA supporting nonlinearity applies (e.g., some cytotoxic and hormonal agents such as disruptors of hormonal homeostasis), and the chemical does not demonstrate mutagenic effects consistent with linearity.

- An MOA supporting nonlinearity has been demonstrated, and the chemical has some indication of mutagenic activity, but it is judged not to play a significant role in tumor causation.

Thus, a default assumption of nonlinearity is appropriate when there is no evidence for linearity and sufficient evidence to support an assumption of nonlinearity. The MOA may lead to a dose-response relationship that is nonlinear, with response falling much more quickly than linearly with dose, or being most influenced by individual differences in sensitivity. Alternatively, the MOA may theoretically have a threshold (e.g., the carcinogenicity may be a secondary effect of toxicity or of an induced physiological change that is itself a threshold phenomenon).

The nonlinear approach may be used, for instance, in the case of a bladder tumor inducer, where the chemical is not mutagenic and causes only stone formation in male rat bladders at high doses. This dynamic leads to tumor formation only at the high doses. Stone and subsequent tumor formation are not expected to occur at doses lower than those that induce the physiological changes that lead to stone formation. (More detail on this chemical is provided in the cancer section of the Risk Assessment TSD; USEPA, 2000). EPA does not generally try to distinguish between modes of action that might imply a “true threshold” from others with a

[8]In 1980, the target lifetime cancer risk range was set at 10-7 to 10-5. However, both the expert panel for the AWQC workshop (USEPA, 1993) and the peer review workshop experts (USEPA,1999c) recommended that EPA change the risk range to 10-6 to 10-4, to be consistent with SDWA program decisions. See Section 2.4 for more details.

nonlinear dose-response relationship, because there is usually not sufficient information to distinguish between those possibilities empirically.

The nonlinear MOE approach in the 1986 proposed cancer guidelines compares an observed response rate such as the LED_{10}, NOAEL, or LOAEL with actual or nominal environmental exposures of interest by computing the ratio between the two. In the context of deriving AWQC, the environmentally relevant exposures are nominal targets rather than actual exposures.

If the evidence for an agent indicates nonlinearity (e.g., when carcinogenicity is secondary to another toxicity for which there is a threshold), the MOE analysis for the toxicity is similar to what is done for a noncancer endpoint, and an RfD or RfC for that toxicity may also be estimated and considered in the cancer assessment. However, a threshold of carcinogenic response is not necessarily assumed. It should be noted that for cancer assessment, the MOE analysis begins from a POD that is adjusted for toxicokinetic differences between species to give a human equivalent dose.

To support the use of the MOE approach, risk assessment information provides evaluation of the current understanding of the phenomena that may be occurring as dose (exposure) decreases substantially below the observed data. This gives information about the risk reduction that is expected to accompany a lowering of exposure. The various factors that influence the selection of the UF in an MOE approach are also discussed below.

There are two main steps in the MOE approach. The first step is the selection of a POD. The POD may be the LED_{10} for tumor incidence or a precursor, or in some cases, it may also be appropriate to use a NOAEL or LOAEL value. When animal data are used, the POD is a human equivalent dose or concentration arrived at by interspecies dose adjustment (as discussed in Section 3.1.3.3) or toxicokinetic analysis.

The second step in using MOE analysis to establish AWQC is the selection of an appropriate margin or UF to apply to the POD. This is supported by analyses in the MOE discussion in the risk assessment. The following issues should be considered when establishing the overall UF for the derivation of AWQC using the MOE approach (others may be found appropriate in specific cases):

- The nature of the response used for the dose-response assessment, for instance, whether it is a precursor effect or a tumor response. The latter may support a greater MOE.

- The slope of the observed dose-response relationship at the POD and its uncertainties and implications for risk reduction associated with exposure reduction. (A steeper slope implies a greater reduction in risk as exposure decreases. This may support a smaller MOE).

- Human sensitivity compared with that of experimental animals.

- Nature and extent of human variability and sensitivity.

- Human exposure. The MOE evaluation also takes into account the magnitude, frequency, and duration of exposure. If the population exposed in a particular scenario is wholly or largely composed of a subpopulation of special concern (e.g., children) for whom evidence indicates a special sensitivity to the agent's MOA, an adequate MOE would be larger than for general population exposure.

E. Both Linear and Nonlinear Approaches

Any of the following conclusions leads to selection of both a linear and nonlinear approach to dose-response assessment. Relative support for each dose-response method and advice on the use of that information needs to be documented for the AWQC. In some cases, evidence for one MOA is stronger than for the other, allowing emphasis to be placed on that dose-response approach. In other cases, both modes of action are equally possible, and both dose-response approaches should be emphasized.

- Modes of action for a single tumor type support both linear and nonlinear dose response in different parts of the dose-response curve (e.g., 4,4' methylene chloride).

- A tumor mode of action supports different approaches at high and low doses; e.g., at high dose, nonlinearity, but, at low dose, linearity (e.g., formaldehyde).

- The agent is not DNA-reactive and all plausible modes of action are consistent with nonlinearity, but not fully established.

- Modes of action for different tumor types support differing approaches, e.g., nonlinear for one tumor type and linear for another due to lack of MOA information (e.g., trichloroethylene).

3.1.3.5 <u>AWQC Calculation</u>

A. Linear Approach

The following equation is used for the calculation of the AWQC for carcinogens where an RSD is obtained from the linear approach:

$$AWQC = RSD \cdot \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \cdot BAF_i)} \right) \qquad \text{(Equation 3-4)}$$

AWQC	=	Ambient water quality criterion (mg/L)
RSD	=	Risk-specific dose (mg/kg-day)
BW	=	Human body weight (kg)
DI	=	Drinking water intake (L/day)

FI_i	=	Fish intake at trophic level I (I = 2, 3, and 4) (kg/day)
BAF_i	=	Bioaccumulation factor for trophic level I (I = 2, 3, and 4), lipid normalized (L/kg)

B. Nonlinear Approach

In those cases where the nonlinear, MOE approach is used, a similar equation is used to calculate the AWQC [9]

$$AWQC = \frac{POD}{UF} \cdot RSC \cdot \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \cdot BAF_i)} \right) \qquad \text{(Equation 3-5)}$$

where variables are defined as for Equation 3-4 and:

POD	=	Point of departure (mg/kg-day)
UF	=	Uncertainty factor (unitless)
RSC	=	Relative source contribution (percentage or subtraction)

Differences between the AWQC values obtained using the linear and nonlinear approaches should be noted. First, the AWQC value obtained using the default linear approach corresponds to a specific estimated incremental lifetime cancer risk level in the range of 10^{-4} to 10^{-6}. In contrast, the AWQC obtained using the nonlinear approach does not describe a specific cancer risk. The AWQC calculations shown above are appropriate for waterbodies that are used as sources of drinking water.

The actual AWQC chosen for the protection of human health is based on a review of all relevant information, including cancer and noncancer data. The AWQC may, or may not, utilize the value obtained from the cancer analysis in the final AWQC value. The endpoint selected for the AWQC will be based on consideration of the weight of evidence and a complete analysis of all toxicity endpoints.

3.1.3.6 Risk Characterization

Risk assessment is an integrative process that is documented in a risk characterization summary. Risk characterization is the final step of the risk assessment process in which all preceding analyses (i.e., hazard, dose-response, and exposure assessments) are tied together to convey the overall conclusions about potential human risk. This component of the risk assessment process characterizes the data in nontechnical terms, explaining the extent and weight of evidence, major points of interpretation and rationale, and strengths and weaknesses of

[9] Although appearing in this equation as a factor to be multiplied, the RSC can also be an amount subtracted.

the evidence, and discussing alternative approaches, conclusions, uncertainties, and variability that deserve serious consideration.

Risk characterization information accompanies the numerical AWQC value and addresses the major strengths and weaknesses of the assessment arising from the availability of data and the current limits of understanding the process of cancer causation. Key issues relating to the confidence in the hazard assessment and the dose-response analysis (including the low-dose extrapolation procedure used) are discussed. Whenever more than one interpretation of the weight of evidence for carcinogenicity or the dose-response characterization can be supported, and when choosing among them is difficult, the alternative views are provided along with the rationale for the interpretation chosen in the derivation of the AWQC value. Where possible, quantitative uncertainty analyses of the data are provided; at a minimum, a qualitative discussion of the important uncertainties is presented.

3.1.3.7 Use of Toxicity Equivalence Factors and Relative Potency Estimates

The 1999 draft revised cancer guidelines state:

> *A toxicity equivalence factor (TEF) procedure is one used to derive quantitative dose-response estimates for agents that are members of a category or class of agents. TEFs are based on shared characteristics that can be used to order the class members by carcinogenic potency when cancer bioassay data are inadequate for this purpose. The ordering is by reference to the characteristics and potency of a well-studied member or members of the class. Other class members are indexed to the reference agent(s) by one or more shared characteristics to generate their TEFs.*

In addition, the 1999 draft revised cancer guidelines state that TEFs are generated and used for the limited purpose of assessment of agents or mixtures of agents in environmental media when better data are not available. When better data become available for an agent, the TEF should be replaced or revised. To date, adequate data to support use of TEFs have been found only for dibenzofurans (dioxins) and coplanar polychlorinated biphenyls (PCBs) (USEPA, 1989, 1999b).

The uncertainties associated with TEFs must be described when this approach is used. This is a default approach to be used when tumor data are not available for individual components in a mixture. Relative potency factors (RPFs) can be similarly derived and used for agents with carcinogenicity or other supporting data. The RPF is conceptually similar to TEFs, but does not have the same level of data to support it and thus has a less rigorous definition compared with the TEF. TEFs and RPFs are used only when there is no better alternative. When they are used, assumptions and uncertainties associated with them are discussed. As of today, there are only three classes of compounds for which relative potency approaches have been examined by EPA: dibenzofurans (dioxins), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). There are limitations to the use of TEF and RFP approaches, and caution should be exercised when using them. More guidance can be found in the draft document for conducting health risk assessment of chemical mixtures, published by the EPA Risk Assessment Forum (USEPA,1999b).

3.1.4 References for Cancer Section

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3.2 NONCANCER EFFECTS

3.2.1 1980 AWQC National Guidelines for Noncancer Effects

In the 1980 AWQC National Guidelines, the Agency evaluated noncancer human health effects from exposure to chemical contaminants using Acceptable Daily Intake (ADI) levels. ADIs were calculated by dividing NOAELs by safety factors (SFs) to obtain estimates of doses of chemicals that would not be expected to cause adverse effects over a lifetime of exposure. In accordance with the National Research Council report of 1977 (NRC, 1977), EPA used SFs of 10, 100, or 1,000, depending on the quality and quantity of the overall database. In general, a factor of 10 was suggested when good-quality data identifying a NOAEL from human studies were available. A factor of 100 was suggested if no human data were available, but the database contained valid chronic animal data. For chemicals with no human data and scant animal data, a factor of 1,000 was recommended. Intermediate SFs could also be used for databases that fell between these categories.

AWQC were calculated using the ADI levels together with standard exposure assumptions about the rates of human ingestion of water and fish, and also accounting for intake from other sources (see Equation 1-1 in the Introduction). Surface water concentrations at or below the calculated criteria concentrations would be expected to result in human exposure levels at or below the ADI. Inherent in these calculations is the assumption that, generally, adverse effects from noncarcinogens exhibit a threshold.

3.2.2 Noncancer Risk Assessment Developments Since 1980

Since 1980, the risk assessment of noncarcinogenic chemicals has changed. To remove the value judgments implied by the words “acceptable” and “safety,” the ADI and SF terms have been replaced with the terms RfD and UF/modifying factor (MF), respectively.

For the risk assessment of general systemic toxicity, the Agency currently uses the guidelines contained in the IRIS background document entitled *Reference Dose (RfD): Description and Use in Health Risk Assessments* (hereafter the “IRIS background document”. That document defines an RfD as “an estimate (with uncertainty spanning approximately an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects over a lifetime” (USEPA,

1993a). The most common approach for deriving the RfD does not involve dose-response modeling. Instead, an RfD for a given chemical is usually derived by first identifying the NOAEL for the most sensitive known toxicity endpoint, that is, the toxic effect that occurs at the lowest dose. This effect is called the critical effect. Factors such as the study protocol, the species of experimental animal, the nature of the toxicity endpoint assessed and its relevance to human effects, the route of exposure, and exposure duration are critically evaluated in order to select the most appropriate NOAEL from among all available studies in the chemical's database. If no appropriate NOAEL can be identified from any study, then the LOAEL for the critical effect endpoint is used and an uncertainly factor for LOAEL-to-NOAEL extrapolation is applied. Using this approach, the RfD is equal to the NOAEL (or LOAEL) divided by the product of UFs and, occasionally, an MF:

$$\text{RfD (mg/kg/day)} = \frac{\text{NOAEL (or LOAEL)}}{\text{UF} \cdot \text{MF}} \qquad \text{(Equation 3-6)}$$

The definitions and guidance for use of the UFs and the MFs are provided in the IRIS background document and are repeated in Table 3-1.

The IRIS background document on the RfD (USEPA, 1993a) provides guidance for critically assessing noncarcinogenic effects of chemicals and for deriving the RfD. Another reference on this topic is Dourson (1994). Furthermore, the Agency has also published separate guidelines for assessing specific toxic endpoints, such as developmental toxicity (USEPA, 1991a), reproductive toxicity (USEPA, 1996a), and neurotoxicity risk assessment (USEPA, 1995). These endpoint-specific guidelines will be used for their respective areas in the hazard assessment step and will complement the overall toxicological assessment. It should be noted, however, that an RfD, derived using the most sensitive known endpoint, is considered protective against all noncarcinogenic effects.

TABLE 3-1. UNCERTAINTY FACTORS AND THE MODIFYING FACTOR

Uncertainty Factor	Definition
UF_H	Use a 1, 3, or 10-fold factor when extrapolating from valid data in studies using long-term exposure to average healthy humans. This factor is intended to account for the variation in sensitivity (intraspecies variation) among the members of the human population.
UF_A	Use an additional factor of 1, 3, or 10 when extrapolating from valid results of long-term studies on experimental animals when results of studies of human exposure are not available or are inadequate. This factor is intended to account for the uncertainty involved in extrapolating from animal data to humans (interspecies variation).
UF_S	Use an additional factor of 1, 3, or 10 when extrapolating from less-than-chronic results on experimental animals when there are no useful long-term human data. This factor is intended to account for the uncertainty involved in extrapolating from less-than-chronic NOAELs to chronic NOAELs.
UF_L	Use an additional factor of 1, 3, or 10 when deriving an RfD from a LOAEL, instead of a NOAEL. This factor is intended to account for the uncertainty involved in extrapolating from LOAELs to NOAELs.
UF_D	Use an additional 3- or 10-fold factor when deriving an RfD from an "incomplete" database. This factor is meant to account for the inability of any single type of study to consider all toxic endpoints. The intermediate factor of 3 (approximately ½ $\log_{10}$ unit, i.e., the square root of 10) is often used when there is a single data gap exclusive of chronic data. It is often designated as UF_D.

Modifying Factor

Use professional judgment to determine the MF, which is an additional uncertainty factor that is greater than zero and less than or equal to 10. The magnitude of the MF depends upon the professional assessment of scientific uncertainties of the study and database not explicitly treated above (e.g., the number of species tested). The default value for the MF is 1.

Note: With each UF or MF assignment, it is recognized that professional scientific judgment must be used. The total product of the uncertainty factors and modifying factor should not exceed 3,000.

Similar to the procedure used in the 1980 AWQC National Guidelines, the revised method of deriving AWQC for noncarcinogens uses the RfD together with various assumptions concerning intake of the contaminant from both water and non-water sources of exposure. The objective of an AWQC for noncarcinogens is to ensure that human exposure to a substance related to its presence in surface water, combined with exposure from other sources, does not exceed the RfD. The algorithm for deriving AWQC for noncarcinogens using the RfD is presented as Equation 1-1 in the Introduction.

3.2.3 Issues and Recommendations Concerning the Derivation of AWQC for Noncarcinogens

During a review of the 1980 AWQC National Guidelines (USEPA, 1993b), the Agency identified several issues that must be resolved in order to develop a final revised methodology for deriving AWQC based on noncancer effects. These issues, as discussed below, mainly concern the derivation of the RfD as the basis for such an AWQC. Foremost among these issues is whether the Agency should revise the present method or adopt entirely new procedures that use quantitative dose-response modeling for the derivation of the RfD. Other issues include the following:

- Presenting the RfD as a single point value or as a range to reflect the inherent imprecision of the RfD;
- Selecting specific guidance documents for derivation of noncancer health effect levels;
- Considering severity of effect in the development of the RfD;
- Using less-than-90-day studies as the basis for RfDs;
- Integrating reproductive/developmental, immunotoxicity, and neurotoxicity data into the RfD calculation;
- Applying toxicokinetic data in risk assessments; and
- Considering the possibility that some noncarcinogenic effects do not exhibit a threshold.

3.2.3.1 Using the Current NOAEL/UF-Based RfD Approach or Adopting More Quantitative Approaches for Noncancer Risk Assessment

The current NOAEL/UF-based RfD methodology, or its predecessor ADI/SF methodology, have been used since 1980. This approach assumes that there is a threshold exposure below which adverse noncancer health effects are not expected to occur. Exposures above this threshold are believed to pose some risk to exposed individuals; however, the current approach does not address the nature and magnitude of the risk above the threshold level (i.e., the shape of the dose-response curve above the threshold). The NOAEL/UF-based RfD approach is intended primarily to ensure that the RfD value derived from the available data falls below the population effects threshold. However, the NOAEL/UF-based RfD procedure has

limitations. In particular, this method requires that one of the actual experimental doses used by the researchers in the critical study be selected as the NOAEL or LOAEL value. The determination that a dose is a NOAEL or LOAEL will depend on the biological endpoints used and the statistical significance of the data. Statistical significance will depend on the number and spacing of dose groups and the numbers of animals used in each dose group. Studies using a small number of animals can limit the ability to distinguish statistically significant differences among measurable responses seen in dose groups and control groups. Furthermore, the determination of the NOAEL or LOAEL also depends on the dose spacing of the study. Doses are often widely spaced, typically differing by factors of three to ten. A study can identify a NOAEL and a LOAEL from among the doses studied, but the "true" effects threshold cannot be determined from those results. The study size and dose spacing limitations also limit the ability to characterize the nature of the expected response to exposures between the observed NOAEL and LOAEL values.

The limitations of the NOAEL/UF approach have prompted development of alternative approaches that incorporate more quantitative dose-response information. The traditional NOAEL approach for noncancer risk assessment has often been a source of controversy and has been criticized in several ways. For example, experiments involving fewer animals tend to produce higher NOAELs and, as a consequence, may produce higher RfDs. Larger sample sizes, on the other hand, should provide greater experimental sensitivity and lower NOAELs. The focus of the NOAEL approach is only on the dose that is the NOAEL, and the NOAEL must be one of the experimental doses. It also ignores the shape of the dose-response curve. Thus, the slope of the dose-response plays little role in determining acceptable exposures for human beings. Therefore, in addition to the NOAEL/UF-based RfD approach described above, EPA will accept other approaches that incorporate more quantitative dose-response information in appropriate situations for the evaluation of noncancer effects and the derivation of RfDs. However, the Agency wishes to emphasize that it still believes the NOAEL/UF RfD methodology is valid and can continue to be used to develop RfDs.

Two alternative approaches that may have relevance in assisting in the derivation of the RfD for a chemical are the BMD and the categorical regression approaches. These alternative approaches may overcome some of the inherent limitations in the NOAEL/UF approach. For example, the BMD analyses for developmental effects show that NOAELs from studies correlate well with a 5 percent response level (Allen et al., 1994). The BMD and the categorical regression approaches usually have greater data requirements than the RfD approach. Thus, it is unlikely that any one approach will apply to every circumstance; in some cases, different approaches may be needed to accommodate the varying databases for the range of chemicals for which water quality criteria must be developed. Acceptable approaches will satisfy the following criteria: (1) meet the appropriate risk assessment goal; (2) adequately describe the toxicity database and its quality; (3) characterize the endpoints properly; (4) provide a measure of the quality of the "fit" of the model when a model is used for dose-response analysis; and (5) describe the key assumptions and uncertainties.

A. The Benchmark Dose

The BMD is defined as the dose estimated to produce a predetermined level of change in response (the Benchmark Response level, or BMR) relative to control. The BMDL is defined as the statistical lower confidence limit on the BMD. In the derivation of an RfD, the BMDL is used as the dose to which uncertainty factors are applied instead of the NOAEL. The BMD approach first models a dose-response curve for the critical effect(s) using available experimental data. Several mathematical algorithms can be used to model the dose-response curve, such as polynomial or Weibull functions. To define a BMD from the modeled curve for quantal data, the assessor first selects the BMR. The choice of the BMR is critical. For quantal endpoints, a particular level of response is chosen (e.g., 1 percent, 5 percent, or 10 percent). For continuous endpoints, the BMR is the degree of change from controls and is based on what is considered a biologically significant change. The BMD is derived from the BMR dose by applying the desired confidence limit calculation. The RfD is obtained by dividing the BMD by one or more uncertainty factors, similar to the NOAEL approach. Because the BMD is used like the NOAEL to obtain the RfD, the BMR should be selected at or near the low end of the range of increased risks that can be detected in a study of typical size. Generally, this falls in the range between the ED_{01} and the ED_{10}.

The Agency will accept use of a BMD approach to derive RfDs for those agents for which there is an adequate database. There are a number of technical decisions associated with the application of the BMD technique. These include the following:

- The definition of an adverse response;
- Selection of response data to model;
- The form of the data used (continuous versus quantal);
- The choice of the measures of increased risk (extra risk versus additional risk);
- The choice of mathematical model (including use of nonstandard models for unusual data sets);
- The selection of the BMR;
- Methods for calculating the confidence interval;
- Selection of the appropriate BMD as the basis for the RfD (when multiple endpoints are modeled from a single study, when multiple models are applied to a single response, and when multiple BMDs are calculated from different studies); and
- The use of uncertainty factors with the BMD approach.

These topics are discussed in detail in Crump et al. (1995) and in the Risk Assessment TSD Volume (USEPA, 2000). The use of the BMD approach has been discussed in general terms by several authors (Gaylor, 1983; Crump, 1984; Dourson et al., 1985; Kimmel and Gaylor, 1988; Brown and Erdreich, 1989; Kimmel, 1990). The International Life Sciences Institute

(ILSI) also held a major workshop on the BMD in September 1993; the workshop proceedings are summarized in ILSI (1993) and in Barnes et al. (1995). For further information on these technical issues, the reader is referred to the publications referenced above.

The BMD approach addresses several of the quantitative or statistical criticisms of the NOAEL approach. These are discussed at greater length in Crump et al. (1995) and are summarized here. First, the BMD approach uses all the dose-response information in the selected study rather than just a single data point, such as the NOAEL or LOAEL. By using response data from all of the dose groups to model a dose-response curve, the BMD approach allows for consideration of the steepness of the slope of the curve when estimating the ED_{10}. The use of the full data set also makes the BMD approach less sensitive to small changes in data than the NOAEL approach, which relies on the statistical comparison of individual dose groups. The BMD approach also allows consistency in the consideration of the level of effect (e.g., a 10 percent response rate) across endpoints.

The BMD approach accounts more appropriately for the size of each dose group than the NOAEL approach. Laboratory tests with fewer animals per dose group tend to yield higher NOAELs, and thus higher RfDs, because statistically significant differences in response rates are harder to detect. Therefore, in the NOAEL approach, dose groups with fewer animals lead to a higher (less conservative) RfD. In contrast, with the BMD approach, smaller dose groups will tend to have the effect of extending the confidence interval around the ED_{10}; therefore, the lower confidence limit on the ED_{10} (the BMD) will be lower. With the BMD approach, greater uncertainty (smaller test groups) leads to a lower (more conservative) RfD.

There are some issues to be resolved before the BMD approach is used routinely. These were identified in a 1996 Peer Consultation Workshop (USEPA, 1996b). Methods for routine use of the BMD are currently under development by EPA. Several RfCs and RfDs based on the BMD approach are included in EPA's IRIS database. These include reference values for methylmercury based on delayed postnatal development in humans; carbon disulfide based on neurotoxicity; 1,1,1,2-tetrafluoroethane based on testicular effects in rats; and antimony trioxide based on chronic pulmonary interstitial inflammation in female rats.

Various mathematical approaches have been proposed for modeling developmental toxicity data (e.g., Crump, 1984; Kimmel and Gaylor, 1988; Rai and Van Ryzin, 1985; Faustman et al., 1989), which could be used to calculate a BMD. Similar methods can be used to model other types of toxicity data, such as neurotoxicity data (Gaylor and Slikker, 1990, 1992; Glowa and MacPhail, 1995). The choice of the mathematical model may not be critical, as long as estimation is within the observed dose range. Since the model fits a mathematical equation to the observed data, the assumptions in a particular model regarding the existence or absence of a threshold for the effect may not be pertinent (USEPA, 1997). Thus, any model that suitably fits the empirical data is likely to provide a reasonable estimate of a BMD. However, research has shown that flexible models that are nonsymmetric (e.g., the Weibull) are superior to symmetric models (e.g., the probit) in estimating the BMD because the data points at the higher doses have less influence on the shape of the curve than at low doses. In addition, models should incorporate fundamental biological factors where such factors are known (e.g., intralitter correlation for developmental toxicity data) in order to account for as much variability in the

data as possible. The Agency is currently using the BMD approach in risk assessments where the data support its use. Draft guidelines for application of the BMD approach also are being developed by the Agency.

Use of BMD methods involves fitting mathematical models to dose-response data obtained primarily from toxicology studies. When considering available models to use for a BMD analysis, it is important to select the model that fits the data the best and is the most biologically appropriate. EPA has developed software following several years of research and development, expert peer review, public comment, subsequent revision, and quality assurance testing. The software (BMDS, Version 1.2) can be downloaded from http://www.epa.gov/ncea/bmds.htm. BMDS facilitates these operations by providing simple data-management tools, a comprehensive help manual, an online help system, and an easy-to-use interface to run multiple models on the same dose-response data.

As part of this software package, EPA has included sixteen (16) different models that are appropriate for the analysis of dichotomous (quantal) data (Gamma, Logistic, Log-Logistic, Multistage, Probit, Log-Probit, Quantal-Linear, Quantal-Quadratic, Weibull), continuous data (Linear, Polynomial, Power, Hill), and nested developmental toxicology data (NLogistic, NCTR, Rai & Van Ryzin). Results from all models include a reiteration of the model formula and model run options chosen by the user, goodness-of-fit information, the BMD, and the estimate of the lower-bound confidence limit on the benchmark dose (BMDL). Model results are presented in textual and graphical output files which can be printed or saved and incorporated into other documents.

B. Categorical Regression

Categorical regression is an emerging technique that may have relevance for the derivation of RfDs or for estimating risk above the RfD (Dourson et al., 1997; Guth et al., 1997). The categorical regression approach, like the BMD approach, can be used to estimate a dose that corresponds to a given probability of adverse effects. This dose would then be divided by UFs to establish an RfD. However, unlike the BMD approach, the Categorical regression approach can incorporate information on different health endpoints in a single dose-response analysis. For those health effects for which studies exist, responses to the substance in question are grouped into severity categories; for example (1) no effect, (2) no adverse effect, (3) mild-to-moderate adverse effect, and (4) frank effect. These categories correspond to the dose categories currently used in setting the RfD, namely, the no-observed-effect level (NOEL), NOAEL, LOAEL, and frank-effect level (FEL), respectively. Logistic transformation or other applicable mathematical operations are used to model the probability of experiencing effects in a certain category as a function of dose (Harrell, 1986; Hertzberg, 1989). The "acceptability" of the fit of the model to the data can be judged using several statistical measures, including the χ^2 statistic, correlation coefficients, and the statistical significance of its model parameter estimates.

The resulting mathematical equation can be used to find a dose (or the lower confidence bound on the dose) at which the probability of experiencing adverse effects does not exceed a selected level, e.g., 10 percent. This dose (like the NOAEL or BMD) would then be divided by

relevant UFs to calculate an RfD. For more detail on how to employ the categorical regression approach, see the discussion in the Risk Assessment TSD (USEPA, 2000).

As with the BMD approach, the categorical regression approach has the advantage of using more of the available dose-response data to account for response variability as well as accounting for uncertainty due to sample size through the use of confidence intervals. Additional advantages of categorical regression include the combining of data sets prior to modeling, thus allowing the calculation of the slope of a dose-response curve for multiple adverse effects rather than only one effect at a time. Another advantage is the ability to estimate risks for different levels of severity from exposures above the RfD.

On the other hand, as with BMD, opinions differ over the amount and adequacy of data necessary to implement the method. The categorical regression approach also requires judgments regarding combining data sets, judging goodness-of-fit, and assigning severity to a particular effect. Furthermore, this approach is still in the developmental stage. It is not recommended for routine use, but may be used when data are available and justify the extensive analyses required.

C. Summary

Whether a NOAEL/UF-based methodology, a BMD, a categorical regression model, or other approach is used to develop the RfD, the dose-response-evaluation step of a risk assessment process should include additional discussion about the nature of the toxicity data and its applicability to human exposure and toxicity. The discussion should present the range of doses that are effective in producing toxicity for a given agent; the route, timing, and duration of exposure; species specificity of effects; and any toxicokinetic or other considerations relevant to extrapolation from the toxicity data to human-health-based AWQC. This information should always accompany the characterization of the adequacy of the data.

3.2.3.2 Presenting the RfD as a Single Point or as a Range for Deriving AWQC

Although the RfD has traditionally been presented and used as a single point, its definition contains the phrase ". . . an estimate (with uncertainty spanning perhaps an order of magnitude) . . ." (USEPA, 1993a). Underlying this concept is the reasoning that the selection of the critical effect and the total uncertainty factor used in the derivation of the RfD is based on the "best" scientific judgment, and that competent scientists examining the same database could derive RfDs which varied within an order of magnitude.

In one instance, IRIS presented the RfD as a point value within an accompanying range. EPA derived a single number as the RfD for arsenic (0.3 μg/kg-day), but added that "strong scientific arguments can be made for various values within a factor of 2 or 3 of the currently recommended RfD value, i.e., 0.1 to 0.8 μg/kg/day" (USEPA, 1993c). EPA noted that regulatory managers should be aware of the flexibility afforded them through this action.

There are situations in which the risk manager can select an alternative value to use in place of the RfD in the AWQC calculations. The domain from which this alternative value can

be selected is restricted to a defined range around the point estimate. As explained further below, the Agency is recommending that sometimes the use of a value other than the calculated RfD point estimate is appropriate in characterizing risk. The selection of an alternative value within an appropriate range must be determined for each individual situation, since several factors affect the selection of the alternative value. Observing similar effects in several animal species, including humans, can increase confidence in the selection of the critical effect and thereby narrow the range of uncertainty. There are other factors that can affect the precision. These include the slope of the dose-response curve, seriousness of the observed effect, dose spacing, and possibly the route for the experimental doses. Dose spacing and the number of animals in the study groups used in the experiment can also affect the confidence in the RfD.

To derive the AWQC, the calculated point estimate of the RfD is the default. Based on consideration of the available data, the use of another number within the range defined by the product of the UF(s) (and MF, if used) could be justified in some specific situations. This means that there are risk considerations which indicate that some value in the range other than the point estimate may be more appropriate, based on human health or environmental fate considerations. For example, the bioavailability of the contaminant in fish tissues is one factor to consider. If bioavailability from fish tissues is much lower than that from water and the RfD was derived from a study in which the contaminant exposure was from drinking water, the alternative to the calculated RfD could be selected from the high end of the range and justified using the quantitative difference in bioavailability.

Most inorganic contaminants, particularly divalent cations, have bioavailability values of 20 percent or less from a food matrix, but are much more available (about 80 percent or higher) from drinking water. Accordingly, the external dose necessary to produce a toxic internal dose would likely be higher for a study where the exposure occurred through the diet rather than the drinking water. As a result, the RfD from a dietary study would likely be higher than that for the drinking water study if equivalent external doses had been used. Conversely, in cases where the NOAEL that was the basis for the RfD came from a dietary study, the alternative value could be slightly lower than the calculated RfD.

Because the uncertainty around the dose-response relationship increases as extrapolation below the observed data increases, the use of an alternative point within the range may be more appropriate in characterizing the risk than the use of the calculated RfD, especially in situations when the uncertainty is high. Therefore, as a matter of policy, the 2000 Human Health Methodology permits the selection of a single point within a range about the calculated RfD to be used as the basis of the AWQC if an adequate justification of the alternative point is provided. More complete discussion of this option, including limitations on the span of the range, is provided in the Risk Assessment TSD (USEPA, 2000).

3.2.3.3 Guidelines to be Adopted for Derivation of Noncancer Health Effects Values

The Agency currently is using the IRIS background document as the general basis for the risk assessment of noncarcinogenic effects of chemicals (USEPA, 1993a). EPA recommends continued use of this document for this purpose. However, it should be noted that the process for evaluating chemicals for inclusion in IRIS is undergoing revision (USEPA, 1996c). The

revised assessments for many chemicals are now available on IRIS and can be consulted as examples of the RfD development process and required supporting documentation.

3.2.3.4 Treatment of Uncertainty Factors/Severity of Effects During the RfD Derivation and Verification Process

During the RfD derivation and toxicology review process, EPA considers the uncertainty in extrapolating between animal species and within individuals of a species, as well as specific uncertainties associated with the completeness of the database. The Agency's RfD Work Group has always considered the severity of the observed effects induced by the chemical under review when choosing the value of the UF with a LOAEL. For example, during the derivation and verification of the RfD for zinc (USEPA, 1992), an uncertainty factor less than the standard factor of 10 (UF of 3) was assigned to the relatively mild decrease in erythrocyte superoxide dismutase activity in human subjects. EPA recommends that the severity of the critical effect be assessed when deriving an RfD and that risk managers be made aware of the severity of the effect and the weight placed on this attribute of the effect when the RfD was derived.

3.2.3.5 Use of Less-Than-90-Day Studies to Derive RfDs

Generally, less-than-90-day experimental studies are not used to derive an RfD. This is based on the rationale that studies lasting for less than 90 days may be too short to detect various toxic effects. However, EPA, has in certain circumstances, derived an RfD based on a less-than-90-day study. For example, the RfD for nonradioactive effects of uranium is based on a 30-day rabbit study (USEPA, 1989). The short-term exposure period was used, because it was adequate for determining doses that cause chronic toxicity. In other cases, it may be appropriate to use a less-than-90-day study because the critical effect is expressed in less than 90 days. For example, the RfD for nitrate was derived and verified using studies that were less than 3-months in duration (USEPA, 1991b). For nitrate, the critical effect of methemoglobinemia in infants occurs in less than 90 days. When it can be demonstrated from other data in the toxicological database that the critical adverse effect is expressed within the study period and that a longer exposure duration would not exacerbate the observed effect or cause the appearance of some other adverse effect, the Agency may choose to use less-than-90-day studies as the basis of the RfD. Such values would have to be used with care because of the uncertainty in determining if other effects might be expressed if exposure was of greater duration than 90 days.

3.2.3.6 Use of Reproductive/Developmental, Immunotoxicity, and Neurotoxicity Data as the Basis for Deriving RfDs

All relevant toxicity data have some bearing on the RfD derivation and verification and are considered by EPA. The "critical" effect is the adverse effect most relevant to humans or, in the absence of an effect known to be relevant to humans, the adverse effect that occurs at the lowest dose in animal studies. If the critical effect is neurotoxicity, EPA will use that endpoint as the basis for the derivation and verification of an RfD, as it did for the RfD for acrylamide. Moreover, the Agency is continually revising its procedures for noncancer risk assessment. For example, EPA has released guidelines for deriving developmental RfDs (RfD_{DT}, USEPA, 1991a), for using reproductive toxicity (USEPA, 1996a), and neurotoxicity (USEPA, 1995) data

in risk assessments. The Agency is currently working on guidelines for using immunotoxicity data to derive RfDs. In addition, the Agency is proceeding with the process of generating acceptable emergency health levels for hazardous substances in acute exposure situations based on established guidelines (NRC, 1993).

3.2.3.7 Applicability of Toxicokinetic Data in Risk Assessment

All pertinent toxicity data should be used in the risk assessment process, including toxicokinetic and mechanistic data. The Agency has used toxicokinetic data in deriving the RfD for cadmium and other compounds and currently is using toxicokinetic data to better characterize human inhalation exposures from animal inhalation experiments during derivation/verification of RfCs. In analogy to the RfD, the RfC is considered to be an estimate of a concentration in the air that is not anticipated to cause adverse noncancer effects over a lifetime of inhalation exposure (USEPA, 1994; Jarabek, 1995a). For RfCs, different dosimetry adjustments are made to account for the differences between laboratory animals and humans in gas uptake and disposition or in particle clearance and retention. This procedure results in calculation of a "human equivalent concentration." Based on the use of these procedures, an interspecies UF of 3 (i.e., approximately $10^{0.5}$), instead of the standard factor of 10, is used in the RfC derivation (Jarabek, 1995b).

Toxicokinetics and toxicodynamics of a chemical each contribute to a chemical's observed toxicity, and specifically, to observed differences among species in sensitivity. Toxicokinetics describes the disposition (i.e., deposition, absorption, distribution, metabolism, and elimination of chemicals in the body) and can be approximated using toxicokinetic models. Toxicodynamics describes the toxic interaction of the agent with the target cell. In the absence of specific data on their relative contributions to the toxic effects observed in species, each is considered to account for approximately one-half of the difference in observed effects for humans compared with laboratory animals. The implication of this assumption is that an interspecies uncertainty factor of 3 rather than 10 could be used for deriving an RfD when valid toxicokinetic data and models can be applied to obtain an oral "human equivalent applied dose" (Jarabek, 1995b). If specific data exist on the relative contribution of either element to observed effects, that proportion will be used. The role exposure duration may play, and whether or not the chemical or its damage may accumulate over time in a particular scenario, also requires careful consideration (Jarabek, 1995c).

3.2.3.8 Consideration of Linearity (or Lack of a Threshold) for Noncarcinogenic Chemicals

It is quite possible that there are chemicals with noncarcinogenic endpoints that have no threshold for effects. For example, in the case of lead, it has not been possible to identify a threshold for effects on neurological development. Other examples could include genotoxic teratogens and germline mutagens. Genotoxic teratogens act by causing mutational events during organogenesis, histogenesis, or other stages of development. Germline mutagens interact with germ cells to produce mutations which may be transmitted to the zygote and expressed during one or more stages of development. However, there are few chemicals which currently have sufficient mechanistic information about these possible modes of action. It should be recognized that although an MOA consistent with linearity is possible (especially for agents

known to be mutagenic), this has yet to be reasonably demonstrated for most toxic endpoints other than cancer.

EPA has recognized the potential for nonthreshold noncarcinogenic endpoints and discussed this issue in the *Guidelines for Developmental Toxicity Risk Assessment* (USEPA, 1991a) and in the 1986 *Guidelines for Mutagenicity Risk Assessment* (USEPA, 1986). An awareness of the potential for such teratogenic/mutagenic effects should be established in order to deal with such data. However, without adequate data to support a genetic or mutational basis for developmental or reproductive effects, the default becomes a UF or MOA approach, which are procedures utilized for noncarcinogens assumed to have a threshold. Therefore, genotoxic teratogens and germline mutagens should be considered an exception while the traditional uncertainty factor approach is the general rule for calculating criteria or values for chemicals demonstrating developmental/reproductive effects. For the exceptional cases, since there is no well-established mechanism for calculating criteria protective of human health from the effects of these agents, criteria will be established on a case-by-case basis. Other types of nonthreshold noncarcinogens must also be handled on a case-by-case basis.

3.2.3.9 Minimum Data Guidance

For details on minimum data guidance for RfD development, see the Risk Assessment TSD (USEPA, 2000).

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4. EXPOSURE

The derivation of AWQC for the protection of human health requires information about both the toxicological endpoints of concern for water pollutants and the pathways of human exposure to those pollutants. The two primary pathways of human exposure to pollutants present in a particular ambient waterbody that have been considered in deriving AWQC are direct ingestion of drinking water obtained from that waterbody and the consumption of fish/shellfish obtained from that waterbody. The water pathway also includes other exposures from household uses (e.g., showering). The derivation of an AWQC involves the calculation of the maximum water concentration for a pollutant (i.e., the water quality criteria level) that ensures drinking water and/or fish ingestion exposures will not result in human intake of that pollutant in amounts that exceed a specified level based upon the toxicological endpoint of concern.

The equation for noncancer effects is presented again here, in simplified form, to emphasize the exposure-related parameters (in bold). [Note: the RSC parameter also applies to nonlinear low-dose extrapolation for cancer effects and the other exposure parameters apply to all three of the equations (see Section 1.6).]

$$AWQC = RfD \bullet \boldsymbol{RSC} \bullet \frac{(\boldsymbol{BW})}{\left[\boldsymbol{DI} + (\boldsymbol{FI} \bullet BAF)\right]} \qquad \text{(Equation 4-1)}$$

where:

AWQC	=	Ambient Water Quality Criterion (mg/L)
RfD	=	Reference dose for noncancer effects (mg/kg-day)
RSC	=	Relative source contribution factor to account for non-water sources of exposure
BW	=	Human body weight (kg)
DI	=	Drinking water intake (L/day)
FI	=	Fish intake (kg/day)
BAF	=	Bioaccumulation factor (L/kg)

The following subsections discuss exposure issues relevant to the 2000 Human Health Methodology: exposure policy issues; consideration of non-water sources of exposure (the Relative Source Contribution approach); and the factors used in AWQC computation. In relevant sections, science policy and risk management decisions made by EPA are discussed.

4.1 EXPOSURE POLICY ISSUES

This section discusses broad policy issues related to exposure concerning the major objectives that the Agency believes should be met in setting AWQC.

An Exposure Assessment TSD provides greater detail on numerous topics discussed in this guidance: suggested sources of contaminant concentration and exposure intake information; suggestions of survey methods for obtaining and analyzing exposure data necessary for deriving AWQC; summaries of studies on fish consumption among sport fishers and subsistence fishers; more detailed presentation of parameter values (e.g., fish consumption rates, body weights); and additional guidance on the application of the RSC approach.

4.1.1 Sources of Exposure Associated With Ambient Water

4.1.1.1 Appropriateness of Including the Drinking Water Pathway in AWQC

EPA intends to continue including the drinking water exposure pathway in the derivation of its national default human health criteria (AWQC), as has been done since the 1980 AWQC National Guidelines were first published.

EPA recommends inclusion of the drinking water exposure pathway where drinking water is a designated use for the following reasons: (1) Drinking water is a designated use for surface waters under the CWA and, therefore, criteria are needed to assure that this designated use can be protected and maintained. (2) Although rare, there are some public water supplies that provide drinking water from surface water sources without treatment. (3) Even among the majority of water supplies that do treat surface waters, existing treatments may not necessarily be effective for reducing levels of particular contaminants. (4) In consideration of the Agency's goals of pollution prevention, ambient waters should not be contaminated to a level where the burden of achieving health objectives is shifted away from those responsible for pollutant discharges and placed on downstream users to bear the costs of upgraded or supplemental water treatment.

This policy decision has been supported by the States, most of the public stakeholders, and by external peer reviewers. As with the other exposure parameters, States and authorized Tribes have the flexibility to use alternative intake rates if they believe that drinking water consumption is substantively different than EPA's recommended default assumptions of 2 L/day for adults and 1 L/day for children. EPA recommends that States and authorized Tribes use an intake rate that would be protective of a majority of consumers and will consider whether an alternative assumption is adequately protective of a State's or Tribe's population based on the information or rationale provided at the time EPA reviews State and Tribal water quality standards submissions.

4.1.1.2 Setting Separate AWQC for Drinking Water and Fish Consumption

In conjunction with the issue of the appropriateness of including the drinking water pathway explicitly in the derivation of AWQC for the protection of human health, EPA intends to continue its practice of setting a single AWQC for both drinking water and fish/shellfish consumption, and a separate AWQC based on ingestion of fish/shellfish alone. This latter criterion applies in those cases where the designated uses of a waterbody include supporting fishable uses under Section 101(a) of the CWA and, thus, fish or shellfish for human consumption, but not as a drinking water supply source (e.g., non-potable estuarine waters).

EPA does not believe that national water quality criteria for protection of drinking water uses only are particularly useful for two reasons. First, State and Tribal standards for human health are set to protect Section 101(a) uses (e.g., "fishable, swimmable uses") under the CWA. Second, most waters have multiple designated uses. Additionally, the water quality standards program protects aquatic life. The 2000 Human Health Methodology revisions do not change EPA's policy to apply aquatic life criteria to protect aquatic species where they are more sensitive (i.e., when human health criteria would not be protective enough) or where human health via fish or water ingestion is not an issue.

4.1.1.3 Incidental Ingestion from Ambient Surface Waters

The 2000 Human Health Methodology does not routinely include criteria to address incidental ingestion of water from recreational uses. EPA has considered whether there are cases where water quality criteria for the protection of human health based only on fish ingestion (or only criteria for the protection of aquatic life) may not adequately protect recreational users from health effects resulting from incidental water ingestion.

EPA reviewed information that provided estimates of incidental water ingestion rates averaged over time. EPA generally believes that the averaged amount is negligible and will not have any impact on the chemical criteria values representative of both drinking water and fish ingestion. A lack of impact on the criteria values would likely also be true for chemical criteria based on fish consumption only, unless the chemical exhibits no bioaccumulation potential. However, EPA also believes that incidental/accidental water ingestion could be important for the development of microbial contaminant water quality criteria, and for either chemical or microbial criteria for States where recreational uses such as swimming and boating are substantially higher than the national average. EPA also notes that some States have indicated they already have established incidental ingestion rates for use in developing criteria. Therefore, although EPA will not use this intake parameter when deriving its national 304(a) chemical criteria, limited guidance is provided in the Exposure Assessment TSD volume in order to assist States and authorized Tribes that face situations where this intake parameter could be of significance.

4.2 CONSIDERATION OF NON-WATER SOURCES OF EXPOSURE WHEN SETTING AWQC

4.2.1 Policy Background

The 2000 Human Health Methodology uses different approaches for addressing non-water exposure pathways in setting AWQC for the protection of human health depending upon the toxicological endpoint of concern. With those substances for which the appropriate toxic endpoint is carcinogenicity based on a linear low-dose extrapolation, only the two water sources (i.e., drinking water and fish ingestion) are considered in the derivation of the AWQC. Non-water sources are not considered explicitly. In the case of carcinogens based on linear low-dose extrapolation, the AWQC is being determined with respect to the *incremental* lifetime risk posed by a substance's presence in water, and is not being set with regard to an individual's total risk from all sources of exposure. Thus, the AWQC represents the water concentration that would be

expected to increase an individual's lifetime risk of carcinogenicity from exposure to the particular pollutant by no more than one chance in one million, regardless of the additional lifetime cancer risk due to exposure, if any, to that particular substance from other sources.

Furthermore, health-based criteria values for one medium based on linear low-dose extrapolation typically vary from values for other media in terms of the concentration value, and often the associated risk level. Therefore, the RSC concept could not even theoretically apply unless all risk assessments for a particular carcinogen based on linear low-dose extrapolation resulted in the same concentration value and same risk level; that is, an apportionment would need to be based on a single risk value and level.

In the case of substances for which the AWQC is set on the basis of a carcinogen based on a nonlinear low-dose extrapolation or for a noncancer endpoint where a threshold is assumed to exist, non-water exposures are considered when deriving the AWQC using the RSC approach. The rationale for this approach is that for pollutants exhibiting threshold effects, the objective of the AWQC is to ensure that an individual's total exposure does not exceed that threshold level.

There has been some discussion of whether it is, in fact, necessary in most cases to explicitly account for other sources of exposure when computing the AWQC for pollutants exhibiting threshold effects. It has been argued that because of the conservative assumptions generally incorporated in the calculation of RfDs (or POD/UF values) used as the basis for the AWQC derivation, total exposures slightly exceeding the RfD are unlikely to produce adverse effects.

EPA emphasizes that the purpose of the RSC is to ensure that the level of a chemical allowed by a criterion or multiple criteria, when combined with other identified sources of exposure common to the population of concern, will not result in exposures that exceed the RfD or the POD/UF. The policy of considering multiple sources of exposure when deriving health-based criteria has become common in EPA's program office risk characterizations and criteria and standard-setting actions. Numerous EPA workgroups have evaluated the appropriateness of factoring in such exposures, and the Agency concludes that it is important for adequately protecting human health. Consequently, EPA risk management policy has evolved significantly over the last six years. Various EPA program initiatives and policy documents regarding aggregate exposure and cumulative risk have been developed, including the consideration of inhalation and dermal exposures. Additionally, accounting for other exposures has been included in recent mandates (e.g., the Food Quality Protection Act) and, thus, is becoming a requirement for the Agency. The Exposure Decision Tree approach has been shared with other EPA offices, and efforts to coordinate policies on aggregate exposure, where appropriate, have begun. EPA intends to continue developing policy guidance on the RSC issue and guidance to address the concern that human health may not be adequately protected if criteria allow for higher levels of exposure that, combined, may exceed the RfD or POD/UF. EPA also intends to refine the 2000 Human Health Methodology in the future to incorporate additional guidance on inhalation and dermal exposures. As stated previously, EPA is required to derive national water quality criteria under Section 304(a) of the CWA and does not intend to derive site-specific criteria. However, States and authorized Tribes have the flexibility to make alternative exposure and RSC estimates based on local data, and EPA strongly encourages this.

Uncertainty factors used in the derivation of the RfD (or POD/UF) to account for intra- and interspecies variability and the incompleteness of the toxicity data set(s)/animal studies are specifically relevant to the chemical's internal toxicological action, irrespective of the sources of exposure that humans may be experiencing. The Agency's policy is to consider and account for other sources of exposure in order to set protective health criteria. EPA believes that multiple route exposures may be particularly important when uncertainty factors associated with the RfD are small. Although EPA is well aware that RfDs are not all equivalent in their derivation, EPA does not believe that uncertainty in the toxicological data should result in less stringent criteria by ignoring exposure sources. However, the RSC policy approach does allow less stringent assumptions when multiple sources of exposure are not anticipated.

The AWQC are designed to be protective criteria, generally applicable to the waters of the United States. While EPA cannot quantitatively predict the actual human health risk associated with combined exposures above the RfD or POD/UF, a combination of health criteria for multiple media exceeding the RfD or POD/UF may not be sufficiently protective. Therefore, EPA's policy is to routinely account for all sources and routes of non-occupational exposure when setting AWQC for noncarcinogens and for carcinogens based on nonlinear low-dose extrapolations. EPA believes that maintaining total exposure below the RfD (or POD/UF) is a reasonable health goal and that there are circumstances where health-based criteria for a chemical should not exceed the RfD (or POD/UF), either alone (if only one criterion is relevant, along with other intake sources considered as background exposures) or in combination. EPA believes its RSC policy ensures this goal.

Also, given the inability to reasonably predict future changes in exposure patterns, the uncertainties in the exposure estimates due to typical data inadequacy, possible unknown sources of exposure, and the potential for some populations to experience greater exposures than indicated by the available data, EPA believes that utilizing the entire RfD (or POD/UF) does not ensure adequate protection.

4.2.2 The Exposure Decision Tree Approach

As indicated in Section 1, EPA has, in the past, used a "subtraction" method to account for multiple sources of exposure to pollutants. In the subtraction method, other sources of exposure (i.e., those other than the drinking water and fish exposures) are subtracted from the RfD (or POD/UF). However, EPA also previously used a "percentage" method for the same purpose. In this approach, the percentage of total exposure typically accounted for by the exposure source for which the criterion is being determined, referred to as the relative source contribution (RSC), is applied to the RfD to determine the maximum amount of the RfD "apportioned" to that source. With both procedures, a "ceiling" level of 80 percent of the RfD and a "floor level" of 20 percent of the RfD are applied.

The subtraction method is considered acceptable when only one criterion is relevant for a particular chemical. The percentage method is recommended in the context of the above goals when multiple media criteria are at issue. The percentage method does not simply depend on the amount of a contaminant in the prospective criterion source only. It is intended to reflect health considerations, the relative portions of other sources, and the likelihood for ever-changing levels

in each of those multiple sources (due to ever-changing sources of emissions and discharges). Rather than simply defaulting in every instance, the Agency attempts to compare multiple source exposures with one another to estimate their relative contribution to the total–given that understanding the degree to which their concentrations vary, or making any distributional analysis, is often not possible. The criteria levels, when multiple criteria are at issue, are based on the actual levels, with an assumption that there may be enough relative variability such that an apportionment (relating that percentage to the RfD) is a reasonable way of accounting for the uncertainty regarding that variability.

The specific RSC approach recommended by EPA, which we will use for the derivation of AWQC for noncarcinogens and carcinogens assessed using nonlinear low-dose extrapolation, is called the Exposure Decision Tree and is described below. To account for exposures from other media when setting an AWQC (i.e., non-drinking water/non-fish ingestion exposures, and inhalation or dermal exposures), the Exposure Decision Tree for determining proposed RfD or POD/UF apportionments represents a method of comprehensively assessing a chemical for water quality criteria development. This method considers the adequacy of available exposure data, levels of exposure, relevant sources/media of exposure, and regulatory agendas (i.e., whether there are multiple health-based criteria or regulatory standards for the same chemical). The Decision Tree addresses most of the disadvantages associated with the exclusive use of either the percentage or subtraction approaches, because they are not arbitrarily chosen prior to determining the following: specific population(s) of concern, whether these populations are relevant to multiple-source exposures for the chemical in question (i.e., whether the population is actually or potentially experiencing exposure from multiple sources), and whether levels of exposure, regulatory agendas, or other circumstances make apportionment of the RfD or POD/UF desirable. Both subtraction and percentage methods are potentially utilized under different circumstances with the Exposure Decision Tree approach, and the Decision Tree is recommended with the idea that there is enough flexibility to use other procedures if information on the contaminant in question suggests it is not appropriate to follow the Decision Tree. EPA recognizes that there may be other valid approaches in addition to the Exposure Decision Tree.

The Exposure Decision Tree approach allows flexibility in the RfD (or POD/UF) apportionment among sources of exposure. When adequate data are available, they are used to make protective exposure estimates for the population(s) of concern. When other sources or routes of exposure are anticipated but data are not adequate, there is an even greater need to make sure that public health protection is achieved. For these circumstances, a series of qualitative alternatives is used (with the less adequate data or default assumptions) that allow for the inadequacies of the data while protecting human health. Specifically, the Decision Tree makes use of chemical information when actual monitoring data are inadequate. It considers information on the chemical/physical properties, uses of the chemical, and environmental fate and transformation, as well as the likelihood of occurrence in various media. Review of such information, when available, and determination of a reasonable exposure characterization for the chemical will result in a water quality criterion that more accurately reflects exposures than automatically using a default value. Although the 20 percent default will still generally be used when information is not adequate, the need for using it should be reduced. There may also be some situations where EPA would consider the use of an 80 percent default (see Section 4.2.3).

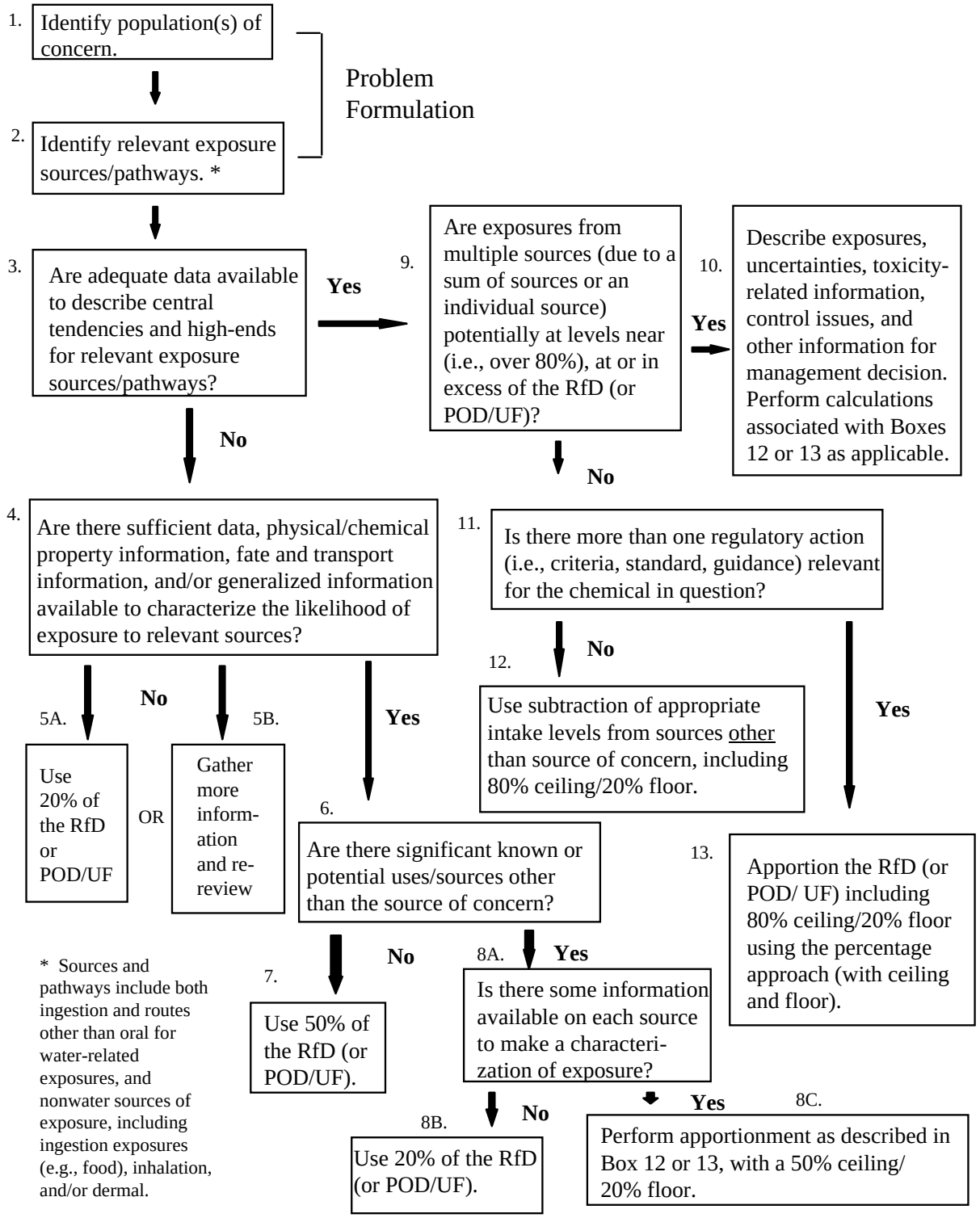
The Decision Tree also allows for use of either the subtraction or percentage method to account for other exposures, depending on whether one or more health-based criterion is relevant for the chemical in question. The subtraction method is considered acceptable when only one criterion is relevant for a particular chemical. In these cases, other sources of exposure can be considered "background" and can be subtracted from the RfD (or POD/UF).

EPA cautions States and Tribes when using the subtraction method in these circumstances. The subtraction method results in a criterion allowing the maximum possible chemical concentration in water after subtracting other sources. As such, it removes any cushion between pre-criteria levels (i.e., actual "current" levels) and the RfD, thereby setting criteria at the highest levels short of exceeding the RfD. It is somewhat counter to the goals of the CWA for maintaining and restoring the nation's waters. It is also directly counter to Agency policies, explicitly stated in numerous programs, regarding pollution prevention. EPA has advocated that it is good health policy to set criteria such that exposures are kept low when current levels are already low. The subtraction method generally results in criteria levels of a contaminant in a particular medium at significantly higher levels than the percentage method and, in this respect, is contradictory to such goals. In fact, many chemicals have pre-criteria levels in environmental media substantially lower (compared to the RfD) than the resulting criteria allow.

When more than one criterion is relevant to a particular chemical, apportioning the RfD (or POD/UF) via the percentage method is considered appropriate to ensure that the combination of criteria and, thus, the potential for resulting exposures do not exceed the RfD (or POD/UF). The Exposure Decision Tree (with numbered boxes) is shown in Figure 4-1. The explanation in the text on the following pages must be read in tandem with the Decision Tree figure; the text in each box of the figure only nominally identifies the process and conditions for determining the outcome for that step of the Decision Tree. The underlying objective is to maintain total exposure below the RfD (or POD/UF) while generally avoiding an extremely low limit in a single medium that represents just a nominal fraction of the total exposure. To meet this objective, all proposed numeric limits lie between 80 percent and 20 percent of the RfD (or POD/UF). Again, EPA will use the Exposure Decision Tree approach when deriving its AWQC but also recognizes that departures from the approach may be appropriate in certain cases. EPA understands that there may be situations where the Decision Tree procedure is not practicable or

Figure 4-1

Exposure Decision Tree for Defining Proposed RfD (or POD/UF) Apportionment



may be simply irrelevant after considering the properties, uses, and sources of the chemical in question. EPA endorses such flexibility by States and authorized Tribes when developing alternative water quality criteria in order to choose other procedures that are more appropriate for setting health-based criteria and, perhaps, apportioning the RfD or POD/UF, as long as reasons are given as to why it is not appropriate to follow the Exposure Decision Tree approach and as long as the steps taken to evaluate the potential sources and levels of exposure are clearly described. Often, however, the common situation of multiple exposure sources for a chemical is likely to merit a Decision Tree evaluation for the purpose of developing human health water quality criteria for a given chemical.

It is clear that this will be an interactive process; input by exposure assessors will be provided to, and received from, risk managers throughout the process, given that there may be significant implications regarding control issues (i.e., cost/feasibility), environmental justice issues, etc. In cases where the Decision Tree is not chosen, communication and concurrence about the decision rationale and the alternative water quality criteria are of great importance.

Descriptions of the boxes within the Decision Tree are separated by the following process headings to facilitate an understanding of the major considerations involved. The decision to perform, or not to perform, an apportionment could actually be made at several points during the Decision Tree process. Working through the process is most helpful for identifying possible exposure sources and the potential for exposure, determining the relevancy of the Decision Tree to developing an AWQC for a particular chemical and, possibly, determining the appropriateness of using an alternative approach to account for overall exposure. "Relevancy" here means determining whether more than one criterion, standard, or other guidance is being planned or is in existence for the chemical in question. Additional guidance for States and Tribes that wish to use the Exposure Decision Tree is provided in the Exposure Assessment TSD.

4.2.2.1 Problem Formulation

Initial Decision Tree discussion centers around the first two boxes: identification of population(s) of concern (Box 1) and identification of relevant exposure sources and pathways (Box 2). The term "problem formulation" refers to evaluating the population(s) and sources of exposure in a manner that allows determination of the potential for the population of concern to experience exposures from multiple sources for the chemical in question. Also, the data for the chemical in question must be representative of each source/medium of exposure and be relevant to the identified population(s). Evaluation includes determining whether the levels, multiple criteria or regulatory standards, or other circumstances make apportionment of the RfD or POD/UF reasonable. The initial problem formulation also determines the exposure parameters chosen, the intake assumptions chosen for each route, and any environmental justice or other social issues that aid in determining the population of concern. The term "data," as used here and discussed throughout this section, refers to ambient sampling data (whether from Federal, regional, State, or area-specific studies) and not internal human exposure measurements.

4.2.2.2 Data Adequacy

In Box 3, it is necessary that adequate data exist for the relevant sources/pathways of exposure if one is to avoid using default procedures. The adequacy of data is a professional judgment for each individual chemical of concern, but EPA recommends that the minimum acceptable data for Box 3 are exposure distributions that can be used to determine, with an acceptable 95 percent confidence interval, the central tendency and high-end exposure levels for each source. In fact, distributional data may exist for some or most of the sources of exposure.

There are numerous factors to consider in order to determine whether a dataset is adequate. These include: (1) sample size (i.e., the number of data points); (2) whether the data set is a random sample representative of the target population (if not, estimates drawn from it may be biased no matter how large the sample); (3) the magnitude of the error that can be tolerated in the estimate (estimator precision); (4) the sample size needed to achieve a given precision for a given parameter (e.g., a larger sample is needed to precisely estimate an upper percentile than a mean or median value); (5) an acceptable analytical method detection limit; and (6) the functional form and variability of the underlying distribution, which determines the estimator precision (e.g., whether the distribution is normal or lognormal and whether the standard deviation is 1 or 10). Lack of information may prevent assessment of each of these factors; monitoring study reports often fail to include background information or sufficient summary statistics (and rarely the raw data) to completely characterize data adequacy. Thus, a case-by-case determination of data adequacy may be necessary.

That being stated, there are some guidelines, as presented below, that lead to a rough rule-of-thumb on what constitutes an "adequate" sample size for exposure assessment. Again, first and foremost, the representativeness of the data for the population evaluated and the analytical quality of the data must be acceptable. If so, the primary objective then becomes estimating an upper percentile (e.g., say the 90th) and a central tendency value of some exposure distribution based on a random sample from the distribution. Assuming that the distribution of exposures is unknown, a nonparametric estimate of the 90th percentile is required. The required estimate, based on a random sample of *n* observations from a target population, is obtained by ranking the data from smallest to largest and selecting the observation whose rank is 1 greater than the largest integer in the product of 0.9 times *n*. For example, in a data set of 25 points, the nonparametric estimate of the 90th percentile is the 23rd largest observation.

In addition to this point estimate, it is useful to have an upper confidence bound on the 90th percentile. To find the rank of the order statistic that gives an upper 95 percent confidence limit on the 90th percentile, the smallest value of *r* that satisfies the following formula is determined:

$$0.95 \approx \sum_{i=0}^{r-1} \binom{n}{i} 0.9^{i}\ 0.1^{n-i} \qquad \text{(Equation 4-2)}$$

where:

r	=	the rank order of the observation
n	=	the number of observations
I	=	integer from 0 to r - 1

For relatively small data sets, the above formula will lead to selecting the largest observation as the upper confidence limit on the 90th percentile. However, the problem with using the maximum is that, in many environmental datasets, the largest observation is an outlier and would provide an unrealistic upper bound on the 90th percentile. It would, therefore, be preferable if the sample size *n* were large enough so that the formula yielded the second largest observation as the confidence limit (see for example Gibbons, 1971).

This motivates establishing the following criterion for setting an "adequate" sample size: pick the smallest *n* such that the nonparametric upper 95 percent confidence limit on the 90th percentile is the second largest value. Application of the above formula with *r* set to *n*-1 yields *n* = 45 for this minimum sample size.

For the upper 95 percent confidence limit to be a useful indicator of a high-end exposure, it must not be overly conservative (too large relative to the 90th percentile). It is, therefore, of interest to estimate the expected magnitude of the ratio of the upper 95 percent confidence limit to the 90th percentile. This quantity generally cannot be computed, since it is a function of the unknown distribution. However, to get a rough idea of its value, consider the particular case of a normal distribution. If the coefficient of variation (i.e., the standard deviation divided by the mean) is between 0.5 and 2.0, the expected value of the ratio in samples of 45 will be approximately 1.17 to 1.31; i.e., the upper 95 percent confidence limit will be only about 17 to 31 percent greater than the 90th percentile on the average.

It should be noted that the nonparametric estimate of the 95 percent upper confidence limit based on the second largest value can be obtained even if the data set has only two detects (it is assumed that the two detects are greater than the detection limit associated with all non-detects). This is an argument for using nonparametric rather than parametric estimation, since use of parametric methods would require more detected values. On the other hand, if non-detects were not a problem and the underlying distribution were known, a parametric estimate of the 90th percentile would generally be more precise.

As stated above, adequacy also depends on whether the samples are relevant to and representative of the population at risk. Data may, therefore, be adequate for some decisions and inadequate for others; this determination requires some professional judgment.

If the answer to Box 3 is no, based on the above determination of adequacy, then the decision tree moves to Box 4. As suggested by the separate boxes, the available data that will be reviewed as part of Box 4 do not meet the requirements necessary for Box 3. In Box 4, any limited data that are available (in addition to information about the chemical/physical properties, uses, and environmental fate and transformation, as well as any other information that would characterize the likelihood of exposure from various media for the chemical) are evaluated to

make a qualitative determination of the relation of one exposure source to another. Although this information should always be reviewed at the outset, it is recommended that this information also be used to estimate the health-based water quality criteria. The estimate should be rather conservative (as indicated in the Decision Tree), given that it is either not based on actual monitoring data or is based on data that has been considered to be inadequate for a more accurate quantitative estimate. Therefore, greater uncertainties exist and accounting for variability is not really possible. Whether the available data are adequate and sufficiently representative will likely vary from chemical to chemical and may depend on the population of concern. If there are some data and/or other information to make a characterization of exposure, a determination can be made as to whether there are significant known or potential uses for the chemical/sources of exposure other than the source of concern (i.e., in this case, the drinking water and fish intakes relevant to developing an AWQC) that would allow one to anticipate/quantify those exposures (Box 6). If there are not, then it is recommended that 50 percent of the RfD or POD/UF can be safely apportioned to the source of concern (Box 7). While this leaves half of the RfD or POD/UF unapportioned, it is recommended as the maximum apportionment due to the lack of data needed to more accurately quantify actual or potential exposures. If the answer to the question in Box 6 is yes (there is multiple source information available for the exposures of concern), and some information is available on each source of exposure (Box 8A), apply the procedure in either Box 12 or Box 13 (depending on whether one or more criterion is relevant to the chemical), using a 50 percent ceiling (Box 8C)–again due to the lack of adequate data. If the answer to the question in Box 8A is no (there is no available information to characterize exposure), then the 20 percent default of the RfD or POD/UF is used (Box 8B).

If the answer to the question in Box 4 is no; that is, there are not sufficient data/information to characterize exposure, EPA intends to generally use the "default" assumption of 20 percent of the RfD or POD/UF (Box 5A) when deriving or revising the AWQC. It may be better to gather more data or information and re-review when this information becomes available (Box 5B). EPA has done this on occasion when resources permit the acquisition of additional data to enable better estimates of exposure instead of the default. If this is not possible, then the assumption of 20 percent of the RfD or POD/UF (Box 5A) should be used. Box 5A is likely to be used infrequently with the Exposure Decision Tree approach, given that the information described in Box 4 should be available in most cases. However, EPA intends to use 20 percent of the RfD (or POD/UF), which has also been used in past water program regulations, as the default value.

4.2.2.3 Regulatory Actions

If there are adequate data available to describe the central tendencies and high ends from each exposure source/pathway, then the levels of exposure relative to the RfD or POD/UF are compared (Box 9). If the levels of exposure for the chemical in question are not near (currently defined as greater than 80 percent), at, or in excess of the RfD or POD/UF, then a subsequent determination is made (Box 11) as to whether there is more than one health-based criterion or regulatory action relevant for the given chemical (i.e., more than one medium-specific criterion,

standard or other guidance being planned, performed or in existence for the chemical). The subtraction method is considered acceptable when only one criterion (standard, etc.) is relevant for a particular chemical. In these cases, other sources of exposure can be considered "background" and can be subtracted from the RfD (or POD/UF). When more than one criterion is relevant to a particular chemical, apportioning the RfD (or POD/UF) via the percentage method is considered appropriate to ensure that the combination of health criteria, and thus the potential for resulting exposures, do not exceed the RfD (or POD/UF).

As indicated in Section 2, for EPA's national 304(a) criteria, the RSC intake estimates of non-water exposures (e.g., non-fish dietary exposures) will be based on arithmetic mean values when data are available. The assumed body weight used in calculating the national criteria will also be based on average values. The drinking water and fish intake values are 90th percentile estimates. EPA believes that these assumptions will be protective of a majority of the population and recommends them for State and Tribal use. However, States and authorized Tribes have the flexibility to choose alternative intake rate and exposure estimate assumptions to protect specific population groups that they have chosen.

4.2.2.4 Apportionment Decisions

If the answer to the question in Box 11 is no (there is not more than one relevant medium-specific criterion/regulatory action), then the recommended method for setting a health-based water quality criterion is to utilize a subtraction calculation (Box 12). Specifically, appropriate intake values for each exposure source other than the source of concern are subtracted out. EPA will rely on average values commonly used in the Agency for food ingestion and inhalation rates, combined with mean contaminant concentration values, for calculating RSC estimates to subtract. Alternatively, contaminant concentrations could be selected based on the variability associated with those concentrations for each source. This implies that a case-by-case determination of the variability and the resulting intake chosen would be made, as each chemical evaluated can be expected to have different variations in concentration associated with each source of intake. However, EPA anticipates that the available data for most contaminants will not allow this for determination (based on past experience). Guidance addressing this possibility is addressed in the Exposure Assessment TSD. EPA does not recommend that high-end intakes be subtracted for every exposure source, since the combination may not be representative of any actually exposed population or individual. The subtraction method would also include an 80 percent ceiling and a 20 percent floor.

If the answer to the question in Box 11 is yes (there is more than one medium-specific criterion/regulation relevant), then the recommended method for setting health-based water quality criteria is to apportion the RfD or POD/UF among those sources for which health-based criteria are being set (Box 13). This is done via a percentage approach (with a ceiling and floor). This simply refers to the percentage of overall exposure contributed by an individual exposure source. For example, if for a particular chemical, drinking water were to represent half of total exposure and diet were to represent the other half, then the drinking water contribution (or RSC) would be 50 percent. The health-based criteria would, in turn, be set at 50 percent of the RfD or POD/UF. This method also utilizes an appropriate combination of intake values for each

exposure source based on values commonly used in the Agency for food ingestion and inhalation rates, combined with mean contaminant concentration values.

Finally, if the levels of exposure for the chemical in question are near (currently defined as greater than 80 percent), at, or in excess of the RfD or POD/UF (i.e., the answer in Box 9 is yes), then the estimates of exposures and related uncertainties, recommended apportionment (either box 12 or 13), toxicity-related information, control issues, and other information are to be presented to managers for a decision (Box 10). The high levels referred to in Box 9 may be due to one source contributing that high level (while other sources contribute relatively little) or due to more than one source contributing levels that, in combination, approach or exceed the RfD or POD/UF. Management input may be necessary due to the control issues (i.e., cost and feasibility concerns), especially when multiple criteria are at issue. In practice, risk managers are routinely a part of decisions regarding regulatory actions and will be involved with any recommended outcome of the Exposure Decision Tree or, for that matter, any alternative to the Exposure Decision Tree. However, because exposures approach or exceed the RfD or POD/UF and because the feasibility of controlling different sources of exposure are complicated issues, risk managers will especially need to be directly involved in final decisions in these circumstances.

It is emphasized here that the procedures in these circumstances are not different than the procedures when exposures are not at or above the RfD (or POD/UF). Therefore, in these cases, estimates should be performed as with Boxes 11, 12, and 13. The recommendation should be made based on health-based considerations only, just as when the chemical in question was not a Box 10 situation. If the chemical is relevant to one health criterion or regulatory action only, the other sources of exposure could be subtracted from the RfD or POD/UF to determine if there is any leftover amount for setting the criterion. If the chemical is a multiple media criteria issue, then an apportionment should be made, even though it is possible that all sources would need to be reduced. Regardless of the outcome of Box 9, all apportionments made (via the methods of Boxes 12 or 13) should include a presentation of the uncertainty in the estimate and in the RfD or POD/UF for a more complete characterization.

The process for a Box 10 situation (versus a situation that is not) differs in that the presentations for Boxes 12 and 13 are based on apportionments (following the review of available information and a determination of appropriate exposure parameters) that must address additional control issues and may result in more selective reductions. With Box 10, one or several criteria possibilities ("scenarios") could be presented for comparison along with implications of the effects of various control options. It is appropriate to present information in this manner to risk managers given the complexity of these additional control issues.

4.2.3 Additional Points of Clarification on the Exposure Decision Tree Approach for Setting AWQC

As with Box 9, if a determination is made in Box 8A (i.e., information is available to characterize exposure) that exposures are near, at, or above the RfD (or POD/UF) based on the available information, the apportionments made need to be presented to risk managers for decision. If information is lacking on some of the multiple exposure sources, then EPA would use a default of 20 percent of the RfD or POD/UF (Box 8B).

Results of both Boxes 12 and 13 rely on the 80 percent ceiling and 20 percent floor. The 80 percent ceiling was implemented to ensure that the health-based goal will be low enough to provide adequate protection for individuals whose total exposure to a contaminant is, due to any of the exposure sources, higher than currently indicated by the available data. This also increases the margin of safety to account for possible unknown sources of exposure. The 20 percent floor has been traditionally rationalized to prevent a situation where small fractional exposures are being controlled. That is, below that point, it is more appropriate to reduce other sources of exposure, rather than promulgating standards for *de minimus* reductions in overall exposure.

If it can be demonstrated that other sources and routes of exposure are not anticipated for the pollutant in question (based on information about its known/anticipated uses and chemical/physical properties), then EPA would use the 80 percent ceiling. EPA qualifies this policy with the understanding that as its policy on cumulative risk assessment continues to develop, the 80 percent RSC may prove to be underprotective.

In the cases of pollutants for which substantial data sets describing exposures across all anticipated pathways of exposure exist, and probabilistic analyses have been conducted based on those data, consideration will be given to the results of those assessments as part of the Exposure Decision Tree approach for setting AWQC.

For many chemicals, the rate of absorption from ingestion can differ substantially from absorption by inhalation. There is also available information for some chemicals that demonstrates appreciable differences in gastrointestinal absorption depending on whether the chemical is ingested from water, soil, or food. For some contaminants, the absorption of the contaminant from food can differ appreciably for plant compared with animal food products. Regardless of the apportionment approach used, EPA recommends using existing data on differences in bioavailability between water, air, soils, and different foods when estimating total exposure for use in apportioning the RfD or POD/UF. The Agency has developed such exposure estimates for cadmium (USEPA, 1994). In the absence of data, EPA will assume equal rates of absorption from different routes and sources of exposure.

4.2.4 Quantification of Exposure

When selecting contaminant concentration values in environmental media and exposure intake values for the RSC analysis, it is important to realize that each value selected (including those recommended as default assumptions in the AWQC equation) may be associated with a distribution of values for that parameter. Determining how various subgroups fall within the distributions of overall exposure and how the combination of exposure variables defines what population is being protected is a complicated and, perhaps, unmanageable task, depending on the amount of information available on each exposure factor included. Many times, the default assumptions used in EPA risk assessments are derived from the evaluation of numerous studies and are considered to generally represent a particular population group or a national average. Therefore, describing with certainty the exact percentile of a particular population that is protected with a resulting criteria is often not possible.

By and large, the AWQC are derived to protect the majority of the general population from chronic adverse health effects. However, as stated above in Section 4.1.1.1, States and authorized Tribes are encouraged to consider protecting population groups that they determine are at greater risk and, thus, would be better protected using alternative exposure assumptions. The ultimate choice of the contaminant concentrations used in the RSC estimate and the exposure intake rates requires the use of professional judgment. This is discussed in greater detail in the Exposure Assessment TSD.

4.2.5 Inclusion of Inhalation and Dermal Exposures

EPA intends to develop policy guidelines to apply to this Methodology for explicitly incorporating inhalation and dermal exposures. When estimating overall exposure to pollutants for AWQC development, EPA believes that the sources of inhalation and dermal exposures considered should include, on a case-by-case basis, both non-oral exposures from water and other inhalation and dermal sources (e.g., ambient or indoor air, soil). When the policy guidelines are completed, this Methodology will be refined to include that guidance.

A number of drinking water contaminants are volatile and thus diffuse from water into the air where they may be inhaled. In addition, drinking water is used for bathing and, thus, there is at least the possibility that some contaminants in water may be dermally absorbed. Volatilization may increase exposure via inhalation and decrease exposure via ingestion and dermal absorption. The net effect of volatilization and dermal absorption upon total exposure to volatile drinking water contaminants is unclear in some cases and varies from chemical to chemical. Dermal exposures are also important to consider for certain population groups, such as children and other groups with high soil contact.

With regard to additional non-water related exposures, it is clear that the type and magnitude of toxicity produced via inhalation, ingestion, and dermal contact may differ; that is, the route of exposure can affect absorption of a chemical and can otherwise modify its toxicity. For example, an inhaled chemical such as hydrogen fluoride may produce localized effects on the lung that are not observed (or only observed at much higher doses) when the chemical is administered orally. Also, the active form of a chemical (and principal toxicity) can be the parent compound and/or one or more metabolites. With this Methodology, EPA recommends that differences in absorption and toxicity by different routes of exposure be determined and accounted for in dose estimates and applied to the exposure assessment. EPA acknowledges that the issue of whether the doses received from inhalation and ingestion exposures are cumulative (i.e., toward the same threshold of toxicity) is complicated. Such a determination involves evaluating the chemical's physical characteristics, speciation, and reactivity. A chemical may also exhibit different metabolism by inhalation versus oral exposure and may not typically be metabolized by all tissues. In addition, a metabolite may be much more or much less toxic than the parent compound. Certainly with a systemic effect, if the chemical absorbed via different routes enters the bloodstream, then there is some likelihood that it will contact the same target organ. Attention also needs to be given to the fact that both the RfD and RfC are derived based on the administered level. Toxicologists generally believe that the effective concentration of the active form of a chemical(s) at the site(s) of action determines the toxicity. If specific differences between routes of exposure are not known, it may be reasonable to assume that the

internal concentration at the site from any route contributes as much to the same effect as any other route. A default of assuming equal absorption has often been used. However, for many of the chemicals that the Agency has reviewed, there is a substantial amount of information already known to determine differences in rates of absorption. For example, absorption is, in part, a function of blood solubility (i.e., Henry's Constant) and better estimations than the default can be made.

The RSC analyses that accompany the 2000 Human Health Methodology accommodate inclusion of inhalation exposures. Even if different target organs are involved between different routes of exposure, a conservative policy may be appropriate to keep all exposures below a certain level. A possible alternative is to set allowable levels (via an equation) such that the total of ingestion exposures over the ingestion RfD added to the total of inhalation exposures over the inhalation RfC is not greater than 1 (Note: the RfD is typically presented in mg/kg-day and the RfC is in mg/m^3). Again, EPA intends to develop guidance for this Methodology to explicitly incorporate inhalation and dermal exposures, and will refine the Methodology when that guidance is completed.

4.3 EXPOSURE FACTORS USED IN THE AWQC COMPUTATION

This section presents values for the specific exposure factors that EPA will use in the derivation of AWQC. These include human body weight, drinking water consumption rates, and fish ingestion rates.

When choosing exposure factor values to include in the derivation of a criterion for a given pollutant, EPA recommends considering values that are relevant to population(s) that is (are) most susceptible to that pollutant. In addition, highly exposed populations should be considered when setting criteria. In general, exposure factor values specific to adults and relevant to lifetime exposures are the most appropriate values to consider when determining criteria to protect against effects from long-term exposure which, by and large, the human health criteria are derived to protect. However, infants and children may have higher rates of water and food consumption per unit body weight compared with adults and also may be more susceptible to some pollutants than adults (USEPA, 1997a). There may be instances where acute or subchronic developmental toxicity makes children the population group of concern. In addition, exposure of pregnant women to certain toxic chemicals may cause developmental effects in the fetus (USEPA, 1997b). Exposures resulting in developmental effects may be of concern for some contaminants and should be considered along with information applicable to long-term health effects when setting AWQC. (See Section 3.2 for further discussion of this issue.) Short-term exposure may include multiple intermittent or continuous exposures occurring over a week or so. Exposure factor values relevant for considering chronic toxicity, as well as exposure factor values relevant for short-term exposure developmental concerns, that could result in adverse health effects are discussed in the sections below. In appropriate situations, EPA may consider developing criteria for developmental health effects based on exposure factor values specific to children or to women of childbearing age. EPA encourages States and Tribes to do the same when health risks are associated with short-term exposures.

EPA believes that the recommended exposure factor default intakes for adults in chronic exposure situations are adequately protective of the population over a lifetime. In providing additional exposure intake values for highly exposed subpopulations (e.g., sport anglers, subsistence fishers), EPA is providing flexibility for States and authorized Tribes to establish criteria specifically targeted to provide additional protection using adjusted values for exposure parameters for body weight, drinking water intake, and fish consumption. The exposure factor values provided for women of childbearing age and children would only be used in the circumstances indicated above.

Each of the following sections recommends exposure parameter values for use in developing AWQC. These are based on both science policy decisions that consider the best available data, as well as risk management judgments regarding the overall protection afforded by the choice in the derivation of AWQC. These will be used by EPA to derive new, or revise existing, 304(a) national criteria.

4.3.1 Human Body Weight Values for Dose Calculations

The source of data for default human body weights used in deriving the AWQC is the third *National Health and Nutrition Examination Survey* (NHANES III). NHANES III represents a very large interview and examination endeavor of the National Center for Health Statistics (NCHS) and included participation from the Centers for Disease Control (CDC). The NHANES III was conducted on a nationwide probability sample of over 30,000 persons from the civilian, non-institutionalized population of the United States. The survey began in October 1988 and was completed in October 1994 (WESTAT, 2000; McDowell, 2000). Body weight data were taken from the NHANES III Examination Data File. Sampling weights were applied to all persons examined in the Mobile Examination Centers (MECs) or at home, as was recommended by the NHANES data analysts (WESTAT, 2000).

The NHANES III survey has numerous strengths and very few weaknesses. Its primary strengths are the national representativeness, large sample size, and precise estimates due to this large sample size. Another strength is its high response rate; the examination rate was 73 percent overall, 89 percent for children under 1 year old, and approximately 85 percent for children 1 to 5 years old (McDowell, 2000). Interview response rates were even higher, but the body weight data come from the NHANES examinations; that is, all body weights were carefully measured by survey staff, rather than the use of self-reported body weights. The only significant potential weakness of the NHANES data is the fact that the data are now between 6 and 12 years old. Given that there were upward trends in body weight from NHANES II to NHANES III, and that NCHS has indicated the prevalence of overweight people increased in all age groups, the data could underestimate current body weights if that trend has continued (WESTAT, 2000).

The NHANES III collected standard body measurements of sample subjects, including height and weight, that were made at various times of the day and in different seasons of the year. This technique was used because one's weight may vary between winter and summer and may fluctuate with recency of food and water intake and other daily activities (McDowell, 2000).

As with the other exposure assumptions, States and authorized Tribes are encouraged to use alternative body weight assumptions for population groups other than the general population and to use local or regional data over default values as more representative of their target population group(s).

4.3.1.1 Rate Protective of Human Health from Chronic Exposure

EPA recommends maintaining the default body weight of 70 kg for calculating AWQC as a representative average value for both male and female adults. As previously indicated, exposure factor values specific to adults are recommended to protect against effects from long-term exposure. The value of 70 kg is based on the following information. In the analysis of the NHANES III database, median and mean values for female adults 18-74 years old are 65.8 and 69.5 kg, respectively (WESTAT, 2000). For males in the same age range, the median and mean values are 79.9 and 82.1 kg, respectively. The mean body weight value for men and women ages 18 to 74 years old from this survey is 75.6 kg (WESTAT, 2000). This mean value is higher than the mean value for adults ages 20-64 years old of 70.5 kg from a study by the National Cancer Institute (NCI) which primarily measured drinking water intake (Ershow and Cantor, 1989). The NCI study is described in the subsection on Drinking Water Intake Rates that follows (Section 4.3.2). The value from the NHANES III database is also higher than the value given in the revised EPA *Exposure Factors Handbook* (USEPA, 1997b), which recommends 71.8 kg for adults, based on the older NHANES II data. The Handbook also acknowledges the commonly used 70 kg value and encourages risk assessors to use values which most accurately reflect the exposed population. However, the point is also made that the 70 kg value is used in the derivation of cancer slope factors and unit risks that appear in IRIS. Consistency is advocated between the dose-response relationship and exposure factors assumed. Therefore, if a value higher than 70 kg is used, the assessor needs to adjust the dose-response relationship as described in the Appendix to Chapter 1, Volume 1 of the Handbook (USEPA, 1997b).

4.3.1.2 Rates Protective of Developmental Human Health Effects

As noted above, pregnant women may represent a more appropriate population for which to assess risks from exposure to chemicals in ambient waters in some cases, because of the potential for developmental effects in fetuses. In these cases, body weights representative of women of childbearing age may be appropriate to adequately protect offspring from such health effects. To determine a mean body weight value appropriate to this population, separate body weight values for women in individual age groups within the range of 15 to 44 years old were analyzed from the NHANES III data (WESTAT, 2000). The resulting median and mean body weight values are 63.2 and 67.3 kg, respectively. Ershow and Cantor (1989) present body weight values specifically for pregnant women included in the survey; median and mean weights are 64.4 and 65.8 kilograms, respectively. Ershow and Cantor (1989), however, do not indicate the ages of these pregnant women. Based on this information for women of childbearing age and pregnant women, EPA recommends use of a body weight value of 67 kg in cases where pregnant women are the specific population of concern and the chemical of concern exhibits reproductive and/or developmental effects (i.e., the critical effect upon which the RfD or POD/UF is based). Using the 67 kg assumption would result in lower (more protective) criteria than criteria based on 70 kg.

As discussed earlier, because infants and children generally have a higher rate of water and food consumption per unit body weight compared with adults, a higher intake rate per unit body weight may be needed when comparing estimated exposure doses with critical doses when RfDs are based on health effects in children. To calculate intake rates relevant to such effects, the body weight of children should be used. As with the default body weight for pregnant women, EPA is not recommending the development of additional AWQC (i.e., similar to drinking water health advisories) that focus on acute or short-term effects, since these are not seen routinely as having a meaningful role in the water quality criteria program. However, there may be circumstances where the consideration of exposures for these groups is warranted. Although the AWQC generally are based on chronic health effects data, they are intended to also be protective with respect to adverse effects that may reasonably be expected to occur as a result of elevated shorter-term exposures. EPA acknowledges this as a potential course of action and is, therefore, recommending these default values which EPA would consider in an appropriate circumstance and for States and authorized Tribes to utilize in such situations.

EPA is recommending an assumption of 30 kg as a default child's body weight to calculate AWQC to provide additional protection for children when the chemical of concern indicates health effects in children are of predominant concern (i.e., test results show children are more susceptible due to less developed immune systems, neurological systems, and/or lower body weights). The value is based on the mean body weight value of 29.9 kg for children ages 1 to14 years old, which combines body weight values for individual age groups within this larger group. The mean value is based on body weight information from NHANES III for individual-year age groups between one and 14 years old (WESTAT, 2000). A mean body weight of 28 kg is obtained using body weight values from Ershow and Cantor (1989) for five age groups within this range of 0-14 years and applying a weighting method for different ages by population percentages from the U.S. Bureau of the Census. The 30 kg assumption is also consistent with the age range for children used with the estimated fish intake rates. Unfortunately, fish intake rates for finer age group divisions are not possible due to the limited sampling base from the fish intake survey; there is limited confidence in calculated values (e.g., the mean) for such fine age groups. Given this limitation, the broad age category of body weight for children is suitable for use with the default fish intake assumption.

Given the hierarchy of preferences regarding the use of fish intake information (see Section 4.3.3), States may have more comprehensive data and prefer to target a more narrow, younger age group. If States choose to specifically evaluate toddlers, EPA recommends using 13 kg as a default body weight assumption for children ages 1 to 3 years old. The median and mean values of body weight for children 1 to 3 years old are 13.2 and 13.1 kg, respectively, based on an analysis of the NHANES III database (WESTAT, 2000). The NHANES III median and mean values for females between 1 and 3 years old are 13.0 and 12.9 kg, respectively, and are 13.4 and 13.4 kg for males, respectively. Median and mean body weight values from the earlier Ershow and Cantor (1989) study for children ages 1 to 3 years old were 13.6 and 14.1 kg, respectively. Finally, if infants are specifically evaluated, EPA recommends a default body weight of 7 kg based on the NHANES III analysis. Median and mean body weights for both male and female infants (combined) 2 months old were 6.3 and 6.3 kg, respectively, and for infants 3 months old were 7.0 and 6.9 kg, respectively. With the broader age category of males and females 2 to 6 months old, median and mean body weights were 7.4 and 7.4 kg, respectively. The NHANES

analysis did not include infants under 2 months of age. Although EPA is not recommending body weight values for newborns, the NCHS National Vital Statistics Report indicates that, for 1997, the median birth weight ranged from 3 to 3.5 kg, according to WESTAT (2000).

Body weight values for individual ages within the larger range of 0-14 years are listed in the Exposure Assessment TSD for those States and authorized Tribes who wish to use body weight values for these individual groups. States and Tribes may wish to consider certain general developmental ages (e.g., infants, pre-adolescents, etc.), or certain specific developmental landmarks (e.g., neurological development in the first four years), depending on the chemical of concern. EPA encourages States and authorized Tribes to choose a body weight intake from the tables presented in the TSD, if they believe a particular age subgroup is more appropriate.

4.3.2 Drinking Water Intake Rates

The basis for the drinking water intake rates (also for the fish intake rates presented in Section 4.3.3) is the 1994-96 Continuing Survey of Food Intake by Individuals *(*CSFII) conducted by the U.S. Department of Agriculture (USDA, 1998). The CSFII survey collects dietary intake information from nationally representative samples of non-institutionalized persons residing in United States households. Households in these national surveys are sampled from the 50 states and the District of Columbia. Each survey collects daily consumption records for approximately 10,000 food codes across nine food groups. These food groups are (1) milk and milk products; (2) meat, poultry, and fish; (3) eggs; (4) dry beans, peas, legumes, nuts, and seeds; (5) grain products; (6) fruit; (7) vegetables; (8) fats, oils, and salad dressings; and (9) sweets, sugars, and beverages. The survey also asks each respondent how many fluid ounces of plain drinking water he or she drank during each of the survey days. In addition, the CSFII collects household information, including the source of plain drinking water, water used to prepare beverages, and water used to prepare foods. Data provide "up-to-date information on food intakes by Americans for use in policy formation, regulation, program planning and evaluation, education, and research." The survey is "the cornerstone of the National Nutritional Monitoring and Related Research Program, a set of related federal activities intended to provide regular information on the nutritional status of the United States population" (USDA, 1998).

The 1994-96 CSFII was conducted according to a stratified, multi-area probability sample organized using estimates of the 1990 United States population. Stratification accounted for geographic location, degree of urbanization, and socioeconomics. Each year of the survey consisted of one sample with oversampling for low-income households.

Survey participants provided two non-consecutive, 24-hour days of dietary data. Both days' dietary recall information was collected by an in-home interviewer. Interviewers provided participants with an instructional booklet and standard measuring cups and spoons to assist them in adequately describing the type and amount of food ingested. If the respondent referred to a cup or bowl in their own home, a 2-cup measuring cup was provided to aid in the calculation of the amount consumed. The sample person could fill their own bowl or cup with water to represent the amount eaten or drunk, and the interviewer could then measure the amount consumed by pouring it into the 2-cup measure. The Day 2 interview occurred three to 10 days

after the Day 1 interview, but not on the same day of the week. The interviews allowed participants "three passes" through the daily intake record to maximize recall (USDA, 1998). Proxy interviews were conducted for children aged six and younger and sampled individuals unable to report due to mental or physical limitations. The average questionnaire administration time for Day 1 intake was 30 minutes, while Day 2 averaged 27 minutes.

Two days of dietary recall data were provided by 15,303 individuals across the three survey years. This constitutes an overall two-day response rate of 75.9 percent. Survey weights were corrected by the USDA for nonresponse.

All three 1994-96 CSFII surveys are multistage, stratified-cluster samples. Sample weights, which project the data from a sampled individual to the population, are based on the probability of an individual being sampled at each stage of the sampling design. The sample weights associated with each individual reporting two days of consumption data were adjusted to correct for nonresponse bias.

The 1994-96 CSFII surveys have advantages and limitations for estimating per capita water (or fish) consumption. The primary advantage of the CSFII surveys is that they were designed and conducted by the USDA to support unbiased estimation of food consumption across the population in the United States and the District of Columbia. Second, the survey is designed to record daily intakes of foods and nutrients and support estimation of food consumption.

One limitation of the 1994-96 CSFII surveys is that individual food consumption data were collected for only two days–a brief period which does not necessarily depict "usual intake." Usual dietary intake is defined as "the long-run average of daily intakes by an individual." Upper percentile estimates may differ for short-term and longer-term data because short-term food consumption data tend to be inherently more variable. It is important to note, however, that variability due to duration of the survey does not result in bias of estimates of overall mean consumption levels. Also, the multistage survey design does not support interval estimates for many of the subpopulations of interest because of sparse representation in the sample. Subpopulations with sparse representation include Native Americans on reservations and certain ethnic groups. While these individuals are participants in the survey, they are not present in sufficient numbers to support consumption estimates.

Despite these limitations, the CSFII is considered one of the best sources of current information on consumption of water and fish-containing foods. The objective of estimating per capita water and fish consumption by the United States population is compatible with the statistical design and scope of the CSFII survey.

4.3.2.1 Rate Protective of Human Health from Chronic Exposure

EPA recommends maintaining the default drinking water intake rate of 2 L/day to protect most consumers from contaminants in drinking water. EPA believes that the 2 L/day assumption is representative of a majority of the population over the course of a lifetime. EPA also notes that there is comparatively little variability in water intake within the population compared with

fish intake (i.e., drinking water intake varies, by and large, by about a three-fold range, whereas fish intake can vary by 100-fold). EPA believes that the 2 L/day assumption continues to represent an appropriate risk management decision. The results of the 1994-96 CSFII analysis indicate that the arithmetic mean, 75th, and 90th percentile values for adults 20 years and older are 1.1, 1.5, and 2.2 L/day, respectively (USEPA, 2000a). The 2 L/day value represents the 86th percentile for adults. These values can also be compared to data from an older National Cancer Institute (NCI) study, which estimated intakes of tapwater in the United States based on the USDA's 1977-78 Nationwide Food Consumption Survey (NFCS). The arithmetic mean, 75th, and 90th percentile values for adults 20 - 64 years old were 1.4, 1.7, and 2.3 L/day, respectively (Ershow and Cantor, 1989). The 2 L/day value represents the 88th percentile for adults from the NCI study.

The 2 L/day assumption was used with the original 1980 AWQC National Guidelines and has also been used in EPA's drinking water program. EPA believes that the newer studies continue to support the use of 2 L/day as a reasonable and protective consumption rate that represents the intake of most water consumers in the general population. However, individuals who work or exercise in hot climates could have water consumption rates significantly above 2 L/day, and EPA believes that States and Tribes should consider regional or occupational variations in water consumption.

4.3.2.2 Rates Protective of Developmental Human Health Effects

Based on the 1994-96 CSFII study data, EPA also recommends 2 L/day for women of childbearing age. The analysis for women of childbearing age (ages 15-44) indicate mean, 75th, and 90th percentile values of 0.9, 1.3, and 2.0 L/day, respectively. These rates compare well with those based on an analysis of tapwater intake by pregnant and lactating women by Ershow et al. (1991), based on the older USDA data, for women ages 15-49. Arithmetic mean, 75th and 90th percentile values were 1.2, 1.5, and 2.2 L/day, respectively, for pregnant women. For lactating women, the arithmetic mean, 75th and 90th percentile values were 1.3, 1.7, and 1.9 L/day, respectively.

As noted above, because infants and children have a higher daily water intake per unit body weight compared with adults, a water consumption rate measured for children is recommended for use when RfDs are based on health effects in children. Use of this water consumption rate should result in adequate protection for infants and children when setting criteria based on health effects for this target population. EPA recommends a drinking water intake of 1 L/day to, again, represent a majority of the population of children that consume drinking water. The results of the 1994-96 CSFII analysis indicate that for children from 1 to 10 years of age, the arithmetic mean, 75th, and 90th percentile values are 0.4, 0.6, and 0.9 L/day, respectively (USEPA, 2000a). The 1 L/day value represents the 93rd percentile for this group. The arithmetic mean, 75th, and 90th percentile values for smaller children, ages 1 to 3 years, are 0.3, 0.5, and 0.7 L/day, respectively. The 1 L/day value represents the 97th percentile of the group ages 1 to 3 years old. For the category of infants under 1 year of age, the arithmetic mean, 75th, and 90th percentile values are 0.3, 0.7, and 0.9 L/day, respectively. These data can similarly be compared to those of the older National Cancer Institute (NCI) study. The arithmetic mean, 75th, and 90th percentile values for children 1 to 10 years old were 0.74, 0.96, and 1.3 L/day,

respectively. The mean, 75th, and 90th percentile values for children 1 to 3 years old in the NCI study were 0.6, 0.8, and 1.2 L/day, respectively. Finally, the mean, 75th, and 90th percentile values for infants less than 6 months old were 0.3, 0.3, and 0.6 L/day, respectively (Ershow and Cantor, 1989).

4.3.2.3 Rates Based on Combining Drinking Water Intake and Body Weight

As an alternative to considering body weight and drinking water intake rates separately, EPA is providing rates based on intake per unit body weight data (in units of ml/kg) in the Exposure Assessment TSD, with additional discussion on their use. These rates are based on self-reported body weights from the CSFII survey respondents for the 1994-96 data. While EPA intends to derive or revise national default criteria on the separate intake values and body weights, in part due to the strong input received from its State stakeholders, the ml/kg-BW/day values are provided in the TSD for States or authorized Tribes that prefer their use. It should be noted that in their 1993 review, EPA's Science Advisory Board (SAB) felt that using drinking water intake rate assumptions on a per unit body weight basis would be more accurate, but did not believe this change would appreciably affect the criteria values (USEPA, 1993).

4.3.3 Fish Intake Rates

The basis for the fish intake rates is the 1994-96 CSFII conducted by the USDA, and described above in Section 4.3.2.

4.3.3.1 Rates Protective of Human Health from Chronic Exposure

EPA recommends a default fish intake rate of 17.5 grams/day to adequately protect the general population of fish consumers, based on the 1994 to 1996 data from the USDA's CSFII Survey. EPA will use this value when deriving or revising its national 304(a) criteria. This value represents the 90th percentile of the 1994-96 CSFII data. This value also represents the uncooked weight estimated from the CSFII data, and represents intake of freshwater and estuarine finfish and shellfish only. For deriving AWQC, EPA has also considered the States' and Tribes' needs to provide adequate protection from adverse health effects to highly exposed populations such as recreational and subsistence fishers, in addition to the general population. Based on available studies that characterize consumers of fish, recreational fishers and subsistence fishers are two distinct groups whose intake rates may be greater than the general population. It is, therefore, EPA's decision to discuss intakes for these two groups, in addition to the general population.

EPA recommends default fish intake rates for recreational and subsistence fishers of 17.5 grams/day and 142.4 grams/day, respectively. These rates are also based on uncooked weights for fresh/estuarine finfish and shellfish only. However, because the level of fish intake in highly exposed populations varies by geographical location, EPA suggests a four preference hierarchy for States and authorized Tribes to follow when deriving consumption rates that encourages use of the best local, State, or regional data available. A thorough discussion of the development of this policy method and relevant data sources is contained in the Exposure Assessment TSD. The hierarchy is also presented here because EPA strongly emphasizes that States and authorized

Tribes should consider developing criteria to protect highly exposed population groups and use local or regional data over the default values as more representative of their target population group(s). The four preference hierarchy is: (1) use of local data; (2) use of data reflecting similar geography/population groups; (3) use of data from national surveys; and (4) use of EPA's default intake rates.

The recommended four preference hierarchy is intended for use in evaluating fish intake from fresh and estuarine species only. Therefore, to protect humans who additionally consume marine species of fish, the marine portion should be considered an *other source of exposure* when calculating an RSC for dietary intake. Refer to the Exposure Assessment TSD for further discussion. States and Tribes need to ensure that when evaluating overall exposure to a contaminant, marine fish intake is not double-counted with the other dietary intake estimate used. Coastal States and authorized Tribes that believe accounting for total fish consumption (i.e., fresh/estuarine and marine species) is more appropriate for protecting the population of concern may do so, provided that the marine intake component is not double-counted with the RSC estimate. Tables of fish consumption intakes based on the CSFII in the TSD provide rates for fresh/estuarine species, marine species, and total (combined) values to facilitate this option for States and Tribes. Throughout this section, the terms "fish intake" or "fish consumption" are used. These terms refer to the consumption of finfish and shellfish, and the CSFII survey includes both. States and Tribes should ensure that when selecting local or regionally-specific studies, both finfish and shellfish are included when the population exposed are consumers of both types.

EPA's first preference is that States and authorized Tribes use the results from fish intake surveys of local watersheds within the State or Tribal jurisdiction to establish fish intake rates that are representative of the defined populations being addressed for the particular waterbody. Again, EPA recommends that data indicative of fresh/estuarine species only be used which is, by and large, most appropriate for developing AWQC. EPA also recommends the use of uncooked weight intake values, which is discussed in greater detail with the fourth preference. States and authorized Tribes may use either high-end values (such as the 90^{th} or 95^{th} percentile values) or average values for an identified population that they plan to protect (e.g., subsistence fishers, sport fishers, or the general population). EPA generally recommends that arithmetic mean values should be the lowest value considered by States or Tribes when choosing intake rates for use in criteria derivation. When considering geometric mean (median) values from fish consumption studies, States and authorized Tribes need to ensure that the distribution is based on survey respondents who reported consuming fish because surveys based on both consumers and nonconsumers can often result in median values of zero. If a State or Tribe chooses values (whether the central tendency or high-end values) from studies that particularly target high-end consumers, these values should be compared to high-end fish intake rates for the general population to make sure that the high-end consumers within the general population would be protected by the chosen intake rates. EPA believes this is a reasonable procedure and is also consistent with the recent Great Lakes Water Quality Initiative (known as the "GLI") (USEPA, 1995). States and authorized Tribes may wish to conduct their own surveys of fish intake, and EPA guidance is available on methods to conduct such studies in *Guidance for Conducting Fish and Wildlife Consumption Surveys* (USEPA, 1998). Results from broader geographic regions in which the State or Tribe is located can also be used, but may not be as applicable as results from

local watersheds. Since such studies would ultimately form the basis of a State or Tribe's AWQC, EPA would review any surveys of fish intake for consistency with the principles of EPA's guidance as part of the Agency's review of water quality standards under Section 303(c).

If surveys conducted in the geographic area of the State or Tribe are not available, EPA's second preference is that States and authorized Tribes consider results from existing fish intake surveys that reflect similar geography and population groups (e.g., from a neighboring State or Tribe or a similar watershed type), and follow the method described above regarding target values to derive a fish intake rate. Again, EPA recommends the use of uncooked weight intake values and the use of fresh/estuarine species data only. Results of existing local and regional surveys are discussed in greater detail in the TSD.

If applicable consumption rates are not available from local, State, or regional surveys, EPA's third preference is that States and authorized Tribes select intake rate assumptions for different population groups from national food consumption surveys. EPA has analyzed one such national survey, the 1994-96 CSFII. As described in Section 4.3.2, this survey, conducted annually by the USDA, collects food consumption information from a probability sample of the population of all 50 states. Respondents to the survey provide two days of dietary recall data. A detailed description of the combined 1994-96 CSFII survey, the statistical methodology, and the results and uncertainties of the EPA analyses are provided in a separate EPA report (USEPA, 2000b). The Exposure Assessment TSD for this Methodology presents selected results from this report including point and interval estimates of combined finfish and shellfish consumption for the mean, 50^{th} (median), 90^{th}, 95^{th}, and 99^{th} percentiles. The estimated fish consumption rates are by fish habitat (i.e., freshwater/estuarine, marine and all habitats) for the following population groups: (1) all individuals; (2) individuals age 18 and over; (3) women ages 15-44; and (4) children age 14 and under. Three kinds of estimated fish consumption rates are provided: (1) per capita rates (i.e., rates based on consumers and nonconsumers of fish from the survey period– refer to the TSD for further discussion); (2) consumers-only rates (i.e., rates based on respondents who reported consuming finfish or shellfish during the two-day reporting period); and (3) per capita consumption by body weight (i.e., per capita rates reported as milligrams of fish per kilogram of body weight per day).

EPA's fourth preference is that States and authorized Tribes use as fish intake assumptions the following default rates, based on the 1994-96 CSFII data, that EPA believes are representative of fish intake for different population groups: 17.5 grams/day for the general adult population and sport fishers, and 142.4 grams/day for subsistence fishers. These are risk management decisions that EPA has made after evaluating numerous fish intake surveys. These values represent the uncooked weight intake of freshwater/estuarine finfish and shellfish. As with the other preferences, EPA requests that States and authorized Tribes routinely consider whether there is a substantial population of sport fishers or subsistence fishers when developing site-specific estimates, rather than automatically basing them on the typical individual. Because the combined 1994-96 CSFII survey is national in scope, EPA will use the results from this survey to estimate fish intake for deriving national criteria. EPA has recognized the data gaps and uncertainties associated with the analysis of the 1994-96 CSFII survey in the process of making its default recommendations. The estimated mean of freshwater and estuarine fish ingestion for adults is 7.50 grams/day, and the median is 0 grams/day. The estimated 90^{th}

percentile is 17.53 grams/day; the estimated 95th percentile is 49.59 grams/day; and the estimated 99th percentile is 142.41 grams/day. The median value of 0 grams/day may reflect the portion of individuals in the population who never eat fish as well as the limited reporting period (2 days) over which intake was measured. By applying as a default 17.5 grams/day for the general adult population, EPA intends to select an intake rate that is protective of a majority of the population (again, the 90th percentile of consumers and nonconsumers according to the 1994-96 CSFII survey data). Trophic level breakouts are: TL2 = 3.8 grams/day; TL3 = 8.0 grams/day; and TL4 = 5.7 grams/day. EPA further considers 17.5 grams/day to be indicative of the average consumption among sport fishers based on averages in the studies reviewed, which are presented in the Exposure Assessment TSD. Similarly, EPA believes that the assumption of 142.4 grams/day is within the range of average consumption estimates for subsistence fishers based on the studies reviewed. Experts at the 1992 National Workshop that initiated the effort to revise this Methodology acknowledged that the national survey high-end values are representative of average rates for highly exposed groups such as subsistence fishermen, specific ethnic groups, or other highly exposed people. EPA is aware that some local and regional studies indicate greater consumption among Native American, Pacific Asian American, and other subsistence consumers, and recommends the use of those studies in appropriate cases, as indicated by the first and second preferences. Again, States and authorized Tribes have the flexibility to choose intake rates higher than an average value for these population groups. If a State or authorized Tribe has not identified a separate well-defined population of high-end consumers and believes that the national data from the 1994-96 CSFII are representative, they may choose these recommended rates.

As indicated above, the default intake values are based on the uncooked weights of the fish analyzed. There has been some question regarding whether to use cooked or uncooked weights of fish intake for deriving the AWQC. Studies show that, typically, with a filet or steak of fish, the weight loss in cooking is about 20 percent; that is, the uncooked weight is approximately 20 percent higher (Jacobs et al., 1998). This obviously means that using uncooked weights results in a slightly higher intake rate and slightly more stringent AWQC. In researching consumption surveys for this proposal, EPA has found that some surveys have reported rates for cooked fish, others have reported uncooked rates, and many more are unclear as to whether cooked or uncooked rates are used. The basis of the CSFII survey was prepared or *as consumed* intakes; that is, the survey respondents estimated the weight of fish that they consumed. This was also true with the GLI (which was specifically based on studies describing consumption rates of cooked fish) and, by and large, cooked fish is what people consume. However, EPA's *Guidance For Assessing Chemical Contaminant Data For Use In Fish Advisories* recommends analysis and advisories based on uncooked fish (USEPA, 1997a). EPA considered the potential confusion over the fact that the uncooked weights are used in the fish advisory program. Further, the measures of a contaminant in fish tissue samples that are applicable to compliance monitoring and the permitting program are related to the uncooked weights. The choice of intakes is also complicated by factors such as the effect of the cooking process, the different parts of a fish where a chemical may accumulate, and the method of preparation.

After considering all of the above (in addition to public input received), EPA will derive its national default criteria based on the uncooked weight fish intakes. The Exposure

Assessment TSD provides additional guidance on site-specific modifications. Specifically, an alternate approach is described for calculating AWQC with the *as consumed* weight–which is more directly associated with human exposure and risk–and then adjusting the value by the approximate 20 percent loss to an uncooked equivalent (thereby representing the same relative risk as the *as consumed* value). This approach results in a different AWQC value (than using the uncooked weights) and represents a more direct translation of the *as consumed* risk to the uncooked equivalent. However, EPA understands that it is more scientifically rigorous and may be too intensive of a process for States and Tribes to rely on. The option is presented in the TSD to offer States and authorized Tribes greater flexibility with their water quality standards program.

The default fish intake values also reflect specific designations of species classified in accordance with information regarding the life history of the species or based on landings information form the National Marine Fisheries Service. Most significantly, salmon has been reclassified from a freshwater/estuarine species to a marine species. As marine harvested salmon represents approximately 99 percent of salmon consumption in the 1994-96 CSFII Survey, removal reduces the overall fresh/estuarine fish consumption rate by 13 percent. Although they represent a very small percentage of freshwater/estuarine intake, land-locked and farm-raised salmon consumed by 1994-96 CSFII respondents are still included. The rationale for the default intake species designations is explained in the Exposure Assessment TSD. Once again, EPA emphasizes the flexibility for States and authorized Tribes to use alternative assumptions based on local or regional data to better represent their population groups of concern.

4.3.3.2 Rates Protective of Developmental Human Health Effects

Exposures resulting in health effects in children or developmental effects in fetuses may be of primary concern. As discussed at the beginning of this section on exposure factors used, in a situation where acute or sub-chronic toxicity and exposure are the basis of an RfD (or POD/UF), EPA will consider basing its national default criteria on children or women of childbearing age, depending on the target population at greatest risk. EPA recommends that States and authorized Tribes use exposure factors for children or women of childbearing age in these situations. As stated previously, EPA is not recommending the development of additional AWQC but is acknowledging that basing a criterion on these population groups is a potential course of action and is, therefore, recommending the following default intake rates for such situations.

EPA's preferences for States and authorized Tribes in selecting values for intake rates relevant for children is the same as that discussed above for establishing values for average daily consumption rates for chronic effects; i.e., in decreasing order of preference, results from fish intake surveys of local watersheds, results from existing fish intake surveys that reflect similar geography and population groups, the distribution of intake rates from nationally based surveys (e.g., the CSFII), or lastly, the EPA default rates. When an RfD is based on health effects in children, EPA recommends a default intake rate of 156.3 grams/day for assessing those contaminants that exhibit adverse effects. This represents the 90th percentile consumption rate for actual consumers of freshwater/estuarine finfish and shellfish for children ages 14 and under using the combined 1994 to 1996 results from the CSFII survey. The value was calculated based

on data for only those children who ate fish during the 2-day survey period, and the intake was averaged over the number of days during which fish was actually consumed. EPA believes that by selecting the data for consumers only, the 90th percentile is a reasonable intake rate to approximate consumption of fresh/estuarine finfish and shellfish within a short period of time for use in assessments where adverse effects in children are of primary concern. As discussed previously, EPA will use a default body weight of 30 kg to address potential acute or subchronic effects from fish consumption by children. EPA is also providing these default intake values for States and authorized Tribes that choose to provide additional protection when developing criteria that they believe should be based on health effects in children. This is consistent with the rationale in the recent GLI (USEPA, 1995) and is an approach that EPA believes is reasonable. Distributional information on intake values relevant for assessing exposure when health effects to children are of concern is presented in the Exposure Assessment TSD.

There are also cases in which pregnant women may be the population of most concern, due to the possibility of developmental effects that may result from exposures of the mother to toxicants. In these cases, fish intake rates specific to females of childbearing age are most appropriate when assessing exposures to developmental toxicants. When an RfD is based on developmental toxicity, EPA proposes a default intake rate of 165.5 grams/day for assessing exposures for women of childbearing age from contaminants that cause developmental effects. This is equivalent to the 90th percentile consumption rate for actual consumers of freshwater/ estuarine finfish and shellfish for women ages 15 to 44 using the combined 1994 to1996 results from the CSFII survey. As with the rate for children, this value represents only those women who ate fish during the 2-day survey period. As discussed previously, EPA will use a default body weight of 67 kg for women of childbearing age.

4.3.3.3 Rates Based on Combining Fish Intake and Body Weight

As with the drinking water intake values, EPA is providing values for fish intake based on a per unit body weight basis (in units of mg/kg) in the Exposure Assessment TSD. These rates use the self-reported body weights of the 1994-96 CSFII survey. Again, while EPA intends to derive or revise national default criteria on the separate intake values and body weights, the mg/kg-BW/day values are provided in the TSD for States or authorized Tribes that prefer their use.

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5. BIOACCUMULATION

5.1 INTRODUCTION

Aquatic organisms can accumulate certain chemicals in their bodies when exposed to these chemicals through water, their diet, and other sources. This process is called bioaccumulation. The magnitude of bioaccumulation by aquatic organisms varies widely depending on the chemical but can be extremely high for some highly persistent and hydrophobic chemicals. For such highly bioaccumulative chemicals, concentrations in aquatic organisms may pose unacceptable human health risks from fish and shellfish consumption even when concentrations in water are too low to cause unacceptable health risks from drinking water consumption alone. These chemicals may also biomagnify in aquatic food webs, a process whereby chemical concentrations increase in aquatic organisms of each successive trophic level due to increasing dietary exposures (e.g., increasing concentrations from algae, to zooplankton, to forage fish, to predatory fish).

In order to prevent harmful exposures to waterborne chemicals through the consumption of contaminated fish and shellfish, national 304(a) water quality criteria for the protection of human health must address the process of chemical bioaccumulation in aquatic organisms. For deriving national 304(a) criteria to protect human health, EPA accounts for potential bioaccumulation of chemicals in fish and shellfish through the use of national bioaccumulation factors (BAFs). A national BAF is a ratio (in L/kg) that relates the concentration of a chemical in water to its expected concentration in commonly consumed aquatic organisms in a specified trophic level. An illustration of how national BAFs are used in the derivation of 304(a) criteria for carcinogens using linear low-dose extrapolation is shown in the following equation:

$$AWQC = RSD \bullet \left(\frac{BW}{DI + \sum_{i=2}^{4} (FI_i \bullet BAF_i)} \right) \qquad \text{(Equation 5-1)}$$

where:

RSD	=	Risk specific dose (mg/kg-day)
BW	=	Human body weight (kg)
DI	=	Drinking water intake (L/day)
FI_i	=	Fish intake at trophic level I, where I=2, 3, and 4;
BAF_i	=	National bioaccumulation factor at trophic level I, where I=2, 3, and 4

The purpose of this chapter is to present EPA's recommended methodology for deriving national bioaccumulation factors for setting national 304(a) water quality criteria to protect human health. A detailed scientific basis of the recommended national BAF methodology is provided in the Bioaccumulation TSD. While the methodology detailed in this chapter is

intended to be used by EPA for deriving national BAFs, EPA encourages States and authorized Tribes to derive BAFs that are specific to certain regions or waterbodies, where appropriate. Guidance to States and authorized Tribes for deriving site-specific BAFs is provided in the Biaccumulation TSD.

5.1.1 Important Bioaccumulation and Bioconcentration Concepts

Several attributes of the bioaccumulation process are important to understand when deriving national BAFs for use in setting national 304(a) criteria. First, the term "bioaccumulation" refers to the uptake and retention of a chemical by an aquatic organism from all surrounding media (e.g., water, food, sediment). The term "bioconcentration" refers to the uptake and retention of a chemical by an aquatic organism from water only. For some chemicals (particularly those that are highly persistent and hydrophobic), the magnitude of bioaccumulation by aquatic organisms can be substantially greater than the magnitude of bioconcentration. Thus, an assessment of bioconcentration alone would underestimate the extent of accumulation in aquatic biota for these chemicals. Accordingly, EPA's guidelines presented in this chapter emphasize the measurement of chemical bioaccumulation by aquatic organisms, whereas EPA's 1980 Methodology emphasized the measurement of bioconcentration.

Another noteworthy aspect of bioaccumulation process is the issue of steady-state conditions. Specifically, both bioaccumulation and bioconcentration can be viewed simply as the result of competing rates of chemical uptake and depuration (chemical loss) by an aquatic organism. The rates of chemical uptake and depuration can be affected by various factors including the properties of the chemical, the physiology of the organism in question, water quality and other environmental conditions, ecological characteristics of the waterbody (e.g., food web structure), and the concentration and loadings history of the chemical. When the rates of chemical uptake and depuration are equal, tissue concentrations remain constant over time and the distribution of the chemical between the organism and its source(s) is said to be at steady-state. For constant chemical exposures and other conditions, the steady-state concentration in the organism represents the highest accumulation potential of the chemical in that organism under those conditions. The time required for a chemical to achieve steady state has been shown to vary according to the properties of the chemical and other factors. For example, some highly hydrophobic chemicals can require long periods of time to reach steady state between environmental compartments (e.g., many months), while highly hydrophilic chemicals usually reach steady-state relatively quickly (e.g., hours to days).

Since national 304(a) criteria for the protection of human health are typically designed to protect humans from harmful lifetime or long-term exposures to waterborne contaminants, the assessment of bioaccumulation that equals or approximates steady-state accumulation is one of the principles underlying the derivation of national BAFs. For some chemicals that require relatively long periods of time to reach steady-state in tissues of aquatic organisms, changes in water column concentrations may occur on a much more rapid time scale compared to the corresponding changes in tissue concentrations. Thus, if the system departs substantially from steady-state conditions and water concentrations are not averaged over a sufficient time period, the ratio of the tissue concentration to a water concentration may have little resemblance to the steady-state ratio and have little predictive value of long-term bioaccumulation potential.

Therefore, BAF measurements should be based on water column concentrations which are averaged over a sufficient period of time (e.g., a duration comparable to the time required for the chemical to reach steady-state). In addition, BAF measurements should be based on adequate spatial averaging of both tissue and water column concentrations for use in deriving 304(a) criteria for the protection of human health.

For this reason, a BAF is defined in this Methodology as representing the ratio (in L/kg-tissue) of a concentration of a chemical in tissue to its concentration in the surrounding water in situations where the organism and its food are exposed and the ratio does not change substantially over time (i.e., the ratio which reflects bioaccumulation at or near steady-state). A bioconcentration factor (BCF) is the ratio (in L/kg-tissue) of the concentration of a substance in tissue of an aquatic organism to its concentration in the ambient water, in situations where the organism is exposed through the water only and the ratio does not change substantially over time.

5.1.2 Goal of the National BAF

The goal of EPA's national BAF is to represent the long-term, average bioaccumulation potential of a chemical in edible tissues of aquatic organisms that are commonly consumed by humans throughout the United States. National BAFs are not intended to reflect fluctuations in bioaccumulation over short time periods (e.g., a few days) because 304(a) human health criteria are generally designed to protect humans from long-term exposures to waterborne chemicals. National BAFs are also intended to account for some major chemical, biological, and ecological attributes that can affect bioaccumulation in bodies of water across the United States. For example, separate procedures are provided for deriving national BAFs depending on the type of chemical (i.e., nonionic organic, ionic organic, inorganic and organometallic). In addition, EPA's national BAFs are derived separately for each trophic level to account for potential biomagnification of some chemicals in aquatic food webs and broad physiological differences between trophic levels that may influence bioaccumulation. Because lipid content of aquatic organisms and the amount of organic carbon in the water column have been shown to affect bioaccumulation of nonionic organic chemicals, EPA's national BAFs are adjusted to reflect the lipid content of commonly consumed fish and shellfish and the freely dissolved fraction of the chemical in ambient water for these chemicals.

5.1.3 Changes to the 1980 Methodology

Numerous scientific advances have occurred in the area of bioaccumulation since the publication of the 1980 Methodology for deriving AWQC for the protection of human health (USEPA, 1980). These advances have significantly increased our ability to assess and predict the bioaccumulation of chemicals in aquatic biota. As a result, EPA has revised the bioaccumulation portion of the 1980 Methodology to reflect the current state of the science and to improve accuracy in assessing bioaccumulation for setting 304(a) criteria for the protection of human health. The changes contained in the bioaccumulation portion of the 2000 Human Health Methodology are mostly designed to:

- Improve the ability to incorporate chemical exposure from sediments and aquatic food webs in assessing bioaccumulation potential,

- Expand the ability to account for site-specific factors which affect bioaccumulation, and

- Incorporate new data and assessment tools into the bioaccumulation assessment process.

A summary of the key changes that have been incorporated into the bioaccumulation portion of the 2000 Human Health Methodology and appropriate comparisons to the1980 Methodology are provided below.

5.1.3.1 Overall Approach

The 1980 Methodology for deriving 304(a) criteria for the protection of human health emphasized the assessment of bioconcentration (uptake from water only) through the use of the BCF. Based on the 1980 Methodology, measured BCFs were usually determined from laboratory data unless field data demonstrated consistently higher or lower accumulation compared with laboratory data. In these cases, "field BCFs" (currently termed field-measured BAFs) were recommended for use. For lipophilic chemicals where lab or field-measured data were unavailable, EPA recommended predicting BCFs from the octanol-water partition coefficient and the following equation from Veith et al. (1979): "log BCF = (0.85 log K_{ow}) - 0.70".

The 2000 Human Health Methodology revisions contained in this chapter emphasize the measurement of bioaccumulation (uptake from water, sediment, and diet) through the use of the BAF. Consistent with the 1980 Methodology, measured data are preferred over predictive approaches for determining the BAF (i.e., field-measured BAFs are generally preferred over predicted BAFs). However, the 2000 Human Health Methodology contains additional methods for deriving a national BAF that were not available in 1980. The preference for using the BAF methods also differs depending on the type and properties of the chemical. For example, the BAF derivation procedure differs for each of three broadly defined chemical categories: (1) nonionic organic, (2) ionic organic, and (3) inorganic and organometallic chemicals. Furthermore, within the category of nonionic organic chemicals, different procedures are used to derive the BAF depending on a chemicals' hydrophobicity and extent of chemical metabolism that would be expected to occur in aquatic biota.

5.1.3.2 Lipid Normalization

In the 1980 Methodology, BCFs for lipophilic chemicals were normalized by the lipid fraction in the tissue of fish and shellfish used to determine the BCF. Lipid normalization enabled BCFs to be averaged across tissues and organisms. Once the average lipid-normalized BCF was determined, it was adjusted by the consumption-weighted lipid content of commonly consumed aquatic organisms in the United States to obtain an overall consumption-weighted BCF. A similar procedure has been retained in the 2000 Human Health Methodology, whereby BAFs for nonionic organic chemicals are lipid normalized and adjusted by the consumption-weighted lipid content of commonly consumed organisms to obtain a BAF for criteria

calculations. However, the 2000 Human Health Methodology uses more up-to-date lipid data and consumption data for deriving the consumption-weighted BAFs.

5.1.3.3 Bioavailability

Bioconcentration factors derived according to the 1980 Methodology were based on the total concentration of the chemical in water, for both lipophilic and nonlipophilic chemicals. In the 2000 Human Health Methodology, BAFs for nonionic organic chemicals are derived using the most bioavailable fraction (i.e., the freely dissolved fraction) to account for the influence of particulate and dissolved organic carbon on a chemical's bioavailability. Such BAFs are then adjusted to reflect the expected bioavailability at the sites of interest (i.e., by adjusting for organic carbon concentrations at the sites of interest). Procedures for accounting for the effect of organic carbon on bioaccumulation were published previously by EPA under the Great Lakes Water Quality Initiative (GLWQI or GLI) rulemaking (USEPA, 1995a,b). Bioavailability is also considered in developing BAFs for the other chemical classes defined in the 2000 Human Health Methodology (e.g., ionic organics, inorganics/organometallics) but is done so on a chemical-by-chemical basis.

5.1.3.4 Trophic Level Considerations

In the 1980 Methodology, BCFs were determined and used for criteria derivation without explicit regard to the trophic level of the aquatic organism (e.g., benthic filter feeder, forage fish, predatory fish). Over the past two decades, much information has been assembled which demonstrates that an organism's trophic position in the aquatic food web can have an important effect on the magnitude of bioaccumulation of certain chemicals. In order to account for the variation in bioaccumulation that is due to trophic position of the organism, the 2000 Human Health Methodology recommends that BAFs be determined and applied on a trophic level-specific basis.

5.1.3.5 Site-Specific Adjustments

The 1980 Methodology contained little guidance for making adjustments to the national BCFs to reflect site- or region-specific conditions. The 2000 Human Health Methodology has greatly expanded the guidance to States and authorized Tribes for making adjustments to national BAFs to reflect local conditions. This guidance is contained in the Bioaccumulation TSD. In the Bioaccumulation TSD, guidance and data are provided for adjusting national BAFs to reflect the lipid content in locally consumed aquatic biota and the organic carbon content in the waterbodies of concern. This guidance also allows the use of appropriate bioaccumulation models for deriving site-specific BAFs. EPA also plans to publish detailed guidance on designing and conducting field bioaccumulation studies for measuring BAFs and biota-sediment accumulation factors (BSAFs). In general, EPA encourages States and authorized Tribes to make site-specific modifications to EPA's national BAFs provided such adjustments are scientifically defensible and adequately protect the designated use of the waterbody.

While the aforementioned revisions are new to EPA's Methodology for deriving national 304(a) criteria for the protection of human health, many of these refinements have been

incorporated in prior Agency guidance and regulations. For example, the use of food chain multipliers to account for the biomagnification of nonionic organic chemicals in aquatic food webs when measured data are unavailable was introduced by EPA in three documents*: Technical Support Document for Water Quality-Based Toxics Control* (USEPA, 1991), a draft document entitled *Assessment and Control of Bioconcentratable Contaminants in Surface Waters* (USEPA, 1993), and in the *Great Lakes Water Quality Initiative* (GLI) (USEPA, 1995b). Similarly, procedures for predicting BAFs using BSAFsand incorporating the effect of organic carbon on bioavailability were used to derive water quality criteria under the GLI.

5.1.4 Organization of This Section

The methodology for deriving national BAFs for use in deriving National 304(a) Human Health AWQC is provided in the following sections. Important terms used throughout this chapter are defined in Section 5.2. Section 5.3 provides an overview of the BAF derivation guidelines. Detailed procedures for deriving national BAFs are provided in Section 5.4 for nonionic organic chemicals, in Section 5.5 for ionic organic chemicals, and in Section 5.6 for inorganics and organometallic chemicals. Literature cited is provided in Section 5.7.

5.2 DEFINITIONS

The following terms and definitions are used throughout this chapter.

Bioaccumulation. The net accumulation of a substance by an organism as a result of uptake from all environmental sources.

Bioconcentration. The net accumulation of a substance by an aquatic organism as a result of uptake directly from the ambient water, through gill membranes or other external body surfaces.

Bioaccumulation Factor (BAF). The ratio (in L/kg-tissue) of the concentration of a substance in tissue to its concentration in the ambient water, in situations where both the organism and its food are exposed and the ratio does not change substantially over time. The BAF is calculated as:

$$BAF = \frac{C_t}{C_w} \qquad \text{(Equation 5-2)}$$

where:

C_t = Concentration of the chemical in the specified wet tissue
C_w = Concentration of chemical in water

Bioconcentration Factor (BCF). The ratio (in L/kg-tissue) of the concentration of a substance in tissue of an aquatic organism to its concentration in the ambient water, in situations where the organism is exposed through the water only and the ratio does not change substantially over time. The BCF is calculated as:

$$BCF = \frac{C_t}{C_w} \qquad \text{(Equation 5-3)}$$

where:

C_t = Concentration of the chemical in the specified wet tissue
C_w = Concentration of chemical in water

Baseline BAF (BAF_ℓ^{fd}). For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), a BAF (in L/kg-lipid) that is based on the concentration of freely dissolved chemical in the ambient water and the lipid normalized concentration in tissue.

Baseline BCF (BCF_ℓ^{fd}). For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), a BCF (in L/kg-lipid) that is based on the concentration of freely dissolved chemical in the ambient water and the lipid normalized concentration in tissue.

Biomagnification. The increase in tissue concentration of a chemical in organisms at successive trophic levels through a series of predator-prey associations, primarily through the mechanism of dietary accumulation.

Biomagnification Factor (BMF). The ratio (unitless) of the tissue concentration of a chemical in a predator at a particular trophic level to the tissue concentration in its prey at the next lower trophic level for a given waterbody and chemical exposure. For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), a BMF can be calculated using lipid-normalized concentrations in the tissue of organisms at two successive trophic levels as:

$$BMF_{(TL,\ n)} = \frac{C_{\ell\ (TL,\ n)}}{C_{\ell\ (TL,\ n-1)}} \qquad \text{(Equation 5-4)}$$

where:

$C_{\ell\ (TL,\ n)}$ = Lipid-normalized concentration in appropriate tissue of predator organism at a given trophic level (TL “n”)

$C_{\ell\ (TL,\ n-1)}$ = Lipid-normalized concentration in appropriate tissue of prey organism at the next lower trophic level from the predator (TL "n-1")

For inorganic, organometallic, and certain ionic organic chemicals where lipid and organic carbon partitioning does not apply, a BMF can be calculated using chemical concentrations in the tissue of organisms at two successive trophic levels as:

$$BMF_{(TL,\ n)} = \frac{C_{t\ (TL,\ n)}}{C_{t\ (TL,\ n-1)}} \qquad \text{(Equation 5-5)}$$

where:

$C_{t\ (TL,\ n)}$ = Concentration in appropriate tissue of predator organism at trophic level "n" (may be either wet weight or dry weight concentration so long as both the predator and prey concentrations are expressed in the same manner)

$C_{t\ (TL,\ n-1)}$ = Concentration in appropriate tissue of prey organism at the next lower trophic level from the predator (may be either wet weight or dry weight concentration so long as both the predator and prey concentrations are expressed in the same manner)

Biota-Sediment Accumulation Factor (BSAF). For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), the ratio of the lipid-normalized concentration of a substance in tissue of an aquatic organism to its organic carbon-normalized concentration in surface sediment (expressed as kg of sediment organic carbon per kg of lipid), in situations where the ratio does not change substantially over time, both the organism and its food are exposed, and the surface sediment is representative of average surface sediment in the vicinity of the organism. The BSAF is defined as:

$$BSAF = \frac{C_{\ell}}{C_{soc}} \qquad \text{(Equation 5-6)}$$

where:

C_{ℓ} = The lipid-normalized concentration of the chemical in tissues of the biota (µg/g lipid)

C_{soc} = The organic carbon-normalized concentration of the chemical in the surface sediment (µg/g sediment organic carbon)

Depuration. The loss of a substance from an organism as a result of any active or passive process.

Food Chain Multiplier (FCM). For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), the ratio of a baseline BAF_{ℓ}^{fd} for an organism of a particular trophic level to the baseline BCF_{ℓ}^{fd} (usually determined for organisms in trophic level one). For inorganic, organometallic, and certain ionic organic chemicals where lipid and organic carbon partitioning does not apply, a FCM is based on total (wet or dry weight) concentrations of the chemical in tissue.

Freely Dissolved Concentration. For nonionic organic chemicals, the concentration of the chemical that is dissolved in ambient water, excluding the portion sorbed onto particulate or dissolved organic carbon. The freely dissolved concentration is considered to represent the most bioavailable form of an organic chemical in water and, thus, is the form that best predicts bioaccumulation. The freely dissolved concentration can be determined as:

$$C_w^{fd} = (C_w^t) \cdot (f_{fd}) \qquad \text{(Equation 5-7)}$$

where:

C_w^{fd}	=	Freely dissolved concentration of the organic chemical in ambient water
C_w^t	=	Total concentration of the organic chemical in ambient water
f_{fd}	=	Fraction of the total chemical in ambient water that is freely dissolved

Hydrophilic. A term that refers to the extent to which a chemical is attracted to partitioning into the water phase. Hydrophilic organic chemicals have a greater tendency to partition into polar phases (e.g., water) compared to chemicals of hydrophobic chemicals.

Hydrophobic. A term that refers to the extent to which a chemical avoids partitioning into the water phase. Highly hydrophobic organic chemicals have a greater tendency to partition into nonpolar phases (e.g., lipid, organic carbon) compared with chemicals of lower hydrophobicity.

Lipid-normalized Concentration (C_{ℓ}). The total concentration of a contaminant in a tissue or whole organism divided by the lipid fraction in that tissue or whole organism. The lipid-normalized concentration can be calculated as:

$$C_{\ell} = \frac{C_t}{f_{\ell}} \qquad \text{(Equation 5-8)}$$

where:

C_t	=	Concentration of the chemical in the wet tissue (either whole organism or specified tissue)

f_ℓ = Fraction lipid content in the organism or specified tissue

Octanol-water Partition Coefficient (K_{ow}). The ratio of the concentration of a substance in the n-octanol phase to its concentration in the aqueous phase in an equilibrated two-phase octanol-water system. For log K_{ow}, the log of the octanol-water partition coefficient is a base 10 logarithm.

Organic Carbon-normalized Concentration (C_{soc}). For sediments, the total concentration of a contaminant in sediment divided by the fraction of organic carbon in sediment. The organic carbon-normalized concentration can be calculated as:

$$C_{soc} = \frac{C_s}{f_{oc}} \qquad \text{(Equation 5-9)}$$

where:

C_s = Concentration of chemical in sediment
f_{oc} = Fraction organic carbon in sediment

Uptake. Acquisition by an organism of a substance from the environment as a result of any active or passive process.

5.3 FRAMEWORK FOR DETERMINING NATIONAL BIOACCUMULATION FACTORS

5.3.1 Four Different Methods

Bioaccumulation factors used to derive national BAFs can be measured or predicted using some or all of the following four methods, depending on the type of chemical and its properties. These methods are:

(1) a measured BAF obtained from a field study (i.e., a field-measured BAF);

(2) a BAF predicted from a field-measured BSAF;

(3) a BAF predicted from a laboratory-measured BCF (with or without adjustment by an FCM); and

(4) a BAF predicted from a chemical's octanol-water partition coefficient (K_{ow}), with or without adjustment using an FCM.

A brief summary of each of the four methods is provided below. Additional details on the use of these four methods is provided in Section 5.4 (for nonionic organics), Section 5.5 (for ionic organics) and Section 5.6 (for inorganics and organometallics).

1. **Field-Measured BAF.** Use of a field-measured BAF, which is the most direct measure of bioaccumulation, is the only method that can be used to derive a national BAF for all types of chemicals (i.e., nonionic organic, ionic organic, and inorganic and organometallic chemicals). A field-measured BAF is determined from a field study using measured chemical concentrations in the aquatic organism and its surrounding water. Because field studies are conducted in natural aquatic ecosystems, a field-measured BAF reflects an organism's exposure to a chemical through all relevant exposure pathways (i.e., water, sediment, and diet). A field-measured BAF also reflects any metabolism of a chemical that might occur in the aquatic organism or its food web. Therefore, field-measured BAFs are appropriate for all chemicals, regardless of the extent of chemical metabolism in biota.

2. **Field-measured BSAF.** For nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies), a BAF can also be predicted from BSAFs. A BSAF is similar to a field-measured BAF in that the concentration of a chemical in biota is measured in the field and reflects an organism's exposure to all relevant exposure routes. A BSAF also reflects any chemical metabolism that might occur in the aquatic organism or its food web. However, unlike a field-measured BAF which references the biota concentration to the water concentration, a BSAF references the biota concentration to the sediment concentration. Use of the BSAF procedure is restricted to organic chemicals which are classified as being moderately to highly hydrophobic.

3. **Lab-measured BCF.** A laboratory-measured BCF can also be used to estimate a BAF for organic and inorganic chemicals. However, unlike a field-measured BAF or a BAF predicted from a field-measured BSAF, a laboratory-measured BCF only reflects the accumulation of chemical through the water exposure route. Laboratory-measured BCFs may therefore under estimate BAFs for chemicals where accumulation from sediment or dietary sources is important. In these cases, laboratory-measured BCFs can be multiplied by a FCM to reflect accumulation from non-aqueous (i.e., food chain) pathways of exposure. Since a laboratory-measured BCF is determined using the measured concentration of a chemical in an aquatic organism and its surrounding water, a laboratory-measured BCF reflects any metabolism of the chemical that occurs in the organism, but not in the food web.

4. **K_{ow}.** A chemical's octanol-water partition coefficient, or K_{ow}, can also be used to predict a BAF for nonionic organic chemicals. This procedure is appropriate only for nonionic organic chemicals (and certain ionic organic chemicals where similar lipid and organic carbon partitioning behavior applies). The K_{ow} has been extensively correlated with the BCF for nonionic organic chemicals that are poorly metabolized by aquatic organisms. Therefore, where substantial metabolism is known to occur in biota, the K_{ow} is not used

to predict the BAF. For nonionic organic chemicals where chemical exposure through the food web is important, use of the K_{ow} alone will under predict the BAF. In such cases, the K_{ow} is adjusted with a FCM similar to the BCF procedure above.

5.3.2 Overview of BAF Derivation Framework

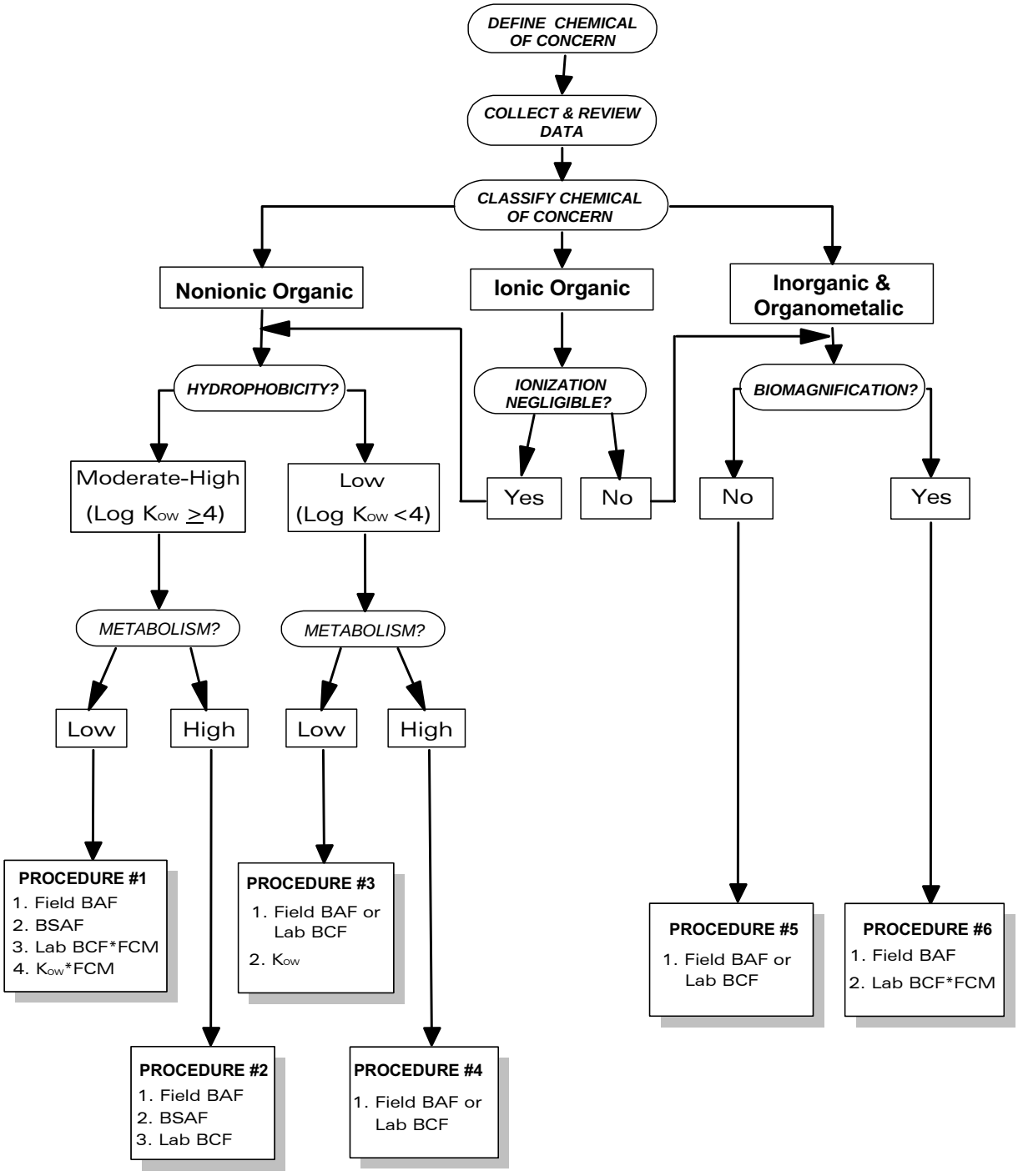
Although up to four methods can be used to derive a BAF as described in the previous section, it is evident that these methods do not apply equally to all types of chemicals. In addition, experience demonstrates that the required data will usually not be available to derive a BAF value using all of the applicable methods. As a result, EPA has developed the following guidelines to direct users in selecting the most appropriate method(s) for deriving a national BAF.

Figure 5-1 shows the overall framework of EPA's national BAF methodology. This framework illustrates the major steps and decisions that will ultimately lead to calculating a national BAF using one of six hierarchical procedures shown at the bottom of Figure 5-1. Each procedure contains a hierarchy of the BAF derivation methods discussed above, the composition of which depends on the chemical type and certain chemical properties (e.g., its degree of hydrophobicity and expected degree of metabolism and biomagnification). The number assigned to each BAF method within a procedure indicates its general order of preference for deriving a national BAF value. The goal of the framework and accompanying guidelines is to enable full use of available data and methods for deriving a national BAF value while appropriately restricting the use of certain methods to reflect their inherent limitations.

The first step in the framework is to define the chemical of concern. As described in Section 5.3.3, the chemical used to derive the national BAF should be consistent with the chemical used to derive the critical health assessment value. The second step is to collect and review all relevant data on bioconcentration and bioaccumulation of the chemical of concern (see Section 5.3.4). Once pertinent data are reviewed, the third step is to classify the chemical of concern into one of three broadly defined chemical categories: (1) nonionic organic chemicals, (2) ionic organic chemicals, and (3) and inorganic and organometallic chemicals. Guidance for classifying chemicals into these three categories is provided in Section 5.3.5.

After a chemical has been classified into one of the three categories, other information is used to select one of six hierarchical procedures to derive the national BAF. The specific procedures for deriving a BAF for each chemical group are discussed in Section 5.4 for nonionic organics, Section 5.5 for ionic organics, and Section 5.6 for inorganics and organometallics.

Figure 5-1. Framework for Deriving a National BAF



Detailed guidance concerning the first three steps of the derivation process (i.e, defining the chemical of concern, collecting and reviewing data, and classifying the chemical of concern) is provided in the following three sections.

5.3.3 Defining the Chemical of Concern

Defining the chemical of concern is the first step in deriving a national BAF. This step involves precisely defining the form(s) of the chemical upon which the national BAF value will be derived. Although this step is usually straightforward for single chemicals, complications can arise when the chemical of concern occurs as a mixture. The following guidelines should be followed for defining the chemical of concern.

1. Information for defining the chemical of concern should be obtained from the health and exposure assessment portions of the criteria derivation effort. The chemical(s) used to derive the national BAF should be consistent with the chemical(s) used to derive the reference dose (RfD), point of departure/uncertainty factor (POD/UF), or cancer potency factor.

2. In most cases, the RfD, POD/UF, or cancer potency factor will be based on a single chemical. In some cases, the RfD, POD/UF, or cancer potency factor will be based on a mixture of compounds, typically within the same chemical class (e.g., toxaphene, chlordane). In these situations, the national BAF should be derived in a manner that is consistent with the mixture used to express the health assessment.

    a. If sufficient data are available to reliably assess the bioaccumulation of each relevant compound contained in the mixture, then the national BAF(s) should be derived using the BAFs for the individual compounds of the mixture and appropriately weighted to reflect the mixture composition used to establish the RfD, POD/UF, or cancer potency factor. An example of this approach is shown in the derivation of BAFs for PCBs in the GLI Rulemaking (USEPA, 1997).

    b. If sufficient data are not available to reliably assess the bioaccumulation of individual compounds of the mixture, then the national BAF(s) should be derived using BAFs for the same or appropriately similar chemical mixture as that used to establish the RfD, POD/UF, or cancer potency value.

5.3.4 Collecting and Reviewing Data

The second step in deriving a national BAF is to collect and review all relevant bioaccumulation data for the chemical of concern. The following guidance should be followed for collecting and reviewing bioaccumulation data for deriving national BAFs.

1. All data on the occurrence and accumulation of the chemical of concern in aquatic animals and plants should be collected and reviewed for adequacy.

2. A comprehensive literature search strategy should be used for gathering bioaccumulation-related data. An example of a comprehensive literature search strategy is provided in the Bioaccumulation TSD.

3. All data that are used should contain sufficient supporting information to indicate that acceptable measurement procedures were used and that the results are probably reliable. In some cases it may be appropriate to obtain additional written information from the investigator.

4. Questionable data, whether published or unpublished, should not be used. Guidance for assessing the acceptability of bioaccumulation and bioconcentration studies is found in Sections 5.4, 5.5, and 5.6.

5.3.5 Classifying the Chemical of Concern

The next step in deriving a national BAF consists of classifying the chemical of concern into one of three categories: nonionic organic, ionic organic, and inorganic and organometallic (Figure 5-1). This step helps to determine which of the four methods described in Section 5.3.1 are appropriate for deriving BAFs. The following guidance applies for classifying the chemical of concern.

1. **Nonionic Organic Chemicals.** For the purposes of the 2000 Human Health Methodology, nonionic organic chemicals are those organic compounds that do not ionize substantially in natural bodies of water. These chemicals are also referred to as neutral or nonpolar organics in the scientific literature. Due to their neutrality, nonionic organic chemicals tend to associate with other neutral (or near neutral) compartments in aquatic ecosystems (e.g., lipid, organic carbon). Examples of nonionic organic chemicals which have been widely studied in terms of their bioaccumulation include polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and furans, many chlorinated pesticides, and polynuclear aromatic hydrocarbons (PAHs). Procedures for deriving a national BAF for nonionic organic chemicals are provided in Section 5.4.

2. **Ionic Organic Chemicals.** For the purposes of the 2000 Human Health Methodology, ionic organic chemicals are considered to include those chemicals that contain functional groups with exchangeable protons such as hydroxyl, carboxylic, and sulfonic groups and functional groups that readily accept protons such as amino and aromatic heterocyclic nitrogen (pyridine) groups. Ionic organic chemicals undergo ionization in water, the extent of which depends on pH and the pKa of the chemical. Because the ionized species of these chemicals behave differently from the neutral species, separate guidance is provided for deriving BAFs for ionic organic chemicals. Procedures for deriving national BAFs for ionic organic chemicals are provided in Section 5.5.

3. **Inorganic and Organometallic Chemicals.** The inorganic and organometallic category is considered to include inorganic minerals, other inorganic compounds and elements, metals (e.g., copper, cadmium, chromium, zinc), metalloids (selenium, arsenic) and

organometallic compounds (e.g., methylmercury, tributyltin, tetraalkyllead). Procedures for deriving BAFs for inorganic and organometallic chemicals are provided in Section 5.6.

5.4 NATIONAL BIOACCUMULATION FACTORS FOR NONIONIC ORGANIC CHEMICALS

5.4.1 Overview

This section contains the methodology for deriving national BAFs for nonionic organic chemicals as defined in Section 5.3.5. The four general steps of this methodology are:

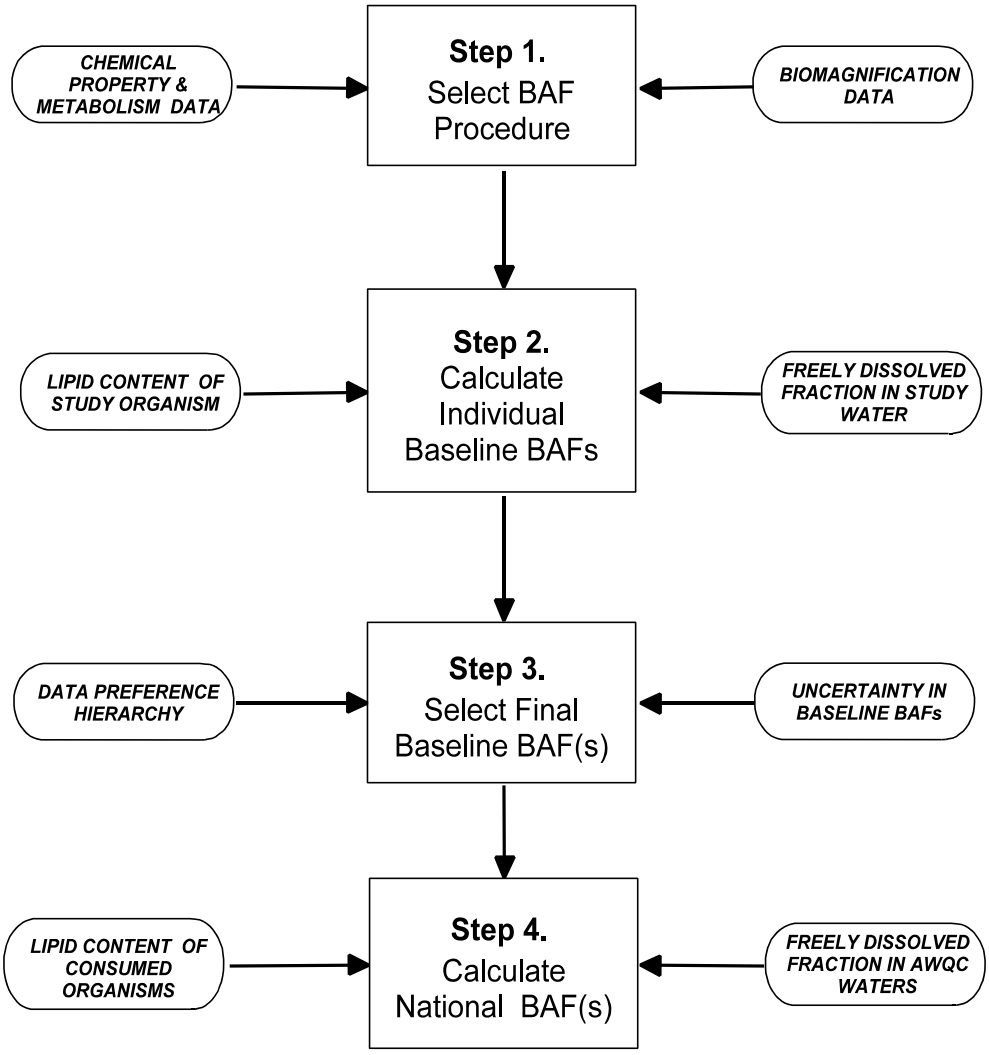
1. Selecting the BAF derivation procedure,
2. Calculating individual baseline BAF_{ℓ}^{fd}s,
3. Selecting the final baseline BAF_{ℓ}^{fd}s, and
4. Calculating the national BAFs from the final baseline BAF_{ℓ}^{fd}s.

A schematic of this four-step process is shown in Figure 5-2.

Step 1 of the methodology (selecting the BAF derivation procedure) determines which of the four BAF procedures summarized in Figure 5-1 will be appropriate for deriving the national BAF. Step 2 involves calculating individual, species-specific BAF_{ℓ}^{fd}s using all of the methods available within the selected BAF derivation procedure. Calculating the individual baseline BAF_{ℓ}^{fd}s involves using data from the field site or laboratory where the original data were collected to account for site-specific factors which affect the bioavailability of the chemical to aquatic organisms (e.g., lipid content of study organisms and freely dissolved concentration in study water). Step 3 of the methodology consists of selecting the final baseline BAF_{ℓ}^{fd}s from the individual baseline BAF_{ℓ}^{fd}s by taking into account the uncertainty in the individual BAFs and the data preference hierarchy selected in Step 1. The final step is to calculate a BAF (or BAFs) that will be used in the derivation of 304(a) criteria (i.e., referred to as the national BAF). This step involves adjusting the final baseline BAF_{ℓ}^{fd}(s) to reflect certain factors that affect bioavailablity of the chemical to aquatic organisms in waters to which the national 304(a) criteria will apply (e.g., the freely dissolved fraction expected in U.S. waters and the lipid content of consumed aquatic organisms). Baseline BAF_{ℓ}^{fd}s are not used directly in the derivation of the 304(a) criteria because they do not reflect the conditions that affect bioavailability in U.S. waters.

Section 5.4.2 below provides detailed guidance for selecting the appropriate BAF derivation procedure (Step 1 of the process). Guidance on calculating individual baseline BAF_{ℓ}^{fd}s, selecting the final baseline BAF, and calculating the national BAF (Steps 2 through 4 of the process) is provided in separate sections under each of the four BAF derivation procedures.

Figure 5-2. BAF Derivation for Nonionic Organic Chemicals



5.4.2 Selecting the BAF Derivation Procedure

This section describes the decisions that should be made to select one of the four available hierarchical procedures for deriving a national BAF for nonionic organic chemicals (Procedures #1 through #4 of Figure 5-1). As shown in Figure 5-1, two decision points exist in selecting the BAF derivation procedure. The first decision point requires knowledge of the chemical's hydrophobicity (i.e., the K_{ow} of the chemical). Guidance for selecting the K_{ow} for a chemical is provided in the Bioaccumulation TSD. The K_{ow} provides an initial basis for assessing whether biomagnification may be a concern for nonionic organic chemicals. The second decision point is based on the rate of metabolism for the chemical in the target organism. Guidance for assessing whether a high or low rate of metabolism is likely for a chemical of concern is provided below in Section 5.4.2.3. With the appropriate information for these two decision points, the BAF derivation procedure should be selected using the following guidelines.

5.4.2.1 <u>Chemicals with Moderate to High Hydrophobicity</u>

1. For the purposes of the 2000 Human Health Methodology, nonionic organic chemicals with log K_{ow} values equal to or greater than 4.0 should be classified as moderately to highly hydrophobic. For moderately to highly hydrophobic nonionic organic chemicals, available data indicate that exposure through the diet and other non-aqueous routes can become important in determining chemical residues in aquatic organisms (e.g., Russell et al., 1999; Fisk et al., 1998; Oliver and Niimi, 1983; Oliver and Niimi, 1988; Niimi, 1985; Swackhammer and Hites, 1988). Dietary and other non-aqueous exposure can become extremely important for those nonionic organic chemicals that are poorly metabolized by aquatic biota (e.g., certain PCB congeners, chlorinated pesticides, and polychlorinated dibenzo-p-dioxins and furans).

2. **Procedure #1** should be used to derive national BAFs for moderately to highly hydrophobic nonionic organic chemicals in cases where:

   (a) the rate of chemical metabolism by target aquatic organisms is expected to be sufficiently low such that biomagnification is of concern, or

   (b) the rate of chemical metabolism by target aquatic organisms is not sufficiently known.

   Procedure #1 accounts for non-aqueous exposure and the potential for biomagnification in aquatic food webs through the use of field-measured values for bioaccumulation (i.e., field measured BAF or BSAF) and FCMs when appropriate field data are unavailable. Guidance on deriving national BAFs using Procedure #1 is found below in Section 5.4.3.

3. **Procedure #2** should be used to derive the national BAFs for moderately to highly hydrophobic nonionic organic chemicals in cases where:

   (a) the rate of chemical metabolism by target aquatic organisms is expected to be sufficiently high such that biomagnification is not of concern.

Procedure #2 relaxes the requirement of using FCMs and eliminates the use of K_{ow}-based estimates of the BAF, two procedures that are most appropriate for poorly metabolized nonionic organic chemicals. Guidance on deriving national BAFs using Procedure #2 is found below in Section 5.4.4.

5.4.2.2 Chemicals with Low Hydrophobicity

1. For the purposes of these guidelines, nonionic organic chemicals with log K_{ow} values less than 4.0 should be classified as exhibiting low hydrophobicity. For nonionic organic chemicals that exhibit low hydrophobicity (i.e., log $K_{ow} < 4.0$), available information indicates that non-aqueous exposure to these chemicals is not likely to be important in determining chemical residues in aquatic organisms (e.g., Fisk et al., 1998; Gobas et al., 1993; Connolly and Pedersen, 1988; Thomann, 1989). For this group of chemicals, laboratory-measured BCFs and K_{ow}-predicted BCFs do not require adjustment with FCMs for determining the national BAF (Procedures #3 and #4), unless other appropriate data indicate differently.

   Other appropriate data include studies clearly indicating that non-aqueous exposure is important such that use of a BCF would substantially underestimate residues in aquatic organisms. In these cases, Procedure #1 should be used to derive the BAF for nonionic organic chemicals with log $K_{ow} < 4.0$. Furthermore, the data supporting the K_{ow} determination should be carefully reviewed for accuracy and appropriate interpretation, since the apparent discrepancy may be due to errors in determining K_{ow}.

2. **Procedure #3** should be used to derive national BAFs for nonionic organic chemicals of low hydrophobicity in cases where:

   (a) the rate of chemical metabolism by target aquatic organisms is expected to be negligible, such that tissue residues of the chemical of concern are not substantially reduced compared to an assumption of no metabolism, or

   (b) the rate of chemical metabolism by target aquatic organisms is not sufficiently known.

   Procedure #3 includes the use of K_{ow}-based estimates of the BCF to be used when lab or field data are absent. Guidance on deriving national BAFs using Procedure #3 is found below in Section 5.4.5.

3. **Procedure #4** should be used to derive national BAFs for nonionic organic chemicals of low hydrophobicity in cases where:

   (a) the rate of chemical metabolism by target aquatic organisms is expected to be sufficiently high, such that tissue residues of the chemical of concern are substantially reduced compared with an assumption of no metabolism.

Procedure #4 eliminates the option of using K_{ow}-based estimates of the BAF because the K_{ow} may over-predict accumulation when a chemical is metabolized substantially by an aquatic organism. Guidance on deriving national BAFs using Procedure #4 is found below in Section 5.4.6.

5.4.2.3 Assessing Metabolism

Currently, assessing the degree to which a chemical is metabolized by aquatic organisms is confounded by a variety of factors. First, conclusive data on chemical metabolism in aquatic biota are largely lacking. Such data include whole organism studies where the metabolic rates and breakdown products are quantified in fish and other aquatic organisms relevant to human consumption. However, the majority of information on metabolism is derived from *in vitro* liver microsomal preparations in which primary and secondary metabolites may be identified and their rates of formation may or may not be quantified. Extrapolating results from *in vitro* studies to the whole organism involves considerable uncertainty. Second, there are no generally accepted procedures for reliably predicting chemical metabolism by aquatic organisms in the absence of measured data. Third, the rate at which a chemical is metabolized by aquatic organisms can be species and temperature dependent. For example, PAHs are known to be metabolized readily by vertebrate aquatic species (primarily fish), although at rates much less than those observed for mammals. However, the degree of metabolism in invertebrate species is generally much less than the degree in vertebrate species (James, 1989). One hypothesis for this difference is that the invertebrate species lack the detoxifying enzymes and pathways that are present in many vertebrate species.

Given the current limitations on assessing the degree of chemical metabolism by aquatic organisms, the assessment of metabolism should be made on a case-by-case basis using a weight-of-evidence approach. When assessing a chemical's likelihood to undergo substantial metabolism in a target aquatic organism, the following data should be carefully evaluated:

(1) *in vivo* chemical metabolism data,
(2) bioconcentration and bioaccumulation data,
(3) data on chemical occurrence in target aquatic biota, and
(4) *in vitro* chemical metabolism data.

1. ***In vivo* Data.** *In vivo* data on metabolism in aquatic organisms are from studies of chemical metabolism using whole organisms. These studies are usually conducted using large fish from which blood, bile, urine, and individual tissues can be collected for the identification and quantification of metabolites formed over time. *In vivo* studies are considered the most useful for evaluating a chemical's degree of metabolism in an organism because both oxidative (Phase I) and conjugative (Phase II) metabolism can be assessed in these studies. Mass-balance studies, in which parent compound elimination is quantified separately from biotransformation and elimination of metabolites, allow calculation of conversion rate of parent to metabolite as well as metabolite elimination. This information might be used to estimate loss due to metabolism separately from that due to elimination of the parent compound for adjustment of K_{ow}-predicted BAFs. However, due to the analytical and experimental challenges these studies pose, data of

this type are limited. Less rigorous *in vivo* metabolism studies might include the use of metabolic blockers to demonstrate the influence of metabolism on parent compound kinetics. However, caution should be used in interpretation of absolute rates from these data due to the lack of specificity of mammalian derived blockers in aquatic species (Miranda et al., 1998).

2. **Bioconcentration or Bioaccumulation Data.** Data on chemical bioconcentration or bioaccumulation in aquatic organisms can be used indirectly for assessing metabolism. This assessment involves comparing acceptable lab-measured BCFs or field-measured BAFs (after converting to baseline values using procedures below) with the chemical's predicted value based on K_{ow}. The theoretical basis of bioconcentration and bioaccumulation for nonionic organic chemicals indicates that a chemical's baseline BCF should be similar to its K_{ow}-predicted value if metabolism is not occurring or is minimal (see the Bioaccumulation TSD). This theory also indicates that baseline BAFs should be similar to or higher than the K_{ow} for poorly metabolized organic chemicals, with highly hydrophobic chemicals often exhibiting higher baseline BAFs than K_{ow} values. Thus, if a chemical's baseline BCF or BAF is substantially lower than its K_{ow}, this may be an indication that the chemical is being metabolized by the aquatic organism of concern. Note, however, that this difference may also indicate problems in the experimental design or analytical chemistry, and that it may be difficult to discern the difference.

3. **Chemical Occurrence Data.** Although by no means definitive, data on the occurrence of chemicals in aquatic biota (i.e., residue studies) may offer another useful line of evidence for evaluating a chemical's likelihood to undergo substantial metabolism. Such studies are most useful if they have been conducted repeatedly over time and over wide geographical areas. Such studies might indicate a chemical is poorly metabolized if data show that the chemical is being biomagnified in the aquatic food web (i.e., higher lipid-normalized residues in successive trophic levels). Conversely, such studies might indicate a chemical is being metabolized substantially if residue data show a decline in residues with increasing trophic level. Again, other reasons for increases or decreases in concentrations with increasing trophic level might exist and should be carefully evaluated (e.g., incorrect food web assumptions, differences in exposure concentrations).

4. ***In vitro* Data.** *In vitro* metabolism data include data from studies where specific sub-cellular fractions (e.g., microsomal, cytosolic), cells, or tissues from an organism are tested outside the body (i.e., in test-tubes, cell- or tissue-culture). Compared with *in vivo* studies of chemical metabolism in aquatic organisms, *in vitro* studies are much more plentiful in the literature, with the majority of studies characterizing oxidative (Phase I) reactions de-coupled from conjugative (Phase II) metabolism. Cell, tissue, or organ level *in vitro* studies are less common but provide a more complete assessment of metabolism. While such studies are particularly useful for identifying the pathways, rates of formation, and metabolites formed, as well as the enzymes involved and differences in the temperature dependence of metabolism across aquatic species, they suffer from uncertainty when results are extrapolated to the whole organism. This uncertainty results from the fact that dosimetry (i.e., delivery of the toxicant to, and removal of metabolite

from, the target tissue) cannot currently be adequately reproduced in the laboratory or easily modeled.

When assessing chemical metabolism using the above information, the following guidelines apply.

a. A finding of substantial metabolism should be supported by two or more lines of evidence identified using the data described above.

b. At least one of the lines of evidence should be supported by either *in vivo* metabolism data or acceptable bioconcentration or bioaccumulation data.

c. A finding of substantial metabolism in one organism should not be extrapolated to another organism or another group of organisms unless data indicate similar metabolic pathways exist (or are very likely to exist) in both organisms. *In vitro* data may be particularly useful in cross-species extrapolations.

d. Finally, in situations where sufficient data are not available to properly assess the likelihood of significant metabolism in aquatic biota of concern, the chemical should be assumed to undergo little or no metabolism. This assumptions reflects a policy decision by EPA to err on the side of public health protection when sufficient information on metabolism is lacking.

5.4.3 Deriving National BAFs Using Procedure #1

This section contains guidance for calculating national BAFs for nonionic organic chemicals using Procedure #1 shown in Figure 5-1. The types of nonionic organic chemicals for which Procedure #1 is most appropriate are those that are classified as moderately to highly hydrophobic and subject to low (or unknown) rates of metabolism by aquatic biota (see Section 5.4.2 above). Non-aqueous contaminant exposure and subsequent biomagnification in aquatic food webs are of concern for chemicals that are classified in this category. Some examples of nonionic organic chemicals for which Procedure #1 is considered appropriate include:

- tetra-, penta- & hexachlorobenzenes;
- PCBs;
- octachlorostyrene;
- hexachlorobutadiene;
- endrin, dieldrin, aldrin;
- mirex, photomirex;
- DDT, DDE, DDD; and
- heptachlor, chlordane, nonachlor.

Under Procedure #1, the following four methods may be used in deriving a national BAF:

- using a BAF from an acceptable field study (i.e., a field-measured BAF);
- predicting a BAF from an acceptable field-measured BSAF;

- predicting a BAF from an acceptable laboratory-measured BCF and FCM; and
- predicting a BAF from an acceptable K_{ow} and FCM.

As shown in Figure 5-2, once the derivation procedure has been selected, the next steps in deriving a national BAF for a given trophic level include: calculating individual baseline BAF_{ℓ}^{fd}s (step 2), selecting the final baseline BAF_{ℓ}^{fd} (step 3), and calculating the national BAF from the final baseline BAF_{ℓ}^{fd} (step 4). Each of these three steps is discussed separately below.

5.4.3.1 Calculating Individual Baseline BAF_{ℓ}^{fd}s

Calculating an individual baseline BAF_{ℓ}^{fd} involves normalizing the field-measured BAF_{T}^{t} (or laboratory-measured BCF_{T}^{t}) which are based on total concentrations in tissue and water by the lipid content of the study organisms and the freely dissolved concentration in the study water. Both the lipid content in the organism and the freely dissolved concentration (as influenced by organic carbon in water) have been shown to be important factors that influence the bioaccumulation of nonionic organic chemicals (e.g., Mackay, 1982; Connolly and Pederson, 1988; Thomann, 1989, Suffet et al., 1994). Therefore, baseline BAF_{ℓ}^{fd}s (which are expressed on a freely dissolved and lipid-normalized basis) are considered more amenable to extrapolating between different species and bodies of water compared to BAFs expressed using the total concentration in the tissue and water. Because bioaccumulation can be strongly influenced by the trophic position of aquatic organisms (either due to biomagnification or physiological differences), extrapolation of baseline BAF_{ℓ}^{fd}s should not be performed between species of different trophic levels.

1. For each species for which acceptable data are available, calculate all possible baseline BAF_{ℓ}^{fd}s using each of the four methods shown above for Procedure #1.

2. Individual baseline BAF_{ℓ}^{fd}s should be calculated from field-measured BAF_{T}^{t}s, field-measured BSAFs, laboratory BCF_{T}^{t}s, and the K_{ow} according to the following procedures.

A. Baseline BAF_{ℓ}^{fd}s from Field-Measured BAFs

A baseline BAF_{ℓ}^{fd} should be calculated from each field-measured BAF_{T}^{t} using information on the lipid fraction in the tissue of concern for the study organism and the fraction of the total chemical that is freely dissolved in the study water.

1. **Baseline BAF_{ℓ}^{fd} Equation.** For each acceptable field-measured BAF_{T}^{t}, calculate a baseline BAF_{ℓ}^{fd} using the following equation:

$$\text{Baseline } BAF_{\ell}^{fd} = \left[\frac{\text{Measured } BAF_{T}^{t}}{f_{fd}} - 1 \right] \left(\frac{1}{f_{\ell}} \right) \qquad \text{(Equation 5-10)}$$

where:

Baseline BAF_{ℓ}^{fd}	=	BAF expressed on a freely dissolved and lipid-normalized basis
Measured BAF_{T}^{t}	=	BAF based on total concentration in tissue and water
f_{ℓ}	=	Fraction of the tissue that is lipid
f_{fd}	=	Fraction of the total chemical that is freely dissolved in the ambient water

The technical basis of Equation 5-10 is provided in the Bioaccumulation TSD. Guidance for determining each component of Equation 5-10 is provided below.

2. **Determining the Measured BAF_{T}^{t}.** The field-measured BAF_{T}^{t} shown in Equation 5-10 should be calculated based on the total concentration of the chemical in the appropriate tissue of the aquatic organism and the total concentration of the chemical in ambient water at the site of sampling. The equation to derive a measured BAF_{T}^{t} is:

$$\text{Measured } BAF_{T}^{t} = \frac{C_t}{C_w} \qquad \text{(Equation 5-11)}$$

where:

C_t	=	Total concentration of the chemical in the specified wet tissue
C_w	=	Total concentration of chemical in water

The data used to calculate a field-measured BAF_{T}^{t} should be reviewed thoroughly to assess the quality of the data and the overall uncertainty in the BAF value. The following general criteria apply in determining the acceptability of field-measured BAFs that are being considered for deriving national BAFs using Procedure #1.

a. Aquatic organisms used to calculate a field-measured BAF_{T}^{t} should be representative of aquatic organisms that are commonly consumed in the United States. An aquatic organism that is not commonly consumed in the United States can be used to calculate an acceptable field-measured BAF_{T}^{t} provided that the organism is considered to be a reasonable surrogate for a commonly consumed organism. Information on the ecology, physiology, and biology of the organism should be reviewed when assessing whether an organism is a reasonable surrogate of a commonly consumed organism.

b. The trophic level of the study organism should be determined by taking into account its life stage, diet, size, and the food web structure at the study location. Information from the study site (or similar sites) is preferred when evaluating trophic status. If such information is lacking, general information for assessing trophic status of aquatic organisms can be found in USEPA (2000a,b,c).

c. The percent lipid of the tissue used to determine the field-measured BAF_T^t should be either measured or reliably estimated to permit lipid-normalization of the chemical's tissue concentration.

d. The study from which the field-measured BAF_T^t is derived should contain sufficient supporting information from which to determine that tissue and water samples were collected and analyzed using appropriate, sensitive, accurate, and precise analytical methods.

e. The site of the field study should not be so unique that the BAF cannot be reasonably extrapolated to other locations where the BAF and resulting criteria will apply.

f. The water concentration(s) used to derive the BAF should reflect the average exposure of the aquatic organism that corresponds to the concentration measured in its tissue of concern. For nonionic organic chemicals, greater temporal and spatial averaging of chemical concentrations is required as the K_{ow} increases. In addition, as variability in water concentrations increase, greater temporal and spatial averaging is also generally required. Greater spatial averaging is also generally required for more mobile organisms.

g. The concentrations of particulate organic carbon and dissolved organic carbon in the study water should be measured or reliably estimated.

EPA is currently developing guidance for designing and conducting field studies for determining field-measured BAF_T^ts, including recommendations for minimum data requirements. A more detailed discussion of factors that should be considered when determining field-measured BAF_T^ts is provided in the Bioaccumulation TSD.

3. **Determining the Fraction Freely Dissolved (f_{fd}).** As illustrated by Equation 5-10, the fraction of the nonionic organic chemical that is freely dissolved in the study water is required for calculating a baseline BAF_ℓ^{fd} from a field-measured BAF_T^t. The freely dissolved fraction is the portion of the nonionic organic chemical that is not bound to particulate organic carbon or dissolved organic carbon. Together, the concentration of a nonionic organic chemical that is freely dissolved, bound to dissolved organic carbon, and bound to particulate organic carbon constitute its total concentration in water. As discussed further in the Bioaccumulation TSD, the freely dissolved fraction of a chemical is considered to be the best expression of the bioavailable form of nonionic organic chemicals to aquatic organisms (e.g., Suffet et al., 1994; USEPA, 1995b). Because the fraction of a nonionic organic chemical that is freely dissolved may vary among different bodies of water as a result of differences in dissolved and particulate organic carbon in the water, the bioavailability of the total chemical concentration in water is expected to vary from one body of water to another. Therefore, BAFs which are based on the freely dissolved concentration in water (rather than the total concentration in water) are considered to be more reliable for extrapolating and aggregating BAFs among different bodies of water. Currently, availability of BAFs based on measured freely dissolved

concentrations is very limited, partly because of difficulties in analytically measuring the freely dissolved concentration. Thus, if a BAF based on the total water concentration is reported in a given study, the fraction of the chemical that is freely dissolved should be predicted using information on the organic carbon content in the study water.

a. **Equation for Determining the Freely Dissolved Fraction.** If reliable measured data are unavailable to directly determine the freely dissolved fraction of the chemical in water, the freely dissolved fraction should be estimated using the following equation.

$$f_{fd} = \frac{1}{[1 + (POC \cdot K_{ow}) + (DOC \cdot 0.08 \cdot K_{ow})]} \qquad \text{(Equation 5-12)}$$

where:

POC = concentration of particulate organic carbon (kg/L)
DOC = concentration of dissolved organic carbon (kg/L)
K_{ow} = n-octanol water partition coefficient for the chemical

In Equation 5-12, K_{ow} is being used to estimate the partition coefficient to POC (i.e., K_{POC} in L/kg) and $0.08 \cdot K_{ow}$ is being used to estimate the partition coefficient to DOC (i.e., the K_{DOC} in L/kg). A discussion of the technical basis, assumptions, and uncertainty associated with the derivation and application of Equation 5-12 is provided in the Bioaccumulation TSD.

b. **POC and DOC Values.** When converting from the total concentration of a chemical to a freely dissolved concentration using Equation 5-12 above, the POC and DOC concentrations should be obtained from the original study from which the field-measured BAF is determined. If POC and DOC concentrations are not reported in the BAF study, reliable estimates of POC and DOC might be obtained from other studies of the same site used in the BAF study or closely related site(s) within the same water body. When using POC/DOC data from other studies of the same water body, care should be taken to ensure that environmental and hydrological conditions that might affect POC or DOC concentrations (i.e., runoff events, proximity to ground water or surface water inputs, sampling season) are reasonably similar to those in the BAF study. Additional information related to selecting POC and DOC values is provided in the Bioaccumulation TSD.

In some cases, BAFs are reported using the concentration of the chemical in filtered or centrifuged water. When converting these BAFs to a freely dissolved basis, the concentration of POC should be set equal to zero when using Equation 5-12. Particulates are removed from water samples by filtering or centrifuging the sample.

c. **Selecting K_{ow} Values.** A variety of techniques are available to measure or predict K_{ow} values. The reliability of these techniques depends to a large extent on the K_{ow} of the chemical. Because K_{ow} is an important input parameter for calculating the freely dissolved concentration of nonionic organic chemicals and for deriving BAFs using the other three methods of Procedure #1, care should be taken in selecting the most reliable K_{ow} value. The value of K_{ow} for use in estimating the freely dissolved fraction and other procedures used to derive national BAFs should be selected based on the guidance presented in the Bioaccumulation TSD.

4. **Determining the Fraction Lipid (f_ℓ).** Calculating a baseline BAF_ℓ^{fd} for a nonionic organic chemical using Equation 5-10 also requires that the total chemical concentration measured in the tissue used to determine the field-measured BAF_T^t be normalized by the lipid fraction (f_ℓ) in that same tissue. Lipid normalization of tissue concentrations reflects the assumption that BAFs (and BCFs) for nonionic organic chemicals are directly proportional to the percent lipid in the tissue upon which they are based. This assumption means that an organism with a two percent lipid content would be expected to accumulate twice the amount of a chemical at steady state compared with an organism with one percent lipid content, all else being equal. The assumption that aquatic organisms accumulate nonionic organic chemicals in proportion to their lipid content has been extensively evaluated in the literature (Mackay, 1982; Connell, 1988; Barron, 1990) and is generally accepted. Because the lipid content in aquatic organisms can vary both within and across species, BAFs that are expressed using the lipid-normalized concentration (rather than the total concentration in tissue) are considered to be the most reliable for aggregating multiple BAF values for a given species. Additional discussion of technical basis, assumptions, and uncertainties involved in lipid normalization is provided in the Bioaccumulation TSD.

a. The lipid fraction f_ℓ, is routinely reported in bioaccumulation studies involving nonionic organic chemicals. If the lipid fraction is not reported in the BAF study, it can be calculated using the following equation if the appropriate data are reported:

$$f_\ell = \frac{M_\ell}{M_t} \qquad \text{(Equation 5-13)}$$

where:

M_ℓ = Mass of lipid in specified tissue
M_t = Mass of specified tissue (wet weight)

b. Because lipid content can vary within an aquatic organism (and among tissues within that organism) due to several factors including the age and sex of the organism, changes in dietary composition, season of sampling and reproductive status, the lipid fraction used to calculate a baseline BAF_ℓ^{fd} should be measured in

the same tissue and organisms used to determine the field-measured BAF_T^t, unless comparability is demonstrated across organisms.

c. Experience has shown that different solvent systems used to extract lipids for analytical measurement can result in different quantities of lipids being extracted and measured in aquatic organisms (e.g., Randall et al.,1991, 1998). As a result, lipid measurements determined using different solvent systems might lead to apparent differences in lipid-normalized concentrations and lipid-normalized BAFs. The extent to which different solvent systems might affect lipid extractions (and lipid-normalized concentrations) is thought to vary depending on the solvent, chemical of concern, and lipid composition of the tissue being extracted. Guidance on measurement of lipid content, including the choice of solvent system and how different solvent systems may affect lipid content, is provided in the Bioaccumulation TSD.

B. Baseline BAF_ℓ^{fd} Derived from BSAFs

The second method of determining a baseline BAF_ℓ^{fd} for the chemical of concern in Procedure #1 involves the use of BSAFs. Although BSAFs may be used for measuring and predicting bioaccumulation directly from concentrations of chemicals in surface sediment, they may also be used to estimate BAFs (USEPA, 1995b; Cook and Burkhard, 1998). Since BSAFs are based on field data and incorporate effects of chemical bioavailability, food web structure, metabolism, biomagnification, growth, and other factors, BAFs estimated from BSAFs will incorporate the net effect of all these factors. The BSAF approach is particularly beneficial for developing water quality criteria for chemicals which are detectable in fish tissues and sediments, but are difficult to detect or measure precisely in the water column.

As shown by Equation 5-14 below, predicting baseline BAF_ℓ^{fd}s using BSAFs requires that certain types of data be used for the chemicals of interest (for which BAFs are to be determined) and reference chemicals (for which BAFs are measured) from a common sediment-water-organism data set. Differences between BSAFs for different organic chemicals are good measures of the relative bioaccumulation potentials of the chemicals. When calculated from a common organism-sediment sample set, chemical-specific differences in BSAFs reflect the net effect of biomagnification, metabolism, food chain, bioenergetics, and bioavailability factors on the degree of each chemical's equilibrium/disequilibrium between sediment and biota. At equilibrium, BSAFs are expected to be approximately 1.0. However, deviations from 1.0 (reflecting disequilibrium) are common due to: conditions where water is not at equilibrium with surface sediment; differences in organic carbon content of water and sediment; kinetic limitations for chemical transfer between sediments and water associated with specific biota; biomagnification; or biological processes such as growth or biotransformation. BSAFs are most useful (i.e., most predictable from one site to another) when measured under steady-state (or near steady-state) conditions. The use of non-steady-state BSAFs, such as found with new chemical loadings or rapid increases in loadings, increases uncertainty in this method for the relative degree of disequilibrium between the reference chemicals and the chemicals of interest. In general, the fact that concentrations of hydrophobic chemicals in sediment are less sensitive than concentrations in water to fluctuations in chemical loading and distribution makes the BSAF

method robust for estimating BAFs. Results from validation of the BAF procedure in Lake Ontario, the Fox River and Green Bay, Wisconsin, and the Hudson River, New York, demonstrate good agreement between observed and BSAF-predicted BAFs in the vast majority of comparisons made. Detailed results of the validation studies for the BSAF procedure are provided in the Bioaccumulation TSD.

Baseline BAF_{ℓ}^{fd}s should be calculated using acceptable BSAFs for chemicals of interest and appropriate sediment-to-water fugacity (disequilibrium) ratios $(\prod_{socw})_r/(K_{ow})_r$ for reference chemicals under the following guidelines.

1. **Baseline BAF_{ℓ}^{fd} Equation.** For each species with an acceptable field measured $(BSAF)_I$, a baseline BAF_{ℓ}^{fd} for the chemical of interest may be calculated using the following equation with an appropriate value of $(\prod_{socw})_r/(K_{ow})_r$:

$$(Baseline\ BAF_{\ell}^{fd})_i = (BSAF)_i \frac{(D_{i/r})\ (\prod_{socw})_r\ (K_{ow})_i}{(K_{ow})_r} \qquad \text{(Equation 5-14)}$$

where:

$(\text{Baseline } BAF_{\ell}^{fd})_I$	=	BAF expressed on a freely dissolved and lipid-normalized basis for chemical of interest "I"
$(BSAF)_I$	=	Biota-sediment accumulation factor for chemical of interest "I"
$(\prod_{socw})_r$	=	sediment organic carbon to water freely dissolved concentration ratio of reference chemical "r"
$(K_{ow})_I$	=	octanol-water partition coefficient for chemical of interest "I"
$(K_{ow})_r$	=	octanol-water partition coefficient for the reference chemical "r"
$D_{i/r}$	=	ratio between $\prod_{socw} / K_{ow}$ for chemicals "I" and "r" (normally chosen so that $D_{i/r} = 1$)

The technical basis, assumptions, and uncertainties associated with Equation 5-14 are provided in the Bioaccumulation TSD. Guidance for determining each component of Equation 5-14 is provided below.

2. **Determining Field-Measured BSAFs.** BSAFs should be determined by relating lipid-normalized concentrations of chemicals in an organism (C_{ℓ}) to organic carbon-normalized concentrations of the chemicals in surface sediment samples (C_{soc}) using the following equation:

$$BSAF = \frac{C_{\ell}}{C_{soc}} \qquad \text{(Equation 5-15)}$$

a. **Lipid-Normalized Concentration.** The lipid-normalized concentration of a chemical in an organism should be determined by:

$$C_{\ell} = \frac{C_t}{f_{\ell}} \qquad \text{(Equation 5-16)}$$

where:

C_t = Concentration of the chemical in the wet tissue (either whole organism or specified tissue) (µg/g)
f_{ℓ} = Fraction lipid content in the tissue

b. **Organic Carbon-Normalized Concentration.** The organic carbon-normalized concentration of a chemical in sediment should be determined by:

$$C_{soc} = \frac{C_s}{f_{oc}} \qquad \text{(Equation 5-17)}$$

where:

C_s = Concentration of chemical in sediment (µg/g sediment)
f_{oc} = Fraction organic carbon in sediment

The organic carbon-normalized concentrations of the chemicals in surface sediment samples should be associated with the average exposure environment of the organism.

3. **Sediment-to-Water Partition Coefficient** $(\prod_{socw})_r$. Sediment-to-water partition coefficients for reference chemicals should be determined by:

$$(\prod_{socw})_r = \frac{(C_{soc})_r}{(C_w^{fd})_r} \qquad \text{(Equation 5-18)}$$

where:

$(C_{soc})_r$ = Concentration of a reference chemical in sediment normalized to sediment organic carbon
$(C_w^{fd})_r$ = Concentration of the reference chemical freely dissolved in water

4. **Selecting Reference Chemicals.** Reference chemicals with $(\prod_{socw}) / (K_{ow})$ similar to that of the chemical of interest are preferred for this method. Theoretically, knowledge of the

difference between sediment-to-water fugacity ratios for two chemicals, "I" and "r" ($D_{i/r}$), could be used when reliable reference chemicals that meet the fugacity equivalence condition are not available. Similarity of $(\prod_{socw}) / (K_{ow})$ for two chemicals can be indicated on the basis of similar physical-chemical behavior in water (persistence, volatilization), similar mass loading histories, and similar concentration profiles in sediment cores.

Validation studies have demonstrated that choosing reference chemicals with well quantified concentrations in water is important because the uncertainty associated with measurement of barely detected chemicals is large (see the Bioaccumulation TSD). Similarity between K_{ow} values of the reference and target chemicals is generally desirable, although recent validation studies indicate that the accuracy of the method is not substantially decreased through use of reference chemicals with large differences in K_{ow}, as long as the chemicals are structurally similar and have similar persistence behavior in water and sediments.

5. The following data, procedural, and quality assurance requirements should be met for predicting baseline BAF_{ℓ}^{fd}s using field-measured BSAFs:

   a. Data on the reference chemicals and chemicals of interest should come from a common organism-water-sediment data set at a particular site.

   b. The chemicals of interest and reference chemicals should have similar physicochemical properties and persistence in water and sediment.

   c. The loadings history of the reference chemicals and chemicals of interest should be similar such that their expected sediment-water disequilibrium ratios $(\prod_{socw}/K_{ow})$ would not be expected to be substantially different (i.e., $D_{i/r} \sim 1$).

   d. The use of multiple reference chemicals is generally preferred for determining the value of $(\prod_{socw})_r$ so long as the concentrations are well quantified and the aforementioned conditions for selecting reference chemicals are met. In some cases, use of a single reference chemical may be necessary because of limited data.

   e. Samples of surface sediments (0-1 cm is ideal) should be from locations in which sediment is regularly deposited and is representative of average surface sediment in the vicinity of the organism.

   f. The K_{ow} value for the target and reference chemicals should be selected as described in the Bioaccumulation TSD.

   g. All other data quality and procedural guidelines described earlier for determining field-measured BAFs in Section 5.4.3.1(A) should be met.

Further details on the requirements for predicting BAFs from BSAF measurements, including the data, assumptions, and limitations of this approach are provided in the Bioaccumulation TSD.

C. Baseline BAF_{ℓ}^{fd} from a Laboratory-Measured BCF_T^t and FCM

The third method in Procedure #1 consists of using a laboratory-measured BCF_T^t (i.e., a BCF based on total concentrations in tissue and water) and FCMs to predict a baseline BAF_{ℓ}^{fd} for the chemical of concern. The BCF_T^t is used in conjunction with an FCM because non-aqueous routes of exposure and subsequent biomagnification is of concern for the types of chemicals applicable to Procedure #1. A laboratory-measured BCF inherently accounts for the effects of chemical metabolism that occurs in the organism used to calculate the BCF, but does not account for metabolism which may occur in other organisms of the aquatic food web.

1. **Baseline BAF_{ℓ}^{fd} Equation.** For each acceptable laboratory-measured BCF_T^t, calculate a baseline BAF_{ℓ}^{fd} using the following equation:

$$\text{Baseline } BAF_{\ell}^{fd} = (FCM) \cdot \left[\frac{\text{Measured } BCF_T^t}{f_{fd}} - 1 \right] \cdot \left(\frac{1}{f_{\ell}} \right) \qquad \text{(Equation 5-19)}$$

where:

Baseline BAF_{ℓ}^{fd}	=	BAF expressed on a freely dissolved and lipid-normalized basis
Measured BCF_T^t	=	BCF based on total concentration in tissue and water
f_{ℓ}	=	Fraction of the tissue that is lipid
f_{fd}	=	Fraction of the total chemical in the test water that is freely dissolved
FCM	=	The food chain multiplier either obtained from Table 5-1 by linear interpolation for the appropriate trophic level, or from appropriate field data

The technical basis for Equation 5-19 is provided in the Bioaccumulation TSD. Guidance for determining each component of Equation 5-19 is provided below.

2. **Determining the Measured BCF_T^t.** The laboratory-measured BCF_T^t shown in Equation 5-19 should be calculated using information on the total concentration of the chemical in the tissue of the organism and the total concentration of the chemical in the laboratory test water. The equation to derive a measured BCF_T^t is:

$$\text{Measured } BCF_T^t = \frac{C_t}{C_w} \qquad \text{(Equation 5-20)}$$

where:

C_t = Total concentration of the chemical in the specified wet tissue
C_w = Total concentration of chemical in the laboratory test water

The data used to calculate a laboratory-measured BCF_T^t should be reviewed thoroughly to assess the quality of the data and the overall uncertainty in the BCF value. The following general criteria apply in determining the acceptability of laboratory-measured BCF_T^t.

a. The test organism should not be diseased, unhealthy, or adversely affected by the concentration of the chemical because these attributes may alter accumulation of chemicals compared with healthy organisms.

b. The total concentration of the chemical in the water should be measured and should be relatively constant during the exposure period.

c. The organisms should be exposed to the chemical using a flow-through or renewal procedure.

d. The percent lipid of the tissue used to normalize the BCF_T^t should be either measured or reliably estimated to permit lipid normalization of chemical concentrations.

e. The concentrations of particulate organic carbon and dissolved organic carbon in the study water should be measured or reliably estimated.

f. Aquatic organisms used to calculate a laboratory-measured BCF_T^t should be representative of those aquatic organisms that are commonly consumed in the United States. An aquatic organism which is not commonly consumed in the United States can be used to calculate an acceptable laboratory-measured BCF_T^t provided that the organism is considered to be a reasonable surrogate for a commonly consumed organism. Information on the ecology, physiology, and biology of the organism should be reviewed when assessing whether an organism is a reasonable surrogate of a commonly consumed organism.

g. BCFs may be based on measurement of radioactivity from radiolabeled parent compounds only when the BCF is intended to include metabolites, when there is confidence that there is no interference due to metabolites of the parent compounds, or when studies are conducted to determine the extent of metabolism, thus allowing for a proper correction.

h. The calculation of the BCF_T^t should appropriately address growth dilution, which can be particularly important in affecting BCF_T^t determinations for poorly depurated chemicals.

I. Other aspects of the methodology used should be similar to those described by the American Society of Testing and Materials (ASTM, 1999) and USEPA *Ecological Effects Test Guidelines* (USEPA, 1996).

j. In addition, the magnitude of the K_{ow} and the availability of corroborating BCF data should be considered. For example, if the steady-state method is used for the BCF_T^t determination, exposure periods longer than 28 days will generally be required for highly hydrophobic chemicals to reach steady state between the water and the organism.

k. If a baseline BCF_ℓ^{fd} derived from a laboratory-measured BCF_T^t consistently increases or decreases as the chemical concentration increases in the test solutions for the test organisms, the BCF_T^t should be selected from the test concentration(s) that would most closely correspond to the 304(a) criterion. Note: a BCF_T^t should not be calculated from a control treatment.

3. **Selecting Food Chain Multipliers.** An FCM reflects a chemical's tendency to biomagnify in the aquatic food web. Values of FCMs greater than 1.0 are indicative of biomagnification and typically apply to organic chemicals with log K_{ow} values between 4.0 and 9.0. For a given chemical, FCMs tend to be greater at higher trophic levels, although FCMs for trophic level three can be higher than those for trophic level four.

Food chain multipliers used to derive baseline BAF_ℓ^{fd}s using Procedure #1 can be selected from model-derived or field-derived estimates.

a. **Model-Derived FCMs.** For nonionic organic chemicals appropriate for Procedure #1, EPA has calculated FCMs for various K_{ow} values and trophic levels using the bioaccumulation model of Gobas (1993). The FCMs shown in Table 5-1 were calculated using the Gobas model as the ratio of the baseline BAF_ℓ^{fd}s for trophic levels 2, 3, and 4 to the baseline BCF_ℓ^{fd}.

EPA recommends using the biomagnification model by Gobas (1993) to derive FCMs for nonionic organic chemicals for several reasons. First, the Gobas model includes both benthic and pelagic food chains, thereby incorporating exposure of organisms to chemicals from both the sediment and the water column. Second, the input data needed to run the model can be readily defined. Third, the predicted BAFs using the model are in agreement with field-measured BAFs for chemicals, even those with very high log K_{ow}s. Finally, the model predicts chemical residues in benthic organisms using equilibrium partitioning theory, which is consistent with EPA's equilibrium partitioning sediment guidelines (USEPA, 2000d).

The Gobas model requires input of specific data on the structure of the food chain and the water quality characteristics of the water body of interest. For calculating national BAFs, a mixed pelagic/benthic food web structure consisting of four trophic levels is assumed. Trophic level 1 is phytoplankton, trophic level 2 is

zooplankton, trophic level 3 is forage fish (e.g., sculpin and smelt), and trophic level 4 are predatory fish (e.g., salmonids). Additional assumptions are made regarding the composition of the aquatic species' diets (e.g., salmonids consume 10 percent sculpin, 50 percent alewives, and 40 percent smelt), the physical parameters of the aquatic species (e.g., lipid values), and the water quality characteristics (e.g., water temperature, sediment organic carbon).

A mixed pelagic/benthic food web structure has been assumed for the purpose of calculating FCMs because it is considered to be most representative of the types of food webs that occur in aquatic ecosystems. FCMs derived using the mixed pelagic/benthic structure are also about mid-range in magnitude between a 100% pelagic and 100% benthic driven food web (see the Bioaccumulation TSD). The validity of FCMs derived using the mixed pelagic/benthic food web structure has

Table 5-1
Food-Chain Multipliers for Trophic Levels 2, 3 and 4
(Mixed Pelagic and Benthic Food Web Structure and $\prod_{socw} / K_{OW} = 23$)

Log K_{OW}	Trophic Level 2	Trophic Level 3	Trophic Level 4	Log K_{OW}	Trophic Level 2	Trophic Level 3	Trophic Level 4
4.0	1.00	1.23	1.07	6.6	1.00	12.9	23.8
4.1	1.00	1.29	1.09	6.7	1.00	13.2	24.4
4.2	1.00	1.36	1.13	6.8	1.00	13.3	24.7
4.3	1.00	1.45	1.17	6.9	1.00	13.3	24.7
4.4	1.00	1.56	1.23	7.0	1.00	13.2	24.3
4.5	1.00	1.70	1.32	7.1	1.00	13.1	23.6
4.6	1.00	1.87	1.44	7.2	1.00	12.8	22.5
4.7	1.00	2.08	1.60	7.3	1.00	12.5	21.2
4.8	1.00	2.33	1.82	7.4	1.00	12.0	19.5
4.9	1.00	2.64	2.12	7.5	1.00	11.5	17.6
5.0	1.00	3.00	2.51	7.6	1.00	10.8	15.5
5.1	1.00	3.43	3.02	7.7	1.00	10.1	13.3
5.2	1.00	3.93	3.68	7.8	1.00	9.31	11.2
5.3	1.00	4.50	4.49	7.9	1.00	8.46	9.11
5.4	1.00	5.14	5.48	8.0	1.00	7.60	7.23
5.5	1.00	5.85	6.65	8.1	1.00	6.73	5.58
5.6	1.00	6.60	8.01	8.2	1.00	5.88	4.19
5.7	1.00	7.40	9.54	8.3	1.00	5.07	3.07
5.8	1.00	8.21	11.2	8.4	1.00	4.33	2.20
5.9	1.00	9.01	13.0	8.5	1.00	3.65	1.54
6.0	1.00	9.79	14.9	8.6	1.00	3.05	1.06
6.1	1.00	10.5	16.7	8.7	1.00	2.52	0.721
6.2	1.00	11.2	18.5	8.8	1.00	2.08	0.483
6.3	1.00	11.7	20.1	8.9	1.00	1.70	0.320
6.4	1.00	12.2	21.6	9.0	1.00	1.38	0.210
6.5	1.00	12.6	22.8				

been evaluated in several different ecosystems including Lake Ontario, the tidally influenced Bayou D'Inde in Louisiana, the Fox River and Green Bay, Wisconsin, and the Hudson River in New York. Additional details of the validation of EPA's national default FCMs and the assumptions, uncertainties, and input parameters for the model are provided in the Bioaccumulation TSD.

Although EPA uses the FCMs in Table 5-1 to derive its national 304(a) criteria, EPA recognizes that food webs of other waterbodies might differ from the assumptions used to calculate national BAFs. In these situations, States and authorized Tribes may wish to use alternate food web structures for calculating FCMs for use in setting State or Tribal water quality criteria. Additional guidance on the use of alternate food web structures for calculating State, Tribal, or site-specific criteria is provided in the Bioaccumulation TSD.

b. **Field-Derived FCMs.** In addition to model-derived estimates of FCMs, field data may also be used to derive FCMs. Currently, the use of field-derived FCMs is the only method recommended for estimating FCMs for inorganic and organometalic chemicals because appropriate model-derived estimates are not yet available (see Section 5.6). In contrast to the model-based FCMs described previously, field-derived FCMs account for any metabolism of the chemical of concern by the aquatic organisms used to calculate the FCM.

Field-derived FCMs should be calculated using lipid-normalized concentrations of the nonionic organic chemical in appropriate predator and prey species using the following equations.

$$FCM_{TL2} = BMF_{TL2} \quad \text{(Equation 5-21)}$$

$$FCM_{TL3} = (BMF_{TL3})\,(BMF_{TL2}) \quad \text{(Equation 5-22)}$$

$$FCM_{TL4} = (BMF_{TL4})\,(BMF_{TL3})\,(BMF_{TL2}) \quad \text{(Equation 5-23)}$$

where:

FCM = Food chain multiplier for designated trophic level (TL2, TL3, or TL4)
BMF = Biomagnification factor for designated trophic level (TL2, TL3, or TL4)

The basic difference between FCMs and BMFs is that FCMs relate back to trophic level one (or trophic level two as assumed by the Gobas (1993) model), whereas BMFs always relate back to the next lowest trophic level. For nonionic organic chemicals, BMFs can be calculated from tissue residue concentrations determined in biota at a site according to the following equations.

$$BMF_{TL2} = (C_{\ell, TL2}) / (C_{\ell, TL1}) \quad \text{(Equation 5-24)}$$

$$BMF_{TL3} = (C_{\ell, TL3}) / (C_{\ell, TL2}) \quad \text{(Equation 5-25)}$$

$$BMF_{TL4} = (C_{\ell, TL4}) / (C_{\ell, TL3}) \quad \text{(Equation 5-26)}$$

where:

C_ℓ = Lipid-normalized concentration of chemical in tissue of appropriate biota that occupy the specified trophic level (TL2, TL3, or TL4)

In addition to the acceptability guidelines pertaining to field-measured BAFs, the following procedural and quality assurance requirements apply to field-measured FCMs.

(1) Information should be available to identify the appropriate trophic levels for the aquatic organisms and appropriate predator-prey relationships for the site from which FCMs are being determined. General information on determining trophic levels of aquatic organisms can be found in USEPA 2000a,b,c.

(2) The aquatic organisms sampled from each trophic level should reflect the most important exposure pathways leading to human exposure via consumption of aquatic organisms. For higher trophic levels (e.g., 3 and 4), aquatic species should also reflect those that are commonly consumed by humans.

(3) The studies from which the FCMs are derived should contain sufficient supporting information from which to determine that tissue samples were collected and analyzed using appropriate, sensitive, accurate, and precise methods.

(4) The percent lipid should be either measured or reliably estimated for the tissue used to determine the FCM.

(5) The tissue concentrations should reflect average exposure over the approximate time required to achieve steady-state in the target species.

D. Baseline BAF_ℓ^{fd} from a K_{ow} and FCM

The fourth method in Procedure #1 consists of using a K_{ow} and an appropriate FCM for estimating the baseline BAF_ℓ^{fd}. In this method, the K_{ow} is assumed to be equal to the baseline BCF_ℓ^{fd}. Numerous investigations have demonstrated a linear relationship between the logarithm of the BCF and the logarithm of the octanol-water partition coefficient (K_{ow}) for organic chemicals for fish and other aquatic organisms. Isnard and Lambert (1988) list various regression equations that illustrate this linear relationship. When the regression equations are constructed using lipid-normalized BCFs, the slopes and intercepts are not significantly different from one and zero, respectively (e.g., de Wolf, et al., 1992). The underlying assumption for the linear relationship between the BCF and K_{ow} is that the bioconcentration process can be viewed as the partitioning of a chemical between the lipid of the aquatic organisms and water and that the K_{ow} is a useful surrogate for this partitioning process (Mackay, 1982). To account for biomagnification, Procedure #1 requires the K_{ow} value be used in conjunction with an appropriate FCM.

1. **Baseline BAF_{ℓ}^{fd} Equation.** For each acceptable K_{ow} value and FCM for the chemical of concern, calculate a baseline BAF_{ℓ}^{fd} using the following equation.

$$\text{Baseline } BAF_{\ell}^{fd} = (FCM) \cdot (K_{ow}) \qquad \text{(Equation 5-27)}$$

where:

Baseline BAF_{ℓ}^{fd}	=	BAF expressed on a freely dissolved and lipid-normalized basis for a given trophic level
FCM	=	The food chain multiplier for the appropriate trophic level obtained from Table 5-1 by linear interpolation or from appropriate field data (used with Procedure #1 only)
K_{ow}	=	Octanol-water partition coefficient

The BCF-K_{ow} relationship has been developed primarily for nonionic organic chemicals that are not readily metabolized by aquatic organisms and thus is most appropriate for poorly-metabolized nonionic organic chemicals (i.e., Procedures #1 and #3 as depicted in Figure 5-1). For poorly-metabolized nonionic organic chemicals with large log K_{ow}s (i.e., > 6), reported log BCFs are often not equal to log K_{ow}. EPA believes that this nonlinearity is primarily due to not accounting for several factors which affect the BCF determination. These factors include not basing BCFs on the freely dissolved concentration in water, not accounting for growth dilution, not assessing BCFs at steady-state, inaccuracies in measurements of uptake and elimination rate constants, and complications from the use of solvent carriers in the exposure. Application of Equation 5-27 for predicting BAFs has been conducted in several different ecosystems including Lake Ontario, the tidally influenced Bayou D'Inde in Louisiana, the Fox River and Green Bay, Wisconsin, and the Hudson River in New York. Additional detail on the validation, technical basis, assumptions, and uncertainty associated with Equation 5-27 and is provided in the Bioaccumulation TSD.

2. **FCMs and K_{ow}s**. Food chain multipliers and K_{ow} values should be selected as described previously in Procedure #1.

5.4.3.2 Selecting Final Baseline BAF_{ℓ}^{fd}s

After calculating individual baseline BAF_{ℓ}^{fd}s using as many of the methods in Procedure #1 as possible, the next step is to determine a final baseline BAF_{ℓ}^{fd} for each trophic level from the individual baseline BAF_{ℓ}^{fd}s (see Figures 5-1 and 5-2). The final baseline BAF_{ℓ}^{fd} will be used in the last step to determine the national BAF for each trophic level. The final baseline BAF_{ℓ}^{fd} for each trophic level should be determined from the individual baseline BAF_{ℓ}^{fd}s by considering the data preference hierarchy defined by Procedure #1 and uncertainty in the data. The data preference hierarchy for Procedure #1 is (in order of preference):

1. a baseline BAF_{ℓ}^{fd} from an acceptable field-measured BAF (method 1)

2. a baseline BAF_{ℓ}^{fd} predicted from an acceptable field-measured BSAF (method 2),
3. a baseline BAF_{ℓ}^{fd} predicted from an acceptable BCF and FCM (method 3), or
4. a baseline BAF_{ℓ}^{fd} predicted from an acceptable K_{ow} and FCM (method 4).

This data preference hierarchy reflects EPA's preference for BAFs based on field-measurements of bioaccumulation (methods 1 and 2) over those based on laboratory-measurements and/or predictions of bioaccumulation (methods 3 and 4). However, this data preference hierarchy should not be considered inflexible. Rather, it should be used as a guide for selecting the final baseline BAF_{ℓ}^{fd}s when the uncertainty is similar among two or more baseline BAF_{ℓ}^{fd}s derived using different methods. The following steps and guidelines should be followed for selecting the final baseline BAF_{ℓ}^{fd}s using Procedure #1.

1. **Calculate Species-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method where more than one acceptable baseline BAF_{ℓ}^{fd} is available for a given species, calculate a species-mean baseline BAF_{ℓ}^{fd} as the geometric mean of all available individual baseline BAF_{ℓ}^{fd}s. When calculating a species-mean baseline BAF_{ℓ}^{fd}, individual baseline BAF_{ℓ}^{fd}s should be reviewed carefully to assess the uncertainty in the BAF values. For highly hydrophobic chemicals applicable to Procedure #1, particular attention should be paid to whether sufficient spatial and temporal averaging of water and tissue concentrations was likely achieved in the BAF, BSAF, or BCF study. Highly uncertain baseline BAF_{ℓ}^{fd}s should not be used. Large differences in individual baseline BAF_{ℓ}^{fd}s for a given species (e.g., greater than a factor of 10) should be investigated further. In such cases, some or all of the baseline BAF_{ℓ}^{fd}s for a given species might not be used. Additional discussion on evaluating acceptability of BAF values is provided in the Bioaccumulation TSD.

2. **Calculate Trophic-Level-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method where more than one acceptable species-mean baseline BAF_{ℓ}^{fd} is available within a given trophic level, calculate a trophic-level-mean baseline BAF_{ℓ}^{fd} as the geometric mean of acceptable species-mean baseline BAF_{ℓ}^{fd}s in that trophic level. Trophic-level-mean baseline BAF_{ℓ}^{fd}s should be calculated for trophic levels two, three, and four because available data on U.S. consumers of fish and shellfish indicate significant consumption of organisms in these trophic levels.

3. **Select a Final Baseline BAF_{ℓ}^{fd} for Each Trophic Level.** For each trophic level, select the final baseline BAF_{ℓ}^{fd} using best professional judgment by considering: (1) the data preference hierarchy shown previously, (2) the relative uncertainty in the trophic-level-mean baseline BAF_{ℓ}^{fd}s derived using different methods, and (3) the weight of evidence among the four methods.

    a. In general, when more than one trophic-level-mean baseline BAF_{ℓ}^{fd} is available for a given trophic level, the final trophic-level-mean baseline BAF_{ℓ}^{fd} should be selected from the most preferred BAF method defined by the data preference hierarchy for Procedure #1.

    b. If uncertainty in a trophic-level-mean baseline BAF based on a higher tier (more preferred) method is judged to be substantially greater than a trophic-level-mean

baseline BAF from a lower tier method, and the weight of evidence among the various methods suggests that a BAF value from lower tier method is likely to be more accurate, then the final baseline BAF_{ℓ}^{fd} should be selected using a trophic level-mean baseline BAF_{ℓ}^{fd} from a lower tier method.

c. When considering the weight of evidence among the various BAF methods, greater confidence in the final baseline BAF_{ℓ}^{fd} is generally assigned when BAFs from a greater number of methods are in agreement for a given trophic level. However, lack of agreement among methods does not necessarily indicate less confidence if such disagreements can be adequately explained. For example, if the chemical of concern is metabolized by aquatic organisms represented by a BAF value, one would expect disagreement between a field-measured BAF (the highest priority data) and a predicted BAF using a K_{ow} and model-derived FCM. Thus, field-measured BAFs should generally be given the greatest weight among methods because they reflect direct measures of bioaccumulation and incorporate any metabolism which might occur in the organism and its food web.

d. The above steps should be performed for each trophic level until a final baseline BAF_{ℓ}^{fd} is selected for trophic levels two, three, and four.

5.4.3.3 Calculating National BAFs

The last step in deriving a national BAF for each trophic level is to convert the final baseline BAF_{ℓ}^{fd} determined in the previous step to a BAF that reflects conditions to which the national 304(a) criteria will apply (Figure 5-2). Since a baseline BAF_{ℓ}^{fd} is by definition normalized by lipid content and expressed on a freely dissolved basis, it needs to be adjusted to reflect the lipid fraction of aquatic organisms commonly consumed in the U.S. and the freely dissolved fraction expected in U.S. bodies of water. Converting a final baseline BAF_{ℓ}^{fd} to a national BAF requires information on: (1) the percent lipid of the aquatic organisms commonly consumed by humans, and (2) the freely dissolved fraction of the chemical of concern that would be expected in the ambient waters of interest. For each trophic level, a national BAF should be determined from a final baseline BAF_{ℓ}^{fd} according to the following guidelines.

1. **National BAF Equation.** For each trophic level, calculate a national BAF using the following equation.

$$\text{National BAF}_{(TL\ n)} = [(\text{Final Baseline BAF}_{\ell}^{fd})_{TL\ n} \cdot (f_{\ell})_{TL\ n} + 1] \cdot (f_{fd}) \qquad \text{(Equation 5-28)}$$

where:

Final Baseline BAF_{ℓ}^{fd} = Final trophic-level-mean baseline BAF expressed on a freely dissolved and lipid-normalized basis for trophic level "n"

$f_{\ell(TL\ n)}$	=	Lipid fraction of aquatic species consumed at trophic level "n"
f_{fd}	=	Fraction of the total chemical in water that is freely dissolved

The technical basis of Equation 5-28 is provided in the Bioaccumulation TSD. Guidance for determining each component of Equation 5-28 is provided below.

2. **Determining the Final Baseline BAF_{ℓ}^{fd}.** The final trophic-level-mean baseline BAF_{ℓ}^{fd}s used in this equation are those which have been determined using the guidance presented in Section 5.4.3.2 for selecting the final baseline BAF_{ℓ}^{fd}s.

3. **Lipid Content of Commonly Consumed Aquatic Species.** As illustrated by Equation 5-28, the percent lipid of the aquatic species consumed by humans is needed to accurately characterize the potential exposure to a chemical from ingestion of aquatic organisms.

   a. **National Default Lipid Values.** For the purposes of calculating a national 304(a) criterion, the following national default values for lipid fraction should be used: 1.9% (for trophic level two organisms), 2.6% (for trophic level three organisms), and 3.0% (for trophic level four organisms).

      These national default values for lipid content reflect national per capita average patterns of fish consumption in the United States. Specifically, they were calculated using the consumption-weighted mean lipid content of commonly consumed fish and shellfish as identified by the USDA Continuing Survey of Food Intake by Individuals (CSFII) for 1994 through 1996. This same national survey data was used to derive national default values of fish consumption. To maintain consistency with the fish consumption assumptions, only freshwater and estuarine organisms were included in the derivation of the national default lipid values. Additional details on the technical basis, assumptions, and uncertainty in the national default values of lipid fraction are provided in the Bioaccumulation TSD.

      Although national default lipid values are used by EPA to set national 304(a) criteria, EPA encourages States and authorized Tribes to use local or regional data on lipid content of consumed aquatic species when adopting criteria into their water quality standards because local or regional consumption patterns (and lipid content) can differ from national consumption patterns. Additional guidance on developing site-specific values of lipid content, including a database of lipid content for many commonly consumed aquatic organisms, is found in the Bioaccumulation TSD.

4. **Freely Dissolved Fraction.** The third piece of information required for deriving a national BAF is the freely dissolved fraction of the chemical of concern that is expected

in waters of the United States. As noted previously, expressing BAFs on the freely dissolved concentration in water allows a common basis for averaging BAFs from several studies. However, for use in criteria development, these BAFs should be converted back to values based on the total concentration in the water to be consistent with monitored water column and effluent concentrations, which are typically based on total concentrations of chemicals in the water. This should be done by multiplying the freely dissolved baseline BAF_{ℓ}^{fd} by the fraction of the freely dissolved chemical expected in water bodies of the United States where criteria are to be applied, as shown in Equation 5-29.

$$f_{fd} = \frac{1}{[1 + (POC \cdot K_{ow}) + (DOC \cdot 0.08 \cdot K_{ow})]} \qquad \text{(Equation 5-29)}$$

where:

POC	=	national default value for the particulate organic carbon concentration (kg/L)
DOC	=	national default value for the dissolved organic carbon concentration (kg/L)
K_{ow}	=	n-octanol water partition coefficient for the chemical

Equation 5-29 is identical to Equation 5-12, which was used to determine the freely dissolved fraction for deriving baseline BAF_{ℓ}^{fd}s from field-measured BAFs. However, the POC and DOC concentrations used in Equation 5-29 reflect those values that are expected in U.S. bodies of water, not the POC and DOC values in the study water used to derive the BAF. Guidance for determining each component of Equation 5-29 follows.

a. **National Default Values of POC and DOC.** For estimating the freely dissolved fraction of the chemical of concern that is expected in U.S. water bodies, national default values of 0.5 mg/L (5×10^{-7} kg/L) for POC and 2.9 mg/L (2.9×10^{-6} kg/L) for DOC should be used. These values are 50th percentile values (medians) based on an analysis of over 110,000 DOC values and 85,000 POC values contained in EPA's STORET database from 1980 through 1999. These default values reflect a combination of values for streams, lakes and estuaries across the United States. Additional details on the technical basis, assumptions, and uncertainty in the derivation and application of the national default values of POC and DOC are provided in the Bioaccumulation TSD.

   Although national default values of POC and DOC concentrations are used by EPA to set national 304(a) criteria as described by this document, EPA encourages States and authorized Tribes to use local or regional data on POC and DOC when adopting criteria into their water quality standards. EPA encourages States and Tribes to consider local or regional data on POC and DOC because local or regional conditions may result in differences in POC or DOC

concentrations compared with the values used as national defaults. Additional guidance on developing local or regional values of POC and DOC, including a database of POC and DOC values segregated by waterbody type, is found in the Bioaccumulation TSD.

b. **K_{ow} Value.** The value selected for the K_{ow} of the chemical of concern should be the same value used in earlier calculations (e.g., for calculating baseline BAF_{ℓ}^{fd}s and FCMs). Guidance for selecting the K_{ow} value is found in the Bioaccumulation TSD.

5.4.4 Deriving National BAFs Using Procedure #2

This section provides guidance for calculating national BAFs for nonionic organic chemicals using Procedure #2 shown in Figure 5-1. The types of nonionic organic chemicals for which Procedure #2 is most appropriate are those that are classified as moderately to highly hydrophobic and subject to high rates of metabolism by aquatic biota (see Section 5.4.2 above). Non-aqueous contaminant exposure and subsequent biomagnification in aquatic food webs are not generally of concern for chemicals that are classified in this category. As a result, FCMs are not used in this procedure. In addition, K_{ow} -based predictions of bioconcentration are not used in this procedure since the K_{ow} /BCF relationship is primarily based on poorly metabolized chemicals. Some nonionic organic chemicals for which Procedure #2 is probably appropriate include certain PAHs which are believed to be metabolized substantially by fish (e.g., benzo[a]pyrene, phenanthrene, fluoranthene, pyrene, benzo[a]anthracene and chrysene/triphenylene; USEPA, 1980; Burkhard and Lukasewycz, 2000).

According to Procedure #2, the following three methods can be used in deriving a national BAF:

- using a BAF from an acceptable field study (i.e., a field-measured BAF) (method 1),
- predicting a BAF from an acceptable BSAF (method 2), and
- predicting a BAF from an acceptable BCF (method 3).

Each of these three methods relies on measured data for assessing bioaccumulation and therefore, includes the effects of chemical metabolism by the study organism in the BAF estimate. The field-measured BAF and BSAF methods also incorporate any metabolism which occurs in the aquatic food web.

As shown in Figure 5-2, the next steps in deriving a national BAF after selecting the derivation procedure are: (1) calculating individual baseline BAF_{ℓ}^{fd}s, (2) selecting the final baseline BAF_{ℓ}^{fd}s, and (3) calculating the national BAFs. Each of these three steps is discussed separately below.

5.4.4.1 Calculating Individual Baseline BAF_{ℓ}^{fd}s

As described previously in Procedure #1, calculating individual baseline BAF_{ℓ}^{fd}s involves normalizing the measured BAF_{T}^{t} or BCF_{T}^{t} (which are based on the total chemical in water and

tissue) by the lipid content of the study organisms and the freely dissolved fraction of the chemical in the study water. Converting measured BAF_T^t (or BCF_T^t) values to baseline BAF_ℓ^{fd} (or BCF_ℓ^{fd}) values is designed to account for variation in measured BAF_T^ts that is caused by differences in lipid content of study organisms and differences in the freely dissolved fraction of chemical in study waters. Therefore, baseline BAF_ℓ^{fd}s are considered more amenable for extrapolating and averaging BAFs across different species and different study waters compared with total BAF_T^ts.

1. For each species where acceptable data are available, calculate all possible baseline BAF_ℓ^{fd}s using each of the three methods shown above for Procedure #2.

2. Individual baseline BAF_ℓ^{fd}s should be calculated from field-measured BAF_T^ts, field-measured BSAFs, and laboratory BCF_T^ts according to the following procedures.

A. Baseline BAF_ℓ^{fd} from Field-Measured BAFs

1. Except where noted below, a baseline BAF_ℓ^{fd} should be calculated from a field-measured BAF_T^t using the guidance and equations outlined in Section 5.4.3.1(A) for determining baseline BAF_ℓ^{fd}s from field-measured BAFs in Procedure #1.

2. Because nonionic organic chemicals applicable to Procedure #2 have relatively high rates of metabolism in aquatic organisms, they will tend to reach steady state more quickly than nonionic organic chemicals with similar K_{ow} values but which undergo little or no metabolism. Therefore, less temporal averaging of chemical concentrations would generally be required for determining field-measured BAF_T^ts with highly metabolizable chemicals compared with chemicals that are poorly metabolized by aquatic biota.

B. Baseline BAF_{ℓ}^{fd} Derived from Field-measured BSAFs

1. A baseline BAF_{ℓ}^{fd} should be calculated from a field-measured BSAF using the guidance and equations outlined in Section 5.4.3.1(B) for determining baseline BAF_{ℓ}^{fd}s from field-measured BSAFs in Procedure #1.

C. Baseline BAF_{ℓ}^{fd} from a Laboratory-Measured BCF

1. Except where noted below, a baseline BAF_{ℓ}^{fd} should be calculated from a laboratory-measured BCF_{T}^{t} using the guidance and equations outlined in Section 5.4.3.1(c) for determining baseline BAF_{ℓ}^{fd}s from a laboratory-measured BCF and FCM in Procedure #1.

2. Because biomagnification is not an overriding concern for nonionic organic chemicals applicable to Procedure #2, food chain multipliers are not used in the derivation of a baseline BAF_{ℓ}^{fd} from a laboratory-measured BCF_{T}^{t} .

5.4.4.2 Selecting Final Baseline BAF_{ℓ}^{fd}s

After calculating individual, baseline BAF_{ℓ}^{fd}s using as many of the methods in Procedure #2 as possible, the next step is to determine a final baseline BAF_{ℓ}^{fd} for each trophic level from the individual baseline BAF_{ℓ}^{fd}s. The final baseline BAF_{ℓ}^{fd} will be used in the last step to determine the national BAF for each trophic level. A final baseline BAF_{ℓ}^{fd} for each trophic level should be determined from the individual baseline BAF_{ℓ}^{fd}s by considering the data preference hierarchy defined by Procedure #2 and uncertainty in the data. The data preference hierarchy for Procedure #2 is (in order of preference):

1. a baseline BAF_{ℓ}^{fd} from an acceptable field-measured BAF (method 1),
2. a baseline BAF_{ℓ}^{fd} from an acceptable field-measured BSAF (method 2), or
3. a baseline BAF_{ℓ}^{fd} from an acceptable laboratory-measured BCF (method 3).

This data preference hierarchy reflects EPA's preference for BAFs based on field-measurements of bioaccumulation (methods 1 and 2) over those based on laboratory-measurements (method 3). However, as explained in Procedure #1, this data preference hierarchy should not be considered inflexible. Rather, it should be used as a guide for selecting the final baseline BAF_{ℓ}^{fd}s when the underlying uncertainty is similar among two or more baseline BAF_{ℓ}^{fd}s derived using different methods. Although biomagnification is not generally a concern for chemicals subject to Procedure #2, trophic level differences in bioaccumulation might be substantial to the extent that the rate of chemical metabolism by organisms in different trophic levels differs. For example, certain PAHs have been shown to be metabolized to a much greater extent by some fish compared with some invertebrate species (James, 1989). Therefore, final baseline BAF_{ℓ}^{fd}s for chemicals applicable to Procedure #2 should be determined on a trophic-level-specific basis according to the following guidelines.

1. The final baseline BAF_{ℓ}^{fd}s in Procedure #2 should be selected according to the same steps described in Procedure #1 but with the substitution of the data preference hierarchy described above for Procedure #2. Specifically, the species-mean baseline BAF_{ℓ}^{fd}s,

trophic-level-mean baseline BAF_{ℓ}^{fd}s, and the final baseline BAF_{ℓ}^{fd}s should be determined according to the guidelines presented in Procedure #1 (Section 5.4.3.2, Steps 1, 2, and 3).

5.4.4.3 Calculating the National BAFs

As described in Procedure #1, the last step in deriving national BAFs for nonionic organic chemicals is to convert the final baseline BAF_{ℓ}^{fd}s determined in the previous step to BAFs which reflect conditions to which the national 304(a) criteria will apply (Figure 5-2).

1. For trophic levels two, three, and four, national BAFs should be calculated from the final baseline BAF_{ℓ}^{fd}s using the same equation and procedures described previously in Procedure #1 (see Section 5.4.3.3 entitled "Calculating the National BAFs").

5.4.5 Deriving National BAFs Using Procedure #3

This section provides guidance for calculating national BAFs for nonionic organic chemicals using Procedure #3 shown in Figure 5-1. The types of nonionic organic chemicals for which Procedure #3 is most appropriate are those that are classified as low in hydrophobicity (i.e., log K_{ow} values less than 4.0) and subject to low (or unknown) rates of metabolism by aquatic biota (see Section 5.4.2 above). Non-aqueous contaminant exposure and subsequent biomagnification in aquatic food webs are not generally of concern for chemicals that are classified in this category (Fisk et al., 1998; Gobas et al., 1993; Connolly and Pedersen, 1988; Thomann, 1989). As a result, FCMs are not used in this procedure.

According to Procedure #3, the following three methods can be used in deriving a national BAF:

- using a BAF from an acceptable field study (i.e., a field-measured BAF),
- predicting a BAF from an acceptable laboratory-measured BCF, and
- predicting a BAF from an acceptable K_{ow}.

After selecting the derivation procedure, the next steps in deriving a national BAF at a given trophic level for nonionic organic chemicals are: (1) calculating individual baseline BAF_{ℓ}^{fd}s, (2) selecting the final baseline BAF_{ℓ}^{fd}, and (3) calculating the national BAF (Figure 5-2). Each of these three steps is discussed separately below.

5.4.5.1 Calculating Individual Baseline BAF_{ℓ}^{fd}s

Calculating individual baseline BAF_{ℓ}^{fd}s involves normalizing each measured BAF_{T}^{t} or BCF_{T}^{t} (which are based on the total chemical in water and tissue) by the lipid content of the study organism and the freely dissolved fraction of the chemical in the study water. For additional discussion of the technical basis for calculating baseline BAF_{ℓ}^{fd}s, see Section 5.4.3.1 in Procedure #1.

1. For each species where acceptable data are available, calculate all possible baseline BAF_{ℓ}^{fd}s using each of the three methods shown above for Procedure #3.

2. An individual baseline BAF_{ℓ}^{fd} should be calculated from field-measured BAF_{T}^{t}s, laboratory-measured BCF_{T}^{t}s, and K_{ow} values according to the following procedures.

A. Baseline BAF_{ℓ}^{fd} from Field-Measured BAFs

1. Except where noted below, a baseline BAF_{ℓ}^{fd} should be calculated from a field-measured BAF_{T}^{t} using the guidance and equations outlined in Section 5.4.3.1(A) in Procedure #1.

2. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log $K_{ow} < 4.0$), nonionic organic chemicals applicable to Procedure #3 are expected to remain almost entirely in the freely dissolved form in natural waters with dissolved and particulate organic carbon concentrations typical of most field BAF studies. Therefore, the freely dissolved fraction should be assumed to be equal to 1.0, unless the concentrations of DOC and POC are very high in the field BAF study. For studies with very high DOC or POC concentrations, (e.g., about 100 mg/L or higher for DOC or 10 mg/L or higher for POC), the freely dissolved fraction may be substantially lower than 1.0 and therefore should be calculated using Equation 5-12.

3. **Temporal Averaging of Concentrations.** Also due to their low hydrophobicity, nonionic organic chemicals appropriate to Procedure #3 will also tend to reach steady state quickly compared with those chemicals to which Procedure #1 applies. Therefore, the extent of temporal averaging of tissue and water concentrations is typically much less than that required for highly hydrophobic chemicals to which Procedure #1 is applied. In addition, field studies used to calculate BAFs for these chemicals should have sampled water and tissue at similar points in time because tissue concentrations respond more rapidly to changes in water concentrations. EPA will be providing additional guidance on appropriate BAF study designs for nonionic organic chemicals (including those appropriate to Procedure #3) in its forthcoming guidance document on conducting field BAF and BSAF studies.

B. Baseline BAF_{ℓ}^{fd} from a Laboratory-Measured BCF

1. Except where noted below, a baseline BAF_{ℓ}^{fd} should be calculated from a laboratory-measured BCF_{T}^{t} using the guidance and equations outlined in Section 5.4.3.1(c) of Procedure #1.

2. **Food Chain Multipliers.** Because biomagnification is not an overriding concern for the minimally hydrophobic chemicals applicable to Procedure #3, FCMs are not used in the derivation of a baseline BAF_{ℓ}^{fd} from a laboratory-measured BCF_{T}^{t}.

3. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log $K_{ow} < 4.0$), nonionic organic chemicals to which Procedure #3 is applied are expected to remain

almost entirely in the freely dissolved form in waters containing dissolved and particulate organic carbon concentrations typical of laboratory BCF studies. Therefore, the freely dissolved fraction should usually be assumed equal to 1.0. The freely dissolved fraction will be substantially less than 1.0 only in situations where unusually high concentrations of DOC and POC are present in the laboratory BCF study (e.g., above about 100 mg/L for DOC or about 10 mg/L for POC). In this situation, the freely dissolved fraction should be calculated according to Equation 5-12.

C. Baseline BAF_{ℓ}^{fd} from a K_{ow}

1. Except where noted below, a baseline BAF_{ℓ}^{fd} should be calculated from an acceptable K_{ow} using the guidance and equations outlined in Section 5.4.3.1(D) in Procedure #1.

2. Because biomagnification is not an overriding concern for nonionic organic chemicals with low hydrophobicity (i.e., log K_{ow} < 4.0), food chain multipliers are not used in Procedure #3 for deriving the baseline BAF_{ℓ}^{fd} from a K_{ow}.

5.4.5.2 Selecting Final Baseline BAF_{ℓ}^{fd}s

After calculating individual baseline BAF_{ℓ}^{fd}s using as many of the methods in Procedure #3 as possible, the next step is to determine a final baseline BAF_{ℓ}^{fd} for each trophic level from the individual baseline BAF_{ℓ}^{fd}s (Figure 5-2). The final baseline BAF_{ℓ}^{fd} will be used in the last step to determine the national BAF for each trophic level. The final baseline BAF_{ℓ}^{fd} for each trophic level should be determined from the individual baseline BAF_{ℓ}^{fd}s by considering the data preference hierarchy defined by Procedure #3 and uncertainty in the data. The data preference hierarchy for Procedure #3 is (in order of preference):

1. a baseline BAF_{ℓ}^{fd} from an acceptable field-measured BAF or laboratory-measured BCF, or
2. a baseline BAF_{ℓ}^{fd} predicted from an acceptable K_{ow} value.

This data preference hierarchy reflects EPA's preference for BAFs that are based on measured data (field-measured BAFs and laboratory-measured BCFs) over BAFs based on predictive methods (K_{ow}). This data preference hierarchy should be used as a guide for selecting the final baseline BAF_{ℓ}^{fd}s when the uncertainty is similar among two or more baseline BAF_{ℓ}^{fd}s derived using different methods. Since bioaccumulation via dietary uptake and subsequent biomagnification generally are not of concern for chemicals subject to Procedure #3, field-measured BAFs and laboratory-measured BCFs are considered equally in determining the national BAF.

Final baseline BAF_{ℓ}^{fd}s should be selected for each trophic level using the following steps and guidelines.

1. **Calculate Species-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method (i.e., field-measured BAF, BAF from a lab-measured BCF, or BAF from a K_{ow}) where more than one

acceptable baseline BAF_{ℓ}^{fd} is available for a given species, calculate a species-mean baseline BAF_{ℓ}^{fd} according to the guidance described previously in Procedure #1.

2. **Calculate Trophic-Level-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method where more than one acceptable species-mean baseline BAF_{ℓ}^{fd} is available within a given trophic level, calculate the trophic-level-mean baseline BAF_{ℓ}^{fd} as the geometric mean of acceptable species-mean baseline BAF_{ℓ}^{fd}s in that trophic level.

3. **Select a Final Baseline BAF_{ℓ}^{fd} for Each Trophic Level.** For each trophic level, select the final baseline BAF_{ℓ}^{fd} using best professional judgment by considering: (1) the data preference hierarchy, (2) the relative uncertainties among trophic-level-mean baseline BAF_{ℓ}^{fd}s derived using different methods, and (3) the weight of evidence among the three methods.

    a. In general, when more than one trophic-level-mean baseline BAF_{ℓ}^{fd} is available within a given trophic level, the final baseline BAF_{ℓ}^{fd} should be selected from the most preferred BAF method defined by the data preference hierarchy for Procedure #3. Within the first data preference tier, field-measured BAFs and laboratory-measured BCFs are considered equally desirable for deriving a final trophic-level-mean baseline BAF_{ℓ}^{fd} using Procedure #3. If a trophic-level-mean baseline BAF_{ℓ}^{fd} is available from both a field-measured BAF and a laboratory-measured BCF, the final baseline BAF_{ℓ}^{fd} should be selected using the trophic-level-mean baseline BAF_{ℓ}^{fd} or BCF_{ℓ}^{fd} with the least overall uncertainty.

    b. If uncertainty in a trophic-level-mean baseline BAF_{ℓ}^{fd} based on a higher tier (more preferred) method is judged to be substantially greater than a trophic-level-mean baseline BAF_{ℓ}^{fd} from a lower tier method, then the final baseline BAF_{ℓ}^{fd} should be selected using a trophic-level-mean baseline BAF_{ℓ}^{fd} from a lower tier method.

    c. The above steps should be performed for each trophic level until a final baseline BAF_{ℓ}^{fd} is selected for trophic level two, three, and four.

5.4.5.3 Calculating the National BAFs

As described in Procedure #1, the last step in deriving a national BAF for a given trophic level for nonionic organic chemicals is to convert the final baseline BAF_{ℓ}^{fd} determined in the previous step to a BAF that reflect conditions to which the national 304(a) criterion will apply (Figure 5-2). Each national BAF should be determined from a final baseline BAF_{ℓ}^{fd} according to the following guidelines.

1. **National BAF Equation.** Except where noted below, national BAFs for trophic levels two, three, and four should be calculated from the final, trophic-level-mean baseline BAF_{ℓ}^{fd}s using Equation 5-28 and associated guidance described in Procedure #1 (see Section 5.4.3.3).

2. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log K_{ow} < 4.0), a freely dissolved fraction of 1.0 should be assumed for calculating national BAFs for nonionic organic chemicals using Procedure #3. A freely dissolved fraction of 1.0 should be assumed because at a log K_{ow} of less than 4.0, nonionic organic chemicals are expected to remain over 99 percent in the freely dissolved form at POC and DOC concentrations corresponding to national default values for U.S. bodies of water (i.e., 0.5 mg/L and 2.9 mg/L, respectively).

5.4.6 Deriving National BAFs Using Procedure #4

This section provides guidance for calculating national BAFs for nonionic organic chemicals using Procedure #4 shown in Figure 5-1. The types of nonionic organic chemicals for which Procedure #4 is most appropriate are those that are classified as having low hydrophobicity and subject to high rates of metabolism by aquatic biota (see Section 5.4.2 above). Non-aqueous contaminant exposure and subsequent biomagnification in aquatic food webs are not generally of concern for chemicals that are classified in this category. As a result, FCMs are not used in this procedure. In addition, K_{ow} -based predictions of bioconcentration are not used in this procedure since the K_{ow} /BCF relationship is primarily based on poorly metabolized chemicals. One example of a nonionic organic chemical for which Procedure #4 appears appropriate is butyl benzyl phthalate in fish. Using radiolabeling techniques with confirmation by chromatographic analysis, Carr et al. (1997) present evidence that indicates butyl benzyl phthalate is extensively metabolized in sunfish. Carr et al. (1997) also report measured BCFs (and subsequently lipid-normalized BCFs) which are substantially below predicted BCFs based on log $K_{ow.}$ In a study of chlorinated anilines (which would be essentially un-ionized at ambient pH), de Wolf et al. (1992) reported measured BCFs substantially lower than those predicted based on K_{ow}. The authors suggested that biotransformation (metabolism) involving the amine (NH_2) was responsible for the lower measured BCFs.

According to Procedure #4, the following two methods can be used in deriving a national BAF:

- using a BAF from an acceptable field study (i.e., a field-measured BAF), and
- predicting a BAF from an acceptable BCF.

After selecting the derivation procedure, the next steps in deriving a national BAF for a given trophic level for nonionic organic chemicals are: (1) calculating individual baseline BAF_{ℓ}^{fd}s, (2) selecting the final baseline BAF_{ℓ}^{fd}, and (3) calculating the national BAF (Figure 5-2). Each of these three steps is discussed separately below.

5.4.6.1 Calculating Individual Baseline BAF_{ℓ}^{fd}s

Calculating individual baseline BAF_{ℓ}^{fd}s involves normalizing the measured BAF_T^t or BCF_T^t (which are based on the total chemical in water and tissue) by the lipid content of the study organism and the freely dissolved fraction of the chemical in the study water. For additional discussion of the technical basis for calculating baseline BAF_{ℓ}^{fd}s, see Section 5.4.3.1 in Procedure #1.

1. For each species where acceptable data are available, calculate all possible baseline BAF_{ℓ}^{fd}s using each of the two methods shown above for Procedure #4.

2. Individual baseline BAF_{ℓ}^{fd}s should be calculated from field-measured BAF_{T}^{t}s and laboratory-measured BCF_{T}^{t}s according to the following procedures.

A. Baseline BAF_{ℓ}^{fd} from Field-Measured BAFs

1. A baseline BAF_{ℓ}^{fd} should be calculated from a field-measured BAF_{T}^{t} using the guidance and equations outlined in Section 5.4.3.1(A) in Procedure #1.

2. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log K_{ow} < 4.0), nonionic organic chemicals applicable to Procedure #4 are expected to remain almost entirely in the freely dissolved form in natural waters with dissolved and particulate organic carbon concentrations typical of most field BAF studies. Therefore, the freely dissolved fraction should be assumed equal to 1.0 unless the concentrations of DOC and POC are very high in the field BAF study. For studies with very high DOC or POC concentrations, (e.g., about 100 mg/L or higher for DOC or 10 mg/L or higher for POC), the freely dissolved fraction may be substantially lower than 1.0 and therefore should be calculated using Equation 5-12.

3. **Temporal Averaging of Concentrations.** Also due to their low hydrophobicity, nonionic organic chemicals appropriate to Procedure #4 will also tend to reach steady-state quickly compared with those chemicals to which Procedure #1 applies. Therefore, the extent of temporal averaging of tissue and water concentrations is typically much less than that required for highly hydrophobic chemicals to which Procedure #1 is applied. In addition, field studies used to calculate BAFs for these chemicals should have sampled water and tissue at similar points in time because tissue concentrations should respond rapidly to changes in water concentrations. EPA will be providing additional guidance on appropriate BAF study designs for nonionic organic chemicals (including those appropriate to Procedure #4) in its forthcoming guidance document on conducting field BAF and BSAF studies.

B. Baseline BAF_{ℓ}^{fd} from a Laboratory-Measured BCF

1. Except where noted below, a baseline BAF_{ℓ}^{fd} should be calculated from a laboratory-measured BCF_{T}^{t} using the guidance and equations outlined in Section 5.4.3.1(c) of Procedure #1.

2. **Food Chain Multipliers.** Because biomagnification is not an important concern for the minimally hydrophobic chemicals applicable to Procedure #4, FCMs are not used in the derivation of a baseline BAF_{ℓ}^{fd} from a laboratory-measured BCF_{T}^{t}.

3. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log K_{ow} < 4.0), nonionic organic chemicals to which Procedure #4 is applied are expected to remain

almost entirely in the freely dissolved form in waters containing dissolved and particulate organic carbon concentrations typical of laboratory BCF studies. Therefore, the freely dissolved fraction should usually be assumed to be equal to 1.0. The freely dissolved fraction will be substantially less than 1.0 only in situations where unusually high concentrations of DOC and POC are present in the lab BCF study (e.g., above about 100 mg/L for DOC or about 10 mg/L for POC). In this situation, the freely dissolved fraction should be calculated according to Equation 5-12.

5.4.6.2 Selecting Final Baseline BAF_{ℓ}^{fd}s

After calculating individual baseline BAF_{ℓ}^{fd}s using as many of the methods in Procedure #4 as possible, the next step is to determine a final baseline BAF_{ℓ}^{fd} for a given trophic level from the individual baseline BAF_{ℓ}^{fd}s (Figure 5-2). The final baseline BAF_{ℓ}^{fd} will be used in the last step to determine the national BAF for each trophic level. A final baseline BAF_{ℓ}^{fd} should be determined for each trophic level from the individual baseline BAF_{ℓ}^{fd}s by considering the data preference hierarchy defined by Procedure #4 and uncertainty in the data. The data preference hierarchy for Procedure #4 is:

1. a baseline BAF_{ℓ}^{fd} from an acceptable field-measured BAF or predicted from an acceptable laboratory-measured BCF.

Since bioaccumulation via dietary uptake and subsequent biomagnification generally are not of concern for chemicals subject to Procedure #4, field-measured BAFs and laboratory-measured BCFs are considered equally in determining the national BAF.

Final baseline BAF_{ℓ}^{fd}s should be selected for each trophic level using the following steps and guidelines.

1. **Calculate Species-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method (i.e., field-measured BAF or a BAF from a lab-measured BCF) where more than one acceptable baseline BAF_{ℓ}^{fd} is available for a given species, calculate a species-mean baseline BAF_{ℓ}^{fd} according to the guidance described previously in Procedure #1.

2. **Calculate Trophic-Level-Mean Baseline BAF_{ℓ}^{fd}s.** For each BAF method where more than one acceptable species-mean baseline BAF_{ℓ}^{fd} is available within a given trophic level, calculate the trophic-level-mean baseline BAF_{ℓ}^{fd} as the geometric mean of acceptable species-mean baseline BAF_{ℓ}^{fd}s for that trophic level.

3. **Select a Final Baseline BAF_{ℓ}^{fd} for Each Trophic Level.** For each trophic level, select the final baseline BAF_{ℓ}^{fd} using best professional judgment by considering: (1) the data preference hierarchy, and (2) the relative uncertainties among trophic-level-mean BAFs derived using different methods.

    a. As discussed above, field-measured BAFs and laboratory-measured BCFs are considered equally desirable for deriving a final trophic-level-mean baseline

BAF_{ℓ}^{fd} using Procedure #4. If a trophic-level-mean baseline BAF_{ℓ}^{fd} is available from both a field-measured BAF and a laboratory-measured BCF, the final baseline BAF_{ℓ}^{fd} should be selected using the trophic-level-mean baseline BAF_{ℓ}^{fd} or BCF_{ℓ}^{fd} with the least overall uncertainty.

b. The above steps should be performed for each trophic level until a final baseline BAF_{ℓ}^{fd} is selected for trophic levels two, three, and four.

5.4.6.3 Calculating National BAFs

As described in Procedure #1, the last step in deriving a national BAF for a given trophic level for nonionic organic chemicals is to convert the final baseline BAF_{ℓ}^{fd} determined in the previous step to a BAF that reflects conditions to which the national 304(a) criterion will apply (Figure 5-2). Each national BAF should be determined from a final baseline BAF_{ℓ}^{fd} according to the following guidelines.

1. **National BAF Equation.** Except where noted below, national BAFs for trophic-levels two, three, and four should be calculated from the final, trophic-level-mean baseline BAF_{ℓ}^{fd}s using the same equation and procedures described previously in Procedure #1 (see Section 5.4.3.3 in Procedure #1).

2. **Freely Dissolved Fraction**. Due to their low hydrophobicity (i.e., log $K_{ow} < 4.0$), a freely dissolved fraction of 1.0 should be assumed for calculating national BAFs for nonionic organic chemicals using Procedure #4. A freely dissolved fraction of 1.0 should be assumed because at a log K_{ow} value of less than 4.0, nonionic organic chemicals are expected to remain over 99 percent in the freely dissolved form at POC and DOC concentrations corresponding to national default values for U.S. bodies of water (i.e., 0.5 mg/L and 2.9 mg/L, respectively).

5.5 NATIONAL BIOACCUMULATION FACTORS FOR IONIC ORGANIC CHEMICALS

This section contains guidelines for deriving national BAFs for ionic organic chemicals (i.e., organic chemicals which undergo significant ionization in water). As defined in Section 5.3.5, ionic organic chemicals contain functional groups which can either readily donate protons (e.g., organic acids with hydroxyl, carboxylic, and sulfonic groups) or readily accept protons (e.g., organic bases with amino and aromatic heterocyclic nitrogen groups). Some examples of ionic organic compounds include:

- chlorinated phenols (e.g., 2,4,6-trichlorophenol, pentachlorophenol),
- chlorinated phenoxyalkanoic acids (e.g., 2,4-dichlorophenoxyacetic acid [2,4-D]),
- nitrophenols (e.g., 2-nitrophenol, 2,4,6-trinitrophenol),
- cresols (e.g., 2,4-dinitro-*o*-cresol [DNOC]),
- pyridines (e.g., 2,4-dimethypyidine),
- aliphatic and aromatic amines (e.g., trimethylamine, aniline), and

- linear alkylbenzenesulfonate (LAS) surfactants.

Ionic organic chemicals are considered separately for deriving national BAFs because the anionic or cationic species of these chemicals behave much differently in the aquatic environment compared with their neutral (un-ionized) counterparts. The neutral species of ionic organic chemicals are thought to behave in a similar manner as nonionic organic compounds (e.g., partitioning to lipids and organic carbon as a function of hydrophobicity). However, the ionized (cationic, anionic) species exhibit a considerably more complex behavior involving multiple environmental partitioning mechanisms (e.g., ion exchange, electrostatic, and hydrophobic interactions) and a dependency on pH and other factors including ionic strength and ionic composition (Jafvert et al., 1990; Jafvert 1990; Schwarzenbach, et al., 1993). As a consequence, methods to predict the environmental partitioning of organic cations and anions are less developed and validated compared with methods for nonionic organic chemicals (Spacie, 1994; Suffet et al., 1994).

Given the current limitations in the state of the science for predicting the partitioning and bioaccumulation of the ionized species of ionic organic chemicals, procedures for deriving national BAFs for these chemicals differ depending on the extent to which the fraction of the total chemical is likely to be represented by the ionized (cationic, anionic) species in U.S. surface waters. When a significant fraction of the total chemical concentration is expected to be present as the ionized species in water, procedures for deriving the national BAF rely on empirical (measured) methods (i.e., Procedures #5 and 6 in Section 5.6). When an insignificant fraction of the total chemical is expected to be present as the ionized species (i.e., the chemical exists essentially in the neutral form), procedures for deriving the national BAF will follow those established for nonionic organic chemicals (e.g., Procedures #1 through #4 in Section 5.4). The following guidelines apply for assessing the occurrence of cationic and anionic forms at typical environmental pH ranges.

1. For the ionic organic chemical of concern, the dissociation constant, pK_a, should be compared to the range of pH values expected in fresh and estuarine waters of the U.S. At pH equal to the pK_a, 50% of the organic acid or base is expected to be present in the ionized species. The pH values for U.S. fresh and estuarine waters typically range between 6 and 9, although somewhat higher and lower values can occur in some bodies of water (e.g., acidic bogs and lakes, highly alkaline and eutrophic systems, etc.).

2. For organic acids, the chemical will exist almost entirely in its un-ionized form when pH is about 2 or more units below the pK_a. For organic bases, the chemical will exist almost entirely in its un-ionized form when pH is about 2 or more units above the pK_a. In these cases, the aqueous behavior of the chemical would be expected to be similar to nonionic organic chemicals. Therefore, national BAF should usually be derived using Procedures #1 through #4 in Section 5.4.

3. When pH is greater than the pK_a minus 2 for organic acids (or less than the pKa plus 2 for organic bases), the fraction of the total chemical that is expected to exist in its ionized form can become significant (i.e., $\geq$1% in the ionized). In these cases, the national BAF should usually be derived using Procedures #5 and #6 in Section 5.6.

4. In general, most organic acids (e.g., pentachlorophenol and silvex), exist primarily in the ionized form in ambient waters because their pK_a's (4.75 and 3.07, respectively) are much smaller than the pH of the ambient waters. Conversely, most organic bases, (e.g., aniline) exist mostly in the un-ionized form in ambient waters because their pK_a's (4.63 for aniline) are much smaller than the pH of the ambient waters.

5. The above guidelines are intended to be a general guide for deriving national BAFs for ionic organic chemicals, not an inflexible rule. Modifications to these guidelines should be considered on a case-by-case basis, particularly when such modifications are strongly supported by measured bioaccumulation or bioconcentration data. For example, initial models have been developed for predicting the solid and organic-phase partitioning of certain organic acids (e.g., Jafvert 1990, Jafvert et al., 1990). As these or other models become more fully developed and appropriately validated in the future, they should be considered in the development of national BAFs. In addition, since pH is a controlling factor for dissociation and subsequent partitioning of ionic organic chemicals, consideration should be given to expressing BAFs or BCFs as a function of pH (or other factors) where sufficient data exist to reliably establish such relationships.

5.6 NATIONAL BIOACCUMULATION FACTORS FOR INORGANIC AND ORGANOMETALLIC CHEMICALS

This section contains guidelines for deriving national BAFs for inorganic and organometallic chemicals as defined in Section 5.3.5. The derivation of BAFs for inorganic and organometallic chemicals differs in several ways from procedures for nonionic organic chemicals. First, lipid normalization of chemical concentrations in tissues does not generally apply for inorganic and organometallic chemicals. Thus, BAFs and BCFs cannot be extrapolated from one tissue to another based on lipid-normalized concentrations as is done for nonionic organic chemicals. Second, the bioavailability of inorganics and organometallics in water tends to be chemical-specific and thus, the techniques for expressing concentrations of nonionic organic chemicals based on the freely dissolved form do not generally apply. Third, at the present time there are no generic bioaccumulation models that can be used to predict BAFs for inorganic and organometallic chemicals as a whole, unlike the existence of K_{ow}-based models for nonionic organic chemicals. While some chemical-specific bioaccumulation models have been developed for inorganic and organometallic chemicals (e.g., Mercury Cycling Model by Hudson et. al, 1994), those models currently tend to require site-specific data for input to the model and are restricted to site-specific applications. As the models become more fully developed and validated in the future, they should be considered on a case-by-case basis in conjunction with the following procedures for deriving national BAFs.

5.6.1 Selecting the BAF Derivation Procedure

As shown in Figure 5-1, national BAFs can be derived using two procedures for inorganic and organometallic chemicals (Procedures #5 and #6). The choice of the BAF derivation procedure depends on whether or not the chemical undergoes biomagnification in aquatic food webs.

1. For many inorganic and organometallic chemicals, biomagnification does not occur and the BCF will be equal to the BAF. For these types of chemicals, Procedure #5 should be used to derive the national BAF. Procedure #5 considers BAFs and BCFs to be of equal value in determining the national BAF and does not require the use of FCMs with BCF measurements. Guidance for deriving BAFs using Procedure #5 is provided in Section 5.6.3.

2. For some inorganic and organometallic chemicals (e.g., methylmercury), biomagnification does occur and Procedure #6 should be used to determine the national BAF. Procedure #6 gives general preference to the use of field-measured BAFs over laboratory-measured BCFs and requires FCMs to be used with BCF measurements for predicting BAFs. Guidance for deriving BAFs using Procedure #6 is provided in Section 5.6.4.

3. Determining whether or not biomagnification occurs for inorganic and organometallic chemicals requires chemical-specific data on measured concentrations of the chemical in aquatic organisms and their prey. Concentrations in aquatic organisms that increase substantially at successive trophic levels of a food web suggest that biomagnification is

occurring. Concentrations in aquatic organisms that remain about the same or decrease at successive trophic levels of a food web suggest that biomagnification is not occurring. When comparing tissue concentrations for assessing biomagnification, care should be taken to ensure that the aquatic organisms chosen actually represent functional predator-prey relationships and that all major prey species are considered in the comparisons.

5.6.2 Bioavailability

The chemical-specific nature of inorganic and organometallic bioavailability is likely due in part to chemical-specific differences in several factors which affect bioavailability and bioaccumulation. These factors include differences in the mechanisms for chemical uptake by aquatic organisms (e.g., passive diffusion, facilitated transport, active transport), differences in sorption affinities to biotic and abiotic ligands, and differences in chemical speciation in water. Some inorganic and organometallic chemicals exist in multiple forms and valence states in aquatic ecosystems that can differ in their bioavailability to aquatic organisms and undergo conversions between forms. For example, selenium can exist in various forms in aquatic ecosystems, including inorganic selenite($^{+4}$) and selenate($^{+6}$) oxyanions, elemental selenium (^{0}) under reducing conditions (primarily in sediments), and organoselenium compounds of selenide ($^{-2}$). Dominant forms of mercury in natural, oxic waters include inorganic ($^{+2}$) mercury compounds and methylmercury; the latter is generally considered to be substantially more bioavailable than inorganic mercury compounds to higher trophic level organisms. Although a generic analogue to the "freely dissolved" conversion for nonionic organic chemicals does not presently exist for inorganic and organometallic chemicals as a whole, the occurrence and bioavailability of different forms of these chemicals should be carefully considered when deriving national BAFs.

1. If data indicate that: (1) a particular form (or multiple forms) of the chemical of concern largely governs its bioavailability to target aquatic organisms, and (2) BAFs are more reliable when derived using the bioavailable form(s) compared with using other form(s) of the chemical of concern, then BAFs and BCFs should be based on the appropriate bioavailable form(s).

2. Because different forms of many inorganic and organometallic chemicals may interconvert once released to the aquatic environment, regulatory and mass balance considerations typically require an accounting of the total concentration in water. In these cases, sufficient data should be available to enable conversion between total concentrations and the other (presumably more bioavailable) forms in water.

5.6.3 Deriving BAFs Using Procedure #5

This section contains guidance for calculating national BAFs for inorganic and organometallic chemicals using Procedure #5 as shown in Figure 5-1. The types of inorganic and organometallic chemicals for which Procedure #5 is appropriate are those that are not likely to biomagnify in aquatic food webs (see Section 5.1 above). In Procedure #5, two methods are available to derive the national BAF for a given trophic level:

- using a BAF from an acceptable field study (i.e., field-measured BAF), or
- predicting a BAF from an acceptable laboratory-measured BCF.

Individual BAFs should be determined from field-measured BAFs or laboratory-measured BCFs according to the following guidelines.

5.6.3.1 Determining Field-Measured BAFs

1. Except where noted below, field-measured BAFs should be determined using the guidance provided in Section 5.4.3.1(A) of Procedure #1.

2. As described previously, conversion of field-measured BAFs to baseline BAF_{ℓ}^{fd}s based on lipid-normalized and freely-dissolved concentrations does not apply for inorganic and organometallic chemicals. Therefore, the guidance and equations provided in Procedure #1 which pertain to converting field-measured BAFs to baseline BAF_{ℓ}^{fd}s and subsequently to national BAFs do not generally apply to inorganic chemicals. As discussed in Section 5.6.2 above, an analogous procedure in concept might be required for converting total BAFs to BAFs based on the most bioavailable form(s) for some inorganic and organometallic chemicals of concern. Such procedures should be applied on a chemical-specific basis.

3. BAFs should be expressed on a wet-weight basis; BAFs reported on a dry-weight basis can be used only if they are converted to a wet-weight basis using a conversion factor that is measured or reliably estimated for the tissue used in the determination of the BAF.

4. BAFs should be based on concentrations in the edible tissue(s) of the biota unless it is demonstrated that whole-body BAFs are similar to edible tissue BAFs. For some finfish and shellfish species, whole body is considered to be the edible tissue.

5. The concentrations of an inorganic or organometallic chemical in a bioaccumulation study should be greater than normal background levels and greater than levels required for normal nutrition of the test species if the chemical is a micronutrient, but below levels that adversely affect the species. Bioaccumulation of an inorganic or organometallic chemical that is essential to the nutrition of aquatic organisms might be overestimated if concentrations are at or below normal background levels due to selective accumulation by the organisms to meet their nutritional requirements.

5.6.3.2 Determining Laboratory-Measured BCFs

1. Except where noted below, BAFs should be predicted from laboratory-measured BCFs using the guidance provided in Section 5.4.3.1(c) of Procedure #1.

2. As described previously, conversion of laboratory-measured BCFs to baseline BCF_{ℓ}^{fd}s based on lipid-normalized and freely dissolved concentrations does not apply for inorganic and organometallic chemicals. Therefore, the guidance and equations provided in Procedure #1 which pertain to converting laboratory-measured BCFs to baseline BCF_{ℓ}^{fd}s and subsequently to national BCFs do not generally apply to inorganic and organometallic chemicals. As discussed in Section 5.6.2 above, an analogous procedure in concept might be required for converting total BCFs to BCFs based on the most bioavailable form(s) of some inorganic and organometallic chemicals of concern. Such procedures should be applied on a chemical-specific basis. In addition, the use of FCMs with BCFs does not apply to chemicals applicable to Procedure #5.

3. BCFs should be expressed on a wet-weight basis; BCFs reported on a dry-weight basis can be used only if they are converted to a wet-weight basis using a conversion factor that is measured or reliably estimated for the tissue used in the determination of the BCF.

4. BCFs should be based on concentrations in the edible tissue(s) of the biota unless it is demonstrated that whole-body BCFs are similar to edible tissue BCFs. For some finfish and shellfish species, whole body is considered to be the edible tissue.

5. The concentrations of an inorganic or organometallic chemical in a bioconcentration test should be greater than normal background levels and greater than levels required for normal nutrition of the test species if the chemical is a micronutrient, but below levels that adversely affect the species. Bioaccumulation of an inorganic or organometallic chemical that is essential to the nutrition of aquatic organisms might be overestimated if concentrations are at or below normal background levels due to selective accumulation by the organisms to meet their nutritional requirements.

5.6.3.3 Determining the National BAFs

After calculating individual BAFs using as many of the methods in Procedure #5 as possible, the next step is to determine national BAFs for each trophic level from the individual BAFs. The national BAFs will be used to determine the national 304(a) criteria. The national BAFs should be determined from the individual BAFs by considering the data preference hierarchy defined for Procedure #5 and uncertainty in the data. The data preference hierarchy for Procedure #5 is:

1. a BAF from an acceptable field-measured BAF or predicted from an acceptable laboratory-measured BCF.

Since bioaccumulation via dietary uptake and subsequent biomagnification are not of concern for chemicals subject to Procedure #5, field-measured BAFs and laboratory-measured

BCFs are considered equally in determining the national BAFs. The national BAFs should be selected for each trophic level using the following steps and guidelines.

1. **Calculate Species-Mean BAFs.** For each BAF method where more than one acceptable field-measured BAF (or a BAF predicted from a BCF) is available for a given species, calculate the species-mean BAF as the geometric mean of all acceptable individual measured or BCF-predicted BAFs. When calculating species-mean BAFs, individual measured or BCF-predicted BAFs should be reviewed carefully to assess uncertainties in the BAF values. Highly uncertain BAFs should not be used. Large differences in individual BAFs for a given species (e.g., greater than a factor of 10) should be investigated further and in such cases, some or all of the BAFs for a given species might not be used. Additional discussion on evaluating the acceptability of BAF and BCF values is provided in the Bioaccumulation TSD.

2. **Calculate Trophic-Level-Mean BAFs.** For each BAF method where more than one acceptable species-mean BAF is available within a given trophic level, calculate the trophic-level-mean BAF as the geometric mean of acceptable species-mean BAFs in that trophic level. Trophic-level-mean BAFs should be calculated for trophic levels two, three and four because available data on U.S. consumers of fish and shellfish indicate significant consumption of organisms in these trophic levels.

3. **Select a Final National BAF for Each Trophic Level.** For each trophic level, select the final national BAF using best professional judgment by considering: (1) the data preference hierarchy in Procedure #5, and (2) the relative uncertainties among trophic level-mean BAFs derived using different methods.

    a. As discussed above, field-measured BAFs and laboratory-measured BCFs are considered equally desirable for deriving a final national BAF using Procedure #5. If a trophic-level-mean BAF is available from both a field-measured BAF and a laboratory-measured BCF, the final national BAF should be selected using the trophic-level-mean BAF with the least overall uncertainty.

    b. The above steps should be performed for each trophic level until a national BAF is selected for trophic levels two, three, and four.

5.6.4 Deriving BAFs Using Procedure #6

This section contains guidance for calculating national BAFs for inorganic and organometallic chemicals using Procedure #6 as shown in Figure 5-1. The types of inorganic and organometallic chemicals for which Procedure #6 is appropriate are those that are considered likely to biomagnify in aquatic food webs (see Section 5.6.1 above). Methylmercury is an example of an organometallic chemical to which Procedure #6 applies. In Procedure #6, two methods are available to derive the national BAF:

- using a BAF from an acceptable field study (i.e., field-measured BAF), or

- predicting a BAF from an acceptable laboratory-measured BCF and a FCM.

Individual BAFs should be determined from field-measured BAFs or laboratory-measured BCFs and FCMs according to the following guidelines.

5.6.4.1 Determining Field-Measured BAFs

1. Field-measured BAFs should be determined using the guidance provided in Section 5.6.3.1 of Procedure #5.

5.6.4.2 Determining Laboratory-Measured BCFs

1. Except where noted below, BAFs should be predicted from laboratory-measured BCFs using the guidance provided in Section 5.6.3.2 of Procedure #5.

2. Because biomagnification is of concern for chemicals applicable to Procedure #6, BAFs should be predicted from laboratory-measured BCF using FCMs. Currently, there are no generic models from which to predict FCMs for inorganic or organometallic chemicals. Therefore, FCMs should be determined using field data as described in the section entitled: "Field-Derived FCMs" in Section 5.4.3.1(c) of Procedure #1. Unlike nonionic organic chemicals, field-derived FCMs for inorganic and organometallic chemicals are not based on lipid-normalized concentrations in tissues. For calculating FCMs for inorganic and organometallic chemicals, concentrations in tissues should be based on the consistent use of either wet-weight or dry-weight concentrations in edible tissues. FCMs should be derived for trophic levels two, three, and four.

5.6.4.3 Determining the National BAF

After calculating individual BAFs using as many of the methods in Procedure #6 as possible, the next step is to determine national BAFs for each trophic level from the individual BAFs. The national BAFs will be used to determine the national 304(a) criteria. The national BAFs should be determined from the individual BAFs by considering the data preference hierarchy defined for Procedure #6 and uncertainty in the data. The data preference hierarchy for Procedure #6 is (in order of preference):

1. a BAF from an acceptable field-measured BAF, or
2. a predicted BAF from an acceptable laboratory-measured BCF and FCM.

This data preference hierarchy reflects EPA's preference for field-measured BAFs over BAFs predicted from a laboratory-measured BCF and FCM, because field-measured BAFs are direct measures of bioaccumulation and biomagnification in aquatic food webs. BAFs predicted from laboratory-measured BCFs and FCMs indirectly account for biomagnification through the use of the FCM. For each trophic level, the national BAFs should be determined using the following steps and guidelines.

1. **Calculate Species-Mean BAFs.** For each BAF method where more than one acceptable field-measured BAF or BAF predicted using a BCF and FCM is available, calculate a species-mean BAF according to the guidance described previously in Procedure #5.

2. **Calculate Trophic Level-Mean BAFs.** For each BAF method where more than one acceptable species-mean BAF is available within a given trophic level, calculate the trophic level-mean BAF according to guidance described previously in Procedure #5.

3. **Select a Final National BAF for Each Trophic Level.** For each trophic level, select the final national BAF using best professional judgment by considering: (1) the data preference hierarchy in Procedure #6, and (2) the relative uncertainties among trophic level-mean BAFs derived using different methods.

    a. When a trophic-level mean BAF is available using both methods for a given trophic level (i.e., a field-measured BAF and a BAF predicted from a BCF and FCM), the national BAF should usually be selected using the field-measured BAF which is the preferred BAF method in the data preference hierarchy in Procedure #6.

    b. If uncertainty in the trophic-level mean BAF derived using field-measured BAFs is considered to be substantially greater than a trophic-level mean BAF derived using a BCF and FCM, the national BAF for that trophic level should be selected from the second tier (BCF · FCM) method.

    c. The above steps should be performed for each trophic level until a national BAF is selected for trophic levels two, three, and four.

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EPA United States Environmental Protection Agency

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Human Health Ambient Water Quality Criteria: 2015 Update

Summary

EPA published final updated ambient water quality criteria for the protection of human health for 94 chemical pollutants. These updated recommendations reflect the latest scientific information and EPA policies, including updated body weight, drinking water consumption rate, fish consumption rate, bioaccumulation factors, health toxicity values, and relative source contributions. EPA accepted written scientific views from the public from May to August 2014 on the draft updated human health criteria and has published responses to those comments. EPA water quality criteria serve as recommendations to states and tribes authorized to establish water quality standards under the Clean Water Act.

Background

Ambient water quality criteria developed by EPA under Clean Water Act section 304(a) represent specific levels of chemicals or conditions in a water body that are not expected to cause adverse effects to human health. EPA is required to develop and publish water quality criteria that reflect the latest scientific knowledge. These criteria are not rules, nor do they automatically become part of a state's water quality standards. States may adopt the criteria that EPA publishes, modify EPA's criteria to reflect site-specific conditions, or adopt different criteria based on other scientifically-defensible methods. EPA must, however, approve any new water quality standards adopted by a state before they can be used for Clean Water Act purposes.

In this 2015 update, EPA revised 94 of the existing human health criteria to reflect the latest scientific information, including updated exposure factors (body weight, drinking water consumption rates, fish consumption rate), bioaccumulation factors, and toxicity factors (reference dose, cancer slope factor). The criteria have also been updated to follow the current EPA methodology for deriving human health criteria (USEPA 2000). EPA also developed chemical-specific science documents for each of the 94 chemical pollutants. The science documents detail the latest scientific information supporting the updated final human health criteria, particularly the updated toxicity and exposure input values. Specific updates are described below.

Due to outstanding technical issues, EPA did not update human health criteria for the following chemical pollutants at this time: antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium (III or VI), copper, manganese, methylmercury, nickel, nitrates, nitrosamines, N-nitrosodibutylamine, N-nitrosodiethylamine, N-nitrosopyrrolidine, N-nitrosodimethylamine, N-nitrosodi-n-propylamine, N-nitrosodiphenylamine, polychlorinated biphenyls (PCBs), selenium, thallium, zinc, or 2,3,7,8-TCDD (dioxin).

It is important for states and authorized tribes to consider any new or updated section 304(a) criteria as part of their triennial review to ensure that state or tribal water quality standards reflect current science and protect applicable designated uses. EPA recently proposed revisions to its water quality

standards regulations that would, if finalized without substantive change, require states during their triennial reviews to consider new or updated section 304(a) recommended criteria and, if they do not adopt new or revised criteria for such pollutants, provide an explanation to EPA as to why the state did not do so. These final updated human health criteria recommendations supersede EPA's previous recommendations.

Updated Exposure Inputs

Body Weight

EPA updated the default body weight for human health criteria to 80 kilograms based on National Health and Nutrition Examination Survey (NHANES) data from 1999 to 2006 (USEPA 2011). This represents the mean body weight for adults ages 21 and older. EPA's previously recommended default body weight was 70 kilograms, which was based on the mean body weight of adults from the NHANES III database (1988-1994).

Drinking Water

EPA updated the default drinking water consumption rate to 2.4 liters per day based on NHANES data from 2003 to 2006 (USEPA 2011). This represents the per capita estimate of community water ingestion at the 90th percentile for adults ages 21 and older. EPA previously recommended a default drinking water consumption rate of 2 liters per day, which represented the per capita community water ingestion rate at the 86th percentile for adults surveyed in the US Department of Agriculture's 1994-1996 Continuing Survey of Food Intake by Individuals (CSFII) analysis and the 88th percentile of adults in the National Cancer Institute study of the 1977-1978 Nationwide Food Consumption Survey.

Fish Consumption

EPA updated the default fish consumption rate to 22 grams per day. This rate represents the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the U.S. adult population 21 years of age and older, based on NHANES data from 2003 to 2010 (USEPA 2014). EPA's previously recommended rate of 17.5 grams per day was based on the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the U.S. adult population and was derived from 1994-1996 CSFII data.

As described in EPA's human health criteria methodology (USEPA 2000), the level of fish consumption in highly exposed populations varies by geographical location. Therefore, EPA suggests a four preference hierarchy for states and authorized tribes that encourages use of the best local, state, or regional data available to derive fish consumption rates. EPA recommends that states and authorized tribes consider developing criteria to protect highly exposed population groups and use local or regional data in place of a default value as more representative of their target population group(s). The preferred hierarchy is: (1) use of local data; (2) use of data reflecting similar geography/ population groups; (3) use of data from national surveys; and (4) use of EPA's default consumption rates.

Bioaccumulation Factors

EPA's methodology for deriving human health criteria emphasizes using, when possible, measured or estimated bioaccumulation factors (BAFs), which account for chemical accumulation in aquatic organisms from all potential exposure routes (USEPA 2000). Unlike bioconcentration factors, BAFs account for more exposure pathways than direct water contact. As a result, the updated criteria will better represent exposures to pollutants that affect human health. In order to account for the variation in bioaccumulation that is due to trophic position of the organism, EPA's methodology (USEPA 2000) recommends that BAFs be determined and applied to three trophic levels of fish.

EPA selected BAFs using a framework for deriving national trophic level-specific BAFs (USEPA 2000; USEPA 2003). EPA used field-measured BAFs and laboratory-measured bioconcentration factors available from peer-reviewed, publicly available databases to develop national BAFs. If this information was not available, EPA selected octanol-water partition coefficients (Kow values) from peer-reviewed sources for use in calculating national BAFs. As an additional line of evidence, EPA reported model-estimated BAFs for every chemical based on

the Estimation Program Interface (EPI) Suite (USEPA 2012) to support the field-measured or predicted BAFs.

Updated Health Toxicity Values

EPA considered all available toxicity values for both noncarcinogenic and carcinogenic toxicological effects to develop the updated human health criteria. EPA's Integrated Risk Information System (IRIS) was the primary source for reference dose and cancer slope factors for this update. For some pollutants, however, more recent toxicity assessments were provided by EPA's Office of Water, EPA's Office of Pesticide Programs, and international or state agencies. EPA followed a systematic process to search for and select the toxicity values used to derive the final updated human health criteria for noncarcinogenic and carcinogenic effects.

Relative Source Contribution

EPA updated the human health criteria to reflect chemical-specific relative source contributions (RSC) ranging from 20 to 80 percent following the Exposure Decision Tree approach described in EPA's methodology (USEPA 2000). EPA recommends inclusion of an RSC when developing human health criteria for threshold non-carcinogens or non-linear carcinogens. The RSC allows a percentage of the reference dose's exposure to be attributed to ambient water and fish consumption (including fish and shellfish from inland and nearshore waters) when there are other potential exposure sources. The rationale for this approach is that the objective of the water quality criteria is to ensure that an individual's total exposure from all sources does not exceed the criteria. Exposures outside of the RSC include, but are not limited to, exposure to a particular pollutant from ocean fish consumption (not included in the fish consumption rate), non-fish food consumption (meats, poultry, fruits, vegetables, and grains), dermal exposure, and respiratory exposure.

Where can I find more information?

To access the Federal Register notice, the final updated criteria, and supporting documents visit EPA's National Recommended Human Health Criteria website at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/.

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Comparison of EPA's 2015 Final Updated Human Health AWQC and Previous AWQC
June 2015

Pollutant	CAS No.	2015 EPA Human Health AWQC for the Consumption of		Previous EPA Human Health AWQC for the Consumption of	
		Water + Organism (µg/L)	Organism Only (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
1,1,1-Trichloroethane	71-55-6	10,000	200,000	*	---
1,1,2,2-Tetrachloroethane	79-34-5	0.2	3	0.17	4
1,1,2-Trichloroethane	79-00-5	0.55	8.9	0.59	16
1,1-Dichloroethylene	75-35-4	300	20,000	330	7,100
1,2,4,5-Tetrachlorobenzene	95-94-3	0.03	0.03	0.97	1.1
1,2,4-Trichlorobenzene	120-82-1	0.071	0.076	35	70
1,2-Dichlorobenzene	95-50-1	1,000	3,000	420	1,300
1,2-Dichloroethane	107-06-2	9.9	650	0.38	37
1,2-Dichloropropane	78-87-5	0.90	31	0.5	15
1,2-Diphenylhydrazine	122-66-7	0.03	0.2	0.036	0.2
1,3-Dichlorobenzene	541-73-1	7	10	320	960
1,3-Dichloropropene	542-75-6	0.27	12	0.34	21
1,4-Dichlorobenzene	106-46-7	300	900	63	190
2,4,5-Trichlorophenol	95-95-4	300	600	1,800	3,600
2,4,6-Trichlorophenol	88-06-2	1.5	2.8	1.4	2.4
2,4-Dichlorophenol	120-83-2	10	60	77	290
2,4-Dimethylphenol	105-67-9	100	3,000	380	850
2,4-Dinitrophenol	51-28-5	10	300	69	5,300
2,4-Dinitrotoluene	121-14-2	0.049	1.7	0.11	3.4
2-Chloronaphthalene	91-58-7	800	1,000	1,000	1,600
2-Chlorophenol	95-57-8	30	800	81	150
2-Methyl-4,6-Dinitrophenol	534-52-1	2	30	13	280
3,3'-Dichlorobenzidine	91-94-1	0.049	0.15	0.021	0.028
3-Methyl-4-Chlorophenol	59-50-7	500	2,000	*	*
Acenaphthene	83-32-9	70	90	670	990
Acrolein	107-02-8	3	400	6	9

Comparison of EPA's 2015 Final Updated Human Health AWQC and Previous AWQC
June 2015

Pollutant	CAS No.	2015 EPA Human Health AWQC for the Consumption of		Previous EPA Human Health AWQC for the Consumption of	
		Water + Organism (µg/L)	Organism Only (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
Acrylonitrile	107-13-1	0.061	7.0	0.051	0.25
Aldrin	309-00-2	0.00000077	0.00000077	0.000049	0.00005
alpha-Hexachlorocyclohexane (HCH)	319-84-6	0.00036	0.00039	0.0026	0.0049
alpha-Endosulfan	959-98-8	20	30	62	89
Anthracene	120-12-7	300	400	8,300	40,000
Benzene	71-43-2	0.58 - 2.1	16 - 58	0.61 - 2.2	14 - 51
Benzidine	92-87-5	0.00014	0.011	0.000086	0.0002
Benzo(a)anthracene	56-55-3	0.0012	0.0013	0.0038	0.018
Benzo(a)pyrene	50-32-8	0.00012	0.00013	0.0038	0.018
Benzo(b)fluoranthene	205-99-2	0.0012	0.0013	0.0038	0.018
Benzo(k)fluoranthene	207-08-9	0.012	0.013	0.0038	0.018
beta-Hexachlorocyclohexane (HCH)	319-85-7	0.0080	0.014	0.0091	0.017
beta-Endosulfan	33213-65-9	20	40	62	89
Bis(2-Chloro-1-Methylethyl) Ether	108-60-1	200	4,000	1,400	65,000
Bis(2-Chloroethyl) Ether	111-44-4	0.030	2.2	0.03	0.53
Bis(2-Ethylhexyl) Phthalate	117-81-7	0.32	0.37	1.2	2.2
Bis(Chloromethyl) Ether	542-88-1	0.00015	0.017	0.0001	0.00029
Bromoform	75-25-2	7.0	120	4.3	140
Butylbenzyl Phthalate	85-68-7	0.10	0.10	1,500	1,900
Carbon Tetrachloride	56-23-5	0.4	5	0.223	1.6
Chlordane	57-74-9	0.00031	0.00032	0.0008	0.00081
Chlorobenzene	108-90-7	100	800	130	1,600
Chlorodibromomethane	124-48-1	0.80	21	0.4	13
Chloroform	67-66-3	60	2,000	5.7	470
Chlorophenoxy Herbicide (2,4-D)	94-75-7	1,300	12,000	100	---
Chlorophenoxy Herbicide (2,4,5-TP) [Silvex]	93-72-1	100	400	10	---

Comparison of EPA's 2015 Final Updated Human Health AWQC and Previous AWQC
June 2015

Pollutant	CAS No.	2015 EPA Human Health AWQC for the Consumption of		Previous EPA Human Health AWQC for the Consumption of	
		Water + Organism (µg/L)	Organism Only (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
Chrysene	218-01-9	0.12	0.13	0.0038	0.018
Cyanide	57-12-5	4	400	140	140
Dibenzo(a,h)anthracene	53-70-3	0.00012	0.00013	0.0038	0.018
Dichlorobromomethane	75-27-4	0.95	27	0.55	17
Dieldrin	60-57-1	0.0000012	0.0000012	0.000052	0.000054
Diethyl Phthalate	84-66-2	600	600	17,000	44,000
Dimethyl Phthalate	131-11-3	2,000	2,000	270,000	1,100,000
Di-n-Butyl Phthalate	84-74-2	20	30	2,000	4,500
Dinitrophenols	25550-58-7	10	1,000	69	5,300
Endosulfan Sulfate	1031-07-8	20	40	62	89
Endrin	72-20-8	0.03	0.03	0.059	0.06
Endrin Aldehyde	7421-93-4	1	1	0.29	0.3
Ethylbenzene	100-41-4	68	130	530	2,100
Fluoranthene	206-44-0	20	20	130	140
Fluorene	86-73-7	50	70	1,100	5,300
gamma-Hexachlorocyclohexane (HCH)	58-89-9	4.2	4.4	0.98	1.8
Heptachlor	76-44-8	0.0000059	0.0000059	0.000079	0.000079
Heptachlor Epoxide	1024-57-3	0.000032	0.000032	0.000039	0.000039
Hexachlorobenzene	118-74-1	0.000079	0.000079	0.00028	0.00029
Hexachlorobutadiene	87-68-3	0.01	0.01	0.44	18
Hexachlorocyclohexane (HCH)-Technical	608-73-1	0.0066	0.010	0.0123	0.0414
Hexachlorocyclopentadiene	77-47-4	4	4	40	1,100
Hexachloroethane	67-72-1	0.1	0.1	1.4	3.3
Indeno(1,2,3-cd)pyrene	193-39-5	0.0012	0.0013	0.0038	0.018
Isophorone	78-59-1	34	1,800	35	960
Methoxychlor	72-43-5	0.02	0.02	100	---

Comparison of EPA's 2015 Final Updated Human Health AWQC and Previous AWQC
June 2015

Pollutant	CAS No.	2015 EPA Human Health AWQC for the Consumption of		Previous EPA Human Health AWQC for the Consumption of	
		Water + Organism (µg/L)	Organism Only (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)
Methyl Bromide	74-83-9	100	10,000	47	1,500
Methylene Chloride	75-09-2	20	1,000	4.6	590
Nitrobenzene	98-95-3	10	600	17	690
Pentachlorobenzene	608-93-5	0.1	0.1	1.4	1.5
Pentachlorophenol	87-86-5	0.03	0.04	0.27	3
Phenol	108-95-2	4,000	300,000	10,000	860,000
p,p'-Dichlorodiphenyldichloroethane (DDD)	72-54-8	0.00012	0.00012	0.00031	0.00031
p,p'-Dichlorodiphenyldichloroethylene (DDE)	72-55-9	0.000018	0.000018	0.00022	0.00022
p,p'-Dichlorodiphenyltrichloroethane (DDT)	50-29-3	0.000030	0.000030	0.00022	0.00022
Pyrene	129-00-0	20	30	830	4,000
Tetrachloroethylene (Perchloroethylene)	127-18-4	10	29	0.69	3.3
Toluene	108-88-3	57	520	1,300	15,000
Toxaphene	8001-35-2	0.00070	0.00071	0.00028	0.00028
trans-1,2-Dichloroethylene (DCE)	156-60-5	100	4,000	140	10,000
Trichloroethylene (TCE)	79-01-6	0.6	7	2.5	30
Vinyl Chloride	75-01-4	0.022	1.6	0.025	2.4

*AWQC for this chemical were not provided in EPA's previous update.

Technical Report

San Francisco Bay Seafood Consumption Report

This study was conducted by

Environmental Health Investigators Branch (EHIB)
of the California Department of Health Services

Impact Assessment Incorporated

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San Francisco Bay
Seafood Consumption Study

I. Background/Goals

A. Overview

Elevated levels of mercury and organochlorine compounds in fish from San Francisco Bay have raised public concern regarding potential health risks to those who catch and consume fish from the Bay. In response to this concern, the Regional Monitoring Program for Trace Substances (RMP) decided to conduct a comprehensive Seafood Consumption Study of people who catch and consume fish and shellfish from the Bay. The San Francisco Estuary Institute (SFEI), which administers the RMP, contracted with the Environmental Health Investigations Branch (EHIB) of the California Department of Health Services and Impact Assessment, Inc. to conduct this study. Information gathered through the study will be used to assess anglers' exposures to chemicals from eating Bay fish and to identify highly exposed populations. Additionally, the findings will provide information for improving outreach and education to different segments of the fishing population and for guiding contaminant studies to monitor fish that people consume.

B. Study Area

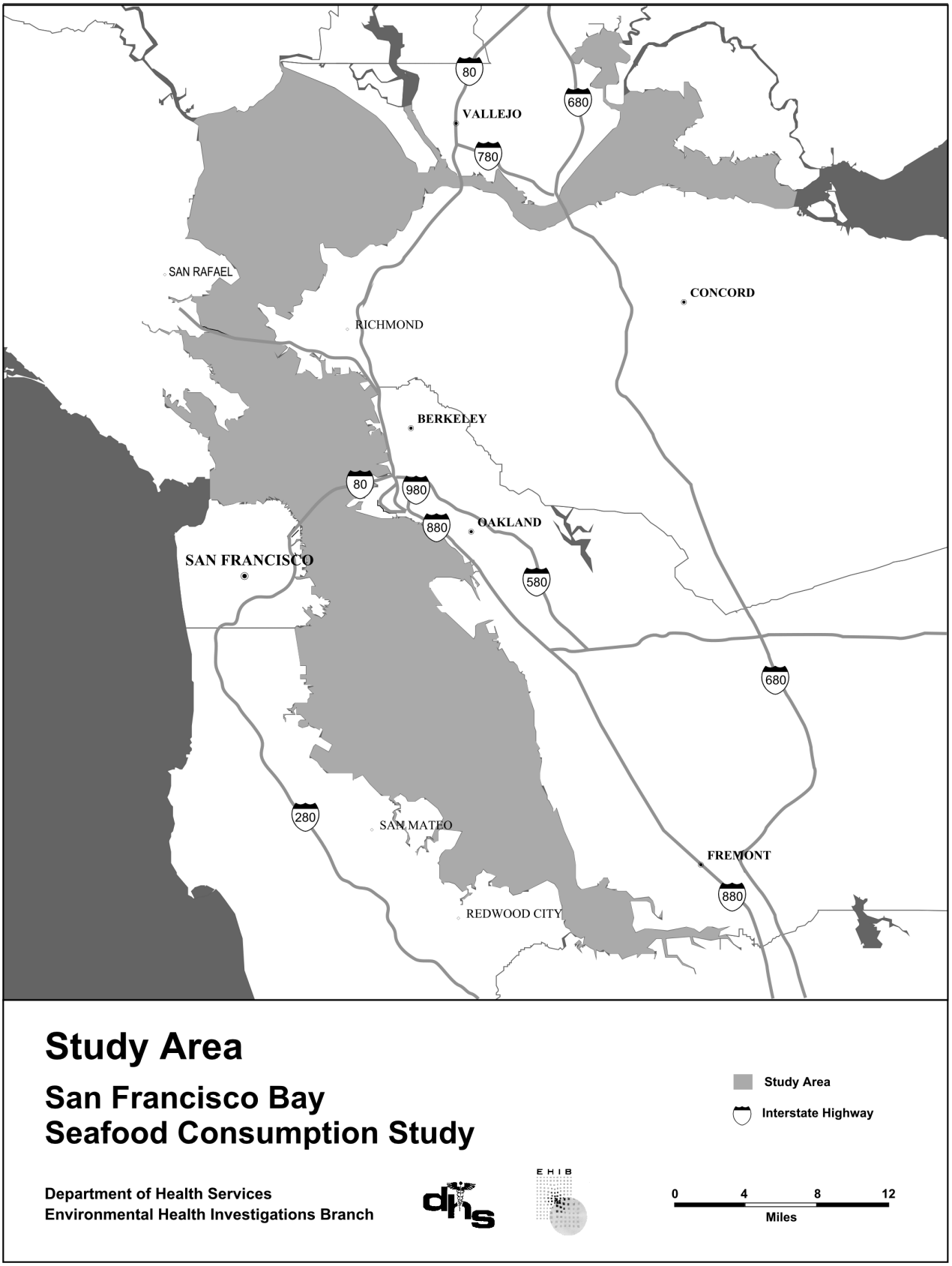
San Francisco Bay (SF Bay) is an important recreational fishing area in California. The Bay covers 478 square miles (marine and estuarine waters) and the nine counties bordering the Bay support a population of over six million (ABAG 2000, CDOF 2000). The study area was defined to include the San Francisco Bay within the Golden Gate Bridge, including San Pablo Bay in the north (see Figure 1). To the east, the study area included the Carquinez Straits and Suisun Bay to Chipps Island (near the city of Pittsburg).

C. Study Justification

Nationwide, there is increasing analytical evidence and growing public concern that fish and shellfish caught and consumed by anglers may contain chemical contaminants that pose health risks (USEPA 1998). To quantify these risks, contaminant levels in fish and the consumption patterns of the fishing population must be understood. To date the Santa Monica Bay Study (Allen *et al.*1996, SCCWRP/MBC 1994) of a Los Angeles area population has provided the best available data set for estimating consumption of sport fish in a California population (Gassel 1997). However, the United States Environmental Protection Agency (USEPA 1998) recommends using or collecting data on regional consumption patterns and population characteristics in order to estimate exposure for the local population(s) of concern. Although several studies have begun to characterize levels of contaminants known to pose health risks in Bay fish (SFEI 1999, SFRWQCB 1995), information that describes the consumption patterns of Bay anglers has been more limited and mostly focused on selected populations (Karras 1998, Ujihara 1997, Wong *et al.*1997, Cohen 1995, EHIB 1994). Consumption patterns include the quantity of fish consumed over time, the species and the parts of the fish consumed, and the preparation and cooking methods used.

Furthermore, little is known about the demographic characteristics of the people who eat Bay fish and how well they understand health advisories for SF Bay fish. Demographic information is needed so that health advisories on fish may be communicated appropriately and effectively. Gathering both consumption and demographic information from people fishing in San Francisco Bay will enable outreach and educational efforts to target populations facing the highest health risks. Because comprehensive data on fish consumption patterns of SF Bay anglers did not exist, we undertook this study to provide this information.

Figure 1. Study Area



D. Goals and Objectives of the San Francisco Bay Seafood Consumption Study

Goals:

1. To gather quantitative data that can be used to characterize exposures of the general fishing population of San Francisco Bay to chemical contaminants from consumption of Bay-caught fish and shellfish
2. To identify highly exposed fish and shellfish consuming sub-populations
3. To gather information needed to develop educational messages for targeted sub-populations

Objectives:

1. Develop estimates of exposure assessment parameters (fish and shellfish consumption, frequency, duration of exposure, and portion size) for San Francisco Bay anglers
2. Characterize pier, boat, and shore fishing populations by age, sex, income, ethnic composition, education, mode of fishing, and consumption rates
3. Characterize consumption of fish tissues other than muscle, such as skin and organs, and preparation/cooking methods
4. Determine which species are most commonly consumed; assess frequency of consumption of white croaker, striped bass, and leopard shark
5. Characterize what people do with the fish they catch and the shellfish they harvest (e.g., release it, eat it themselves, share it with family or friends, etc.)
6. Characterize seasonal variation in consumption and demographics
7. Characterize frequency of consumption of fish from stores and markets, and of fish and shellfish obtained from fishing outside of San Francisco Bay (including freshwater and marine locations)
8. Assess awareness of current health advisories and changes in behavior as a result of awareness (e.g., decreased consumption)
9. Identify how people currently are informed about advisories and their preferred mechanisms for obtaining information
10. Identify anglers' reasons for catching and consuming fish and shellfish
11. Determine whether anglers think the term "sportfish" refers to the fish they catch from San Francisco Bay

E. Previous and Ongoing Studies and Outreach Activities

In 1994, the San Francisco Bay Regional Water Quality Control Board (Regional Board) conducted a pilot study to determine the levels of chemicals found in fish commonly caught in San Francisco Bay (SFBRWQCB 1995). Over 100 chemicals were measured, but only six (mercury, polychlorinated biphenyls (PCBs), dioxins, dieldrin, chlordane, and DDT) were found in concentrations of potential health concern to people who regularly consume fish from the Bay. Of the eight species of fish sampled, white croaker, commonly referred to as kingfish, had the highest concentrations of organochlorines, while shark and striped bass had the highest concentrations of mercury.

In 1997, the Regional Board and the RMP conducted a follow-up contaminant study of SF Bay fish. The results of this study indicated that persistent toxic chemicals (mercury, PCBs, and other organochlorine compounds) in SF Bay fish remain at levels of human health concern (SFEI 1999). In 1999 the Regional Board and the RMP decided to incorporate monitoring bioaccumulative contaminants in fish tissue into the status and trends monitoring component of the RMP on a three-year cycle. The RMP and the Regional Board are planning additional projects to: 1) develop food web and mass balance models, 2) identify and quantify sources and loadings of mercury and PCBs, and 3) develop implementation plans for the reduction of mercury and PCBs (SFEI 2000).

In response to the results of the Regional Board's 1994 pilot study, the Office of Environmental Health Hazard Assessment (OEHHA) within the California Environmental Protection Agency issued an interim health advisory for SF Bay in 1994 (OEHHA 1994). This advisory replaced an earlier advisory issued in 1972 for SF Bay and the Delta region that recommended limits on striped bass consumption due to mercury contamination. The 1994 interim advisory recommends that adults limit their consumption of most species of fish caught from SF Bay to no more than two meals per month. Pregnant and breastfeeding women, women who may become pregnant, and children under six years of age are advised to eat no more than one meal per month. The health advisory recommends that meal size should be adjusted according to body weight, with roughly 1 ounce of fish per 20 pounds of body weight. Thus, meal size for an adult weighing 154 pounds (70 kg) is considered to be an 8-ounce portion prior to cooking (see Appendix A for the full advisory).

Limited data characterizing fishing populations and their consumption patterns exist for the San Francisco Bay Area. A few small surveys have gathered consumption and demographic data on selected populations at fishing piers or shores (Karras 1998, Ujihara 1997, Wong *et al.* 1997, Cohen 1995, EHIB 1994). A household-based survey of Laotians in Contra Costa County also found that the majority of households had members who fished in the Bay (Chiang 1998). The surveys conducted by Save San Francisco Bay Association and Communities for a Better Environment (Karras 1998, Wong *et al.* 1997, Cohen 1995) suggested that health risks from consumption of San Francisco Bay fish may be quite high for certain populations. Additionally they highlighted the need for expanded outreach and education to certain populations. However, the restricted scope of these surveys limits their usefulness for characterizing exposures of the overall fish-consuming population in SF Bay.

A 1991-92 survey, commonly referred to as the Santa Monica Bay Study, provided detailed consumption data for the population fishing in the marine waters of the Los Angeles area, namely the Santa Monica Bay, Palos Verdes Peninsula, and Los Angeles/Long Beach Harbor areas (Allen *et al.*1996, SCCWRP/MBC 1994). OEHHA has recommended using the distribution of consumption rates derived from the Santa Monica Bay Study as default values for California fishing populations when local consumption data are not available (Gassel 1997). However, due to differences in the types of fish commonly caught, the ethnic composition of the population, and other factors, the Santa Monica Bay Study results may not accurately characterize the SF Bay fishing population.

An ongoing survey, the Marine Recreational Fishery Statistics Survey (MRFSS), which in California is implemented by the Pacific States Marine Fisheries Commission for the National Marine Fisheries Service, covers a broad range of fishing activity and focuses on the species and quantity of fish caught by sport anglers. No consumption data are collected and only limited demographic information is obtained for the fishing population (NOAA/PSMFC 1997, Karpov *et al.* 1995).

With respect to outreach and education activities, in 1993, OEHHA originally convened the Education and Outreach Task Force on Fish Consumption and Fish Contamination Issues. The task force was initiated in response to concerns raised by environmental and community groups about the

lack of accessible information to anglers on health advisories in SF Bay. In particular, concerns focused on the lack of posted signs, lower literacy educational materials, and education and outreach materials in languages other than English. In 1997, EHIB assumed responsibility for coordinating the Education and Outreach Task Force on Fish Consumption and Fish Contamination Issues. The Task Force members currently include individuals representing environmental and community groups, and local, county, and state agencies (see Appendix B). A variety of educational activities has been conducted by Task Force members, including presentations to adult groups taking English as a second language classes, fish cleaning and cooking demonstrations, creating displays for community fairs, and development and distribution of signs, informational brochures, and postcards with health advisory information available in multiple languages. In particular, Save San Francisco Bay Association's Seafood Consumption Information Project conducted extensive outreach and education activities prior to the implementation of the SF Bay Seafood Consumption Study (Wong *et al.* 1997). OEHHA has also translated the SF Bay advisory into Chinese, Vietnamese, Korean, Cambodian, and Spanish, and developed other educational materials. In 1995, OEHHA staff conducted a survey to assess sign effectiveness and angler awareness at Berkeley Pier (Russell *et al.*1997). To date, Task Force members have arranged for signs publicizing the health advisory to be posted at 21 fishing sites.

II. Study Design, Implementation, and Management

A. Study Administration and Staff

The RMP formed a Seafood Consumption Advisory Task Force to provide technical support and to review all aspects of the study. The Task Force originated as a subgroup of the RMP's Fish Contamination Committee that provided technical support for designing and implementing fish sampling and contamination studies. Extensive efforts were made to expand the Task Force's membership to include all interested parties in the planning of the study, such as angler groups, environmental organizations, and community groups. Unfortunately, time and resource constraints limited the full participation of some of these groups. Members of the Task Force included representatives from federal, state, and local governmental agencies, academic institutions, environmental organizations, fishing groups, and industry groups (see Appendix C).

Project staff and Task Force members expended considerable time and effort to develop a study design that would allow for the study objectives to be met and also allow for the study to be carried out within the allocated budgetary resources. Project staff reviewed materials available from the United States Environmental Protection Agency (USEPA 1992), the American Fisheries Society (Pollock 1994), and methods and information available from other angler studies. These mainly included studies of SF Bay anglers (Ujihara 1997, Wong *et al.* 1997), the MRFS Survey (NOAA/PSMFC 1997), and the Santa Monica Bay Study (SCCWRP/MBC 1994). Project staff also consulted with recognized experts in areas such as biostatistics, survey design, questionnaire development, and fisheries management. During the study design phase (October 1997 through June 1998), Task Force members reviewed all study protocols and materials developed by project staff.

During the study implementation and data collection phase (July 1998 through June 1999), project staff provided progress reports and preliminary data to Task Force members on a regular basis. From July 1999 through December 2000 (data analysis and report generation phase), Task Force members also reviewed data analysis methods and drafts of this report.

The study was primarily conducted under the direction of staff within the Environmental Health Investigations Branch (EHIB) of the California Department of Health Services. None of the state staff were supported with contract funds. Contract funds were used to support a community relations coordinator (10% FTE), a graphic artist (5% FTE), a team of interviewers, and a half-time field coordinator. A research specialist conducted data analysis after all field data collection activities were completed.

Ten field interviewers were hired beginning in May 1998. They included five Spanish-speaking field interviewers, two Vietnamese-speaking interviewers, and two Chinese (Cantonese and Mandarin) speaking interviewers. One solely English-speaking interviewer had previous experience interviewing party boat anglers and was hired to conduct interviews of party boat anglers. The RMP also allocated a staff person who was solely English speaking to serve as a back-up interviewer when none of the regular interviewer staff were available.

Orientation and training of field interviewers occurred during May and June 1998 and included visits to all sampling sites. Interviewers practiced administering the questionnaire initially with project staff and in the field at sites not included in the sampling plan.

B. Sampling Plan

In order to derive exposure estimates applicable to the overall population of SF Bay anglers, we developed a sampling plan that would allow us to interview a representative sample of all anglers fishing in SF Bay. The key elements of our sampling plan are described below. A more detailed description is also provided in Appendix D.

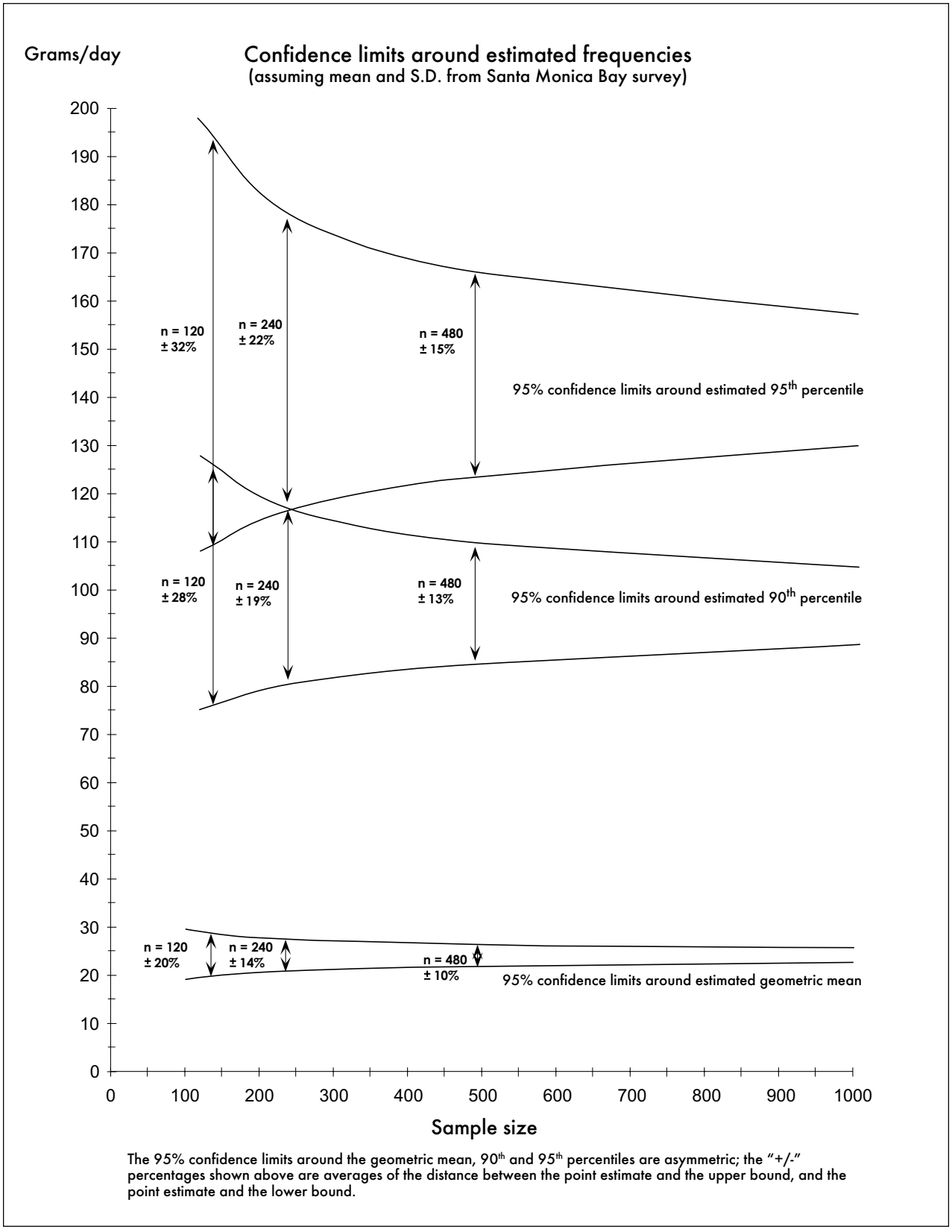
1. Survey Method

We chose on-site personal interviews as the survey method to gather fish consumption and demographic information from anglers. These interviews were conducted over a twelve-month period (July 1998 through June 1999) at selected fishing sites throughout SF Bay. Off-site methods such as mail and phone surveys were not selected because in California, no comprehensive list of anglers from fishing licenses or other sources was available when this study was being planned. Even if such a list had been available, it would not be complete for SF Bay anglers because fishing licenses are not required for fishing at public piers in California (CDFG 2000). A significant amount of fishing activity occurs on public piers in SF Bay, and the proportion of pier anglers with licenses is not known. Additionally, on-site personal interviews conducted by bilingual interviewers would enhance participation of respondents who may have difficulty understanding written questionnaires due to cultural or language barriers or low literacy. Finally, because of the importance of estimating consumption rate, we chose to use a physical model of a fish fillet in order to elicit information about the quantity of fish typically eaten by the angler. The use of the fillet model required personal interviews.

2. Sample Size Estimate

We set a sample size target based on the minimum number of interviews needed to estimate a reasonably precise mean consumption rate. The consumption rate was derived from the subset of anglers who consumed fish caught from SF Bay in the four weeks prior to the interview — a group we refer to as "recent consumers." In choosing a four-week time period, we sought to maximize the time period over which a consumption rate estimate could be made while minimizing recall bias. In addition, to date the Santa Monica Bay Study (SCCWRP/MBC 1994) has provided the best estimates of fish consumption rates from a California population. This study also used a four-week recall to estimate consumption rate. By using a similar method to define consumption rate, we could compare rates derived from both studies.

Figure 2. Confidence Limits



The 95% confidence limits around the geometric mean, 90th and 95th percentiles are asymmetric; the "+/-" percentages shown above are averages of the distance between the point estimate and the upper bound, and the point estimate and the lower bound.

We used consumption rate data from the Santa Monica Bay Study to estimate a target sample size for this study. Using the mean and standard deviation from the Santa Monica Bay Study, we calculated confidence limits around a geometric mean and upper percentiles (90th and 95th) for different sample sizes (Hahn and Meeker 1991). Figure 2 shows that for a sample size of n = 480, the 95% confidence limits average +/-10% around a geometric mean. At n = 480, the 95% confidence limits around the 90th and 95th percentiles are slightly larger (+/-13-15%). As can be expected, the width of the confidence limits decreases as the sample size increases. Figure 2 also shows that as the sample size increases beyond n = 480, little increase in precision of the consumption rate estimate is gained. We considered a 95% confidence limit of +/-10-15% to be reasonable and thus selected n = 480, or n ~ 500, as our target sample size for the group of recent consumers.

Based on our target number for recent consumers, we then estimated the number of anglers we would need to approach to obtain completed interviews of 500 recent consumers. Based on information from the Santa Monica Bay Study and two small shore-based angler surveys conducted in SF Bay (Ujihara 1997, Wong *et al.* 1997), we estimated that 25% of attempted interviews with anglers would yield interviews of recent consumers. Thus, we would need to attempt about 2000 interviews to reach our goal of interviews of 500 recent consumers.

We did not plan the study to obtain sample sizes of subgroups that would be large enough to show consumption rate differences between subgroups, such as ethnic groups. To be able to detect statistically significant differences in consumption rates between subgroups, consumption rate differences or the subgroup size would need to be relatively large. Based on data from the Santa Monica Bay Study, we estimated that a subgroup of 50 or more would be needed to detect a two-fold difference in consumption rates, or a subgroup of 100 or more would be needed to detect a 1.5 fold difference.

3. Allocation of Sampling Effort

The two key elements of our sampling plan were: (1) the sample would reflect the relative amount of fishing activity among fishing modes and other factors, and (2) the study expenses would not exceed our budgetary resources. We developed target numbers of interview attempts for each of three fishing modes based on the relative proportion of fishing activity for each mode within SF Bay. The three modes were defined as shore-based (which included pier and beach and bank sites), private boat, and party boat. Using fishing pressure estimates developed by the MRFSS (Roper 1997), we estimated about 62% of SF Bay fishing activities were conducted from shore-based sites, 28% from private boats, and 10% from party boats.

We also estimated the field interviewer hours available to conduct interviews and allocated these to the three modes. Budgetary limitations resulted in a reduction from our original target of 2000 interview attempts to 1774. Table 1 shows the targeted number of interviews for each of the three modes. These estimates reflected what we expected to achieve given the relative amount of fishing activity among the modes and our budgetary resources.

Table 1. Target Number of Interviews and Interviewer Hours by Fishing Mode

	Mode			
	Shore-Based[a]	Private Boat	Party Boat	Total
Targeted No. of Interviews	1151	407	216	1774
Projected No. of Interviewer Hours	1042	510	162	1714

[a]shore-based sites include pier, and beach and bank sites

4. Site Selection

The list of fishing sites used in the study was primarily drawn from the Marine Recreational Fisheries Statistics Survey (MRFSS) site list (Roper 1997). The 1997 MRFSS site list for SF Bay identified 47 shored-based sites, 24 sites with private boat access, and 8 with party boat access. We also consulted with Task Force members, staff from the California Department of Fish and Game, and other sources to assist with identifying fishing sites.

For shore-based sites, we selected public piers with the highest fishing activity. To reach our target sample size and stay within our budgetary resources, most sites with low fishing activity were excluded from the sampling plan. There was consensus among the Task Force members and external reviewers of the study design that this would not unduly bias the sampling results (see Appendix D). In general, low-activity areas were included only if they were adjacent to a high-activity site and could feasibly be surveyed at the same time. For example, we included beach or bank areas with low activity next to a busy fishing pier.

For the final site combination of shore-based sites, we selected 14 public piers with adjacent beach or bank areas to be sampled once each month. Interviewers were instructed to interview all anglers present at shore-based sites. Thus, the relative amount of fishing activity at a site was reflected in the number of interviews attempted at that site over time (i.e., the one year sampling period). The sites were grouped into pairs based on geographic proximity and site pairs were sampled on the same day. Two sites were specifically included to improve geographic coverage. The Martinez Pier was added because it is located in the Carquinez Straits area, which is not included in the MRFSS. Also, Dumbarton Bridge was added to replace the San Mateo Bridge pier site. The San Mateo Bridge pier site is one of the most heavily used sites in the Bay but was closed during the duration of the survey. The 14 selected shore-based sites sampled in the survey are shown in Figure 3.

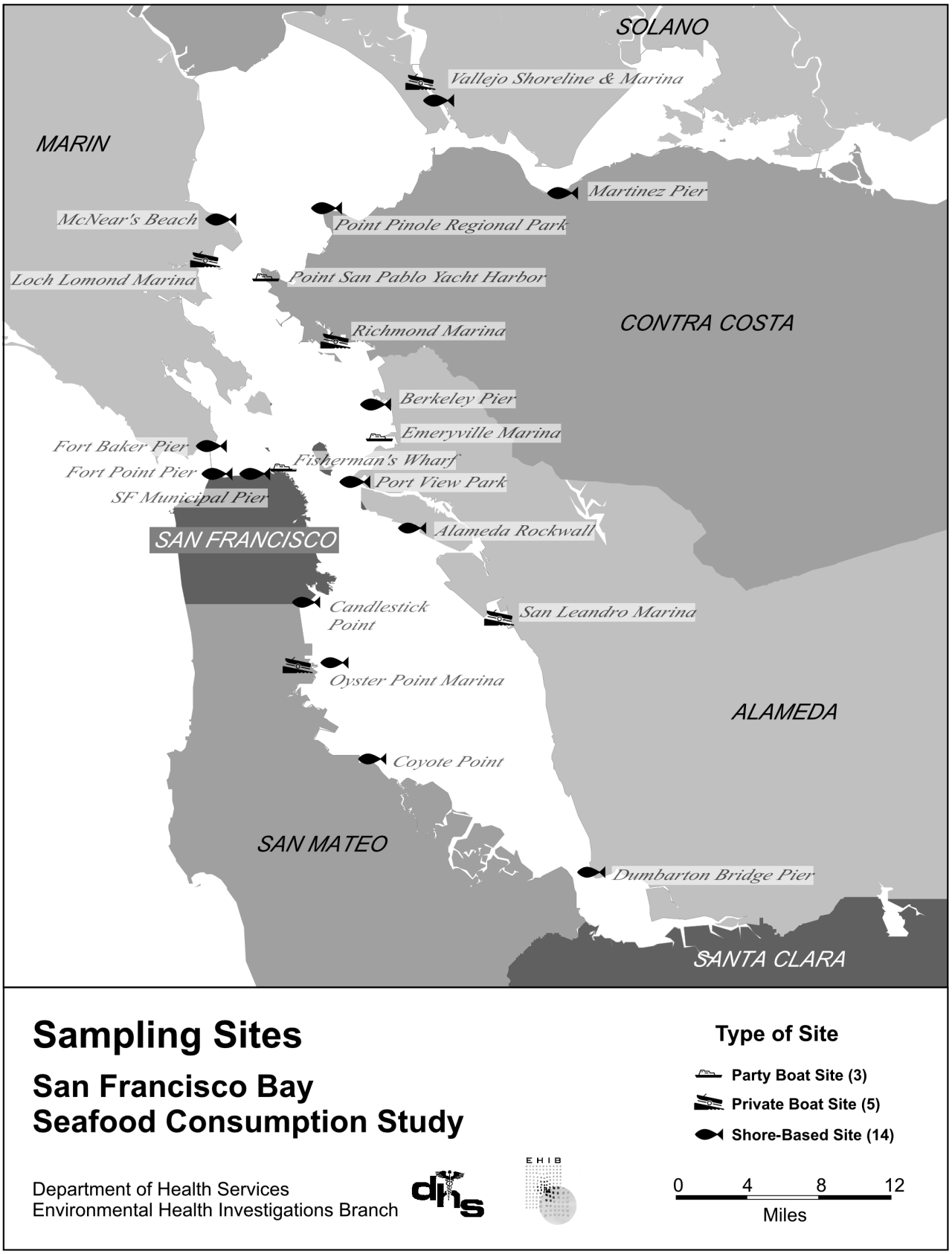
For private boat sites, we selected five boat launch sites with the highest fishing activity. As shown in Figure 3, the five sites provided reasonable geographic distribution of the Bay. We assigned an interview shift that was proportional to the relative amount of fishing activity at each selected site. Thus, interviewers had longer shifts at the more active sites and times. Interviewers attempted to interview all anglers using the site during their shift. In order to conserve on resources, we chose not to sample at one site, San Leandro Marina, on weekdays because this site had very low weekday activity.

For party boats, we examined data collected by the California Department of Fish and Game on party boat activities (CDFG 1998). These data showed that party boat activities within SF Bay were heaviest during warm weather months (from May to August) and lightest in January and December. Based on our estimate of available field interviewer resources, we allocated 18 party boat sampling trips by assigning three sampling trips per month for the busiest months and fewer sampling trips for less busy months.

5. Sampling Days and Times

Another key element of the sampling plan was to randomly select sampling days for shore-based and private boat sites. Because of the difficulty in scheduling more than one interview team per day, sampling days for both shore-based sites and private boat sites were selected without replacement from the same pool. Thus, only one type of site, either shore-based or private boat, could be sampled on a given day. Half the sites each month were designated for weekday sampling and the other half designated for weekend sampling. Weekday/weekend designations alternated every month. Sampling days were re-

Figure 3. Sampling Sites



scheduled if MRFSS staff planned to survey at the same site and day in order to avoid the possibility that anglers would be interviewed for both surveys on the same day.

To ensure coverage of the sampling day, shore-based sites were assigned morning or afternoon shifts. For safety reasons, we assigned sampling times only during daylight hours for both shore-based and private boat sites. In order to maximize coverage of daylight hours, shifts at shore-based sites began earlier and ended later during the longer summer months.

For private boats, sampling times were always in the afternoon to maximize the likelihood of interviewers intercepting anglers returning from their fishing trip. Although interviewers attempted to interview all private boat anglers during their shift, not just those returning, we believed anglers returning from their fishing trip would be more willing to be interviewed than those leaving on a trip.

For party boats, because we had to rely on the party boat captains to allow the interviewer access to their boats, we did not attempt to randomly select sampling days.

C. Survey Instruments

1. Questionnaire

The survey questionnaire was designed to gather information needed to address the specific objectives listed in Section I.D. The questionnaire included questions on ethnicity, income, education, age, fishing frequency, amount of fish eaten, types of fish eaten, preparation and cooking methods, others in the household who eat Bay fish, and awareness and knowledge of the state health advisory. (See Appendix E for a copy of the final questionnaire.) Trained interviewers personally administered the questionnaire to anglers at selected sites. The questionnaire was created using Teleform, Version 5.4, an automatic forms processing software, which allowed us to optically scan the data on the paper questionnaires to create an electronic data base (Teleform 1998). In order to facilitate administration and data entry, the questions mainly followed a partially closed-end question format, with discrete response categories, and an “other” category as needed for a write-in response. Initial drafts were prepared and submitted to the Task Force for review beginning in January 1998.

We also held a discussion group in March 1998 with five individuals (one African American male, one Chinese male, one Hispanic male, one Caucasian male, and one African American female) who fished frequently to solicit input and recommendations for the questionnaire. These individuals were recruited through notices distributed to fishing and community organizations. Field interviewers field-tested the questionnaire at sites not included in the sampling plan in May and June 1998. Revisions primarily served to improve clarity of questions, minimize response biases, maximize recall, and reduce interview time. Final forms were printed with unique identification numbers on water-resistant paper.

A Spanish translation of the questionnaire was also created. No separate interview tools were created for Vietnamese or Chinese interviews, but the interviewers practiced with each other and with other native-speaking individuals and agreed upon consistent terms and phrases to use. If an interview was conducted using the Spanish translated form, the responses were later copied onto a form created with Teleform (English only) to allow for optical scanning. Both the English and Spanish versions were turned in and reviewed by the field coordinator (who was also Spanish literate) prior to scanning.

2. Fish Pictures

For questions about specific fish species, interviewers showed respondents color pictures of 13 species of fish and three types of shellfish during the interview to help them identify the specific SF Bay fish they consumed. Pictures were obtained primarily from the California Department of Fish and Game. We selected the 13 most frequently caught species in the SF Bay using data from the MRFSS. The pictured

species are identified in Appendix F. Consumption practices for white croaker, leopard shark, and striped bass were of particular interest due to the higher levels of contaminants found in these species (organochlorine compounds in white croaker, and mercury in leopard shark and striped bass).

3. Fish Fillet Model

For the question on portion size, interviewers showed a cast plastic model of an 8-ounce raw fish fillet to help the respondent estimate the amount of fish consumed at one time. The respondent was asked "When you eat fish from anywhere (the Bay, other places, stores, restaurants), is the amount that you eat about this size, more or less?" Further probing by the interviewer took place as necessary to determine the respondent's usual portion size.

4. Census Form

At shore-based sites only, interviewers conducted a census of all anglers with fishing poles present at the beginning of the survey shift. Site code, mode, date, and start time were recorded, as well as the numbers of anglers who appeared over 18 years of age and less than 18 years of age.

5. Site Summary Form

Interviewers recorded site code, start and end time for each site, and total number of interview attempts per site on this form for each sampling day.

6. Survey Incentives

In order to promote participation by anglers and to prevent repeat interviews of anglers, a unique survey logo was created and imprinted on clipboards, binders, and name badges, hats, and vests worn by all field interviewers. Also as an incentive for participating, all respondents were given a key chain with a tape measure imprinted with the logo at the conclusion of the interview.

As an incentive for providing information that would allow us to contact them in the future for follow-up activities, respondents were also invited to enter a monthly drawing, making them eligible to receive a $20 gift certificate. They were also asked whether they would like information about the results of the survey sent to them and whether they could be contacted further.

7. Survey Tools

All field interviewers were provided with the following materials:

- Field Interviewer Training Manual
- Name badge, hat and vest with survey logo
- Site maps and directions
- Clipboards with survey logo
- Survey questionnaires
- Census and site summary forms
- Binder with map of San Francisco Bay and pictures of 13 species of fish and three species of shellfish commonly caught from the Bay
- Plastic model of an 8-ounce portion of raw fish fillet
- Health advisories (SF Bay specific health advisory and general fishing advisory available in six different languages)

- Key chain with tape measures imprinted with survey logo

Pictures of some of the above listed survey tools are included in Appendix F.

D. Field Survey Methods

Field survey methods are fully documented in the Field Interviewer Training Manual (see Appendix G) and are summarized briefly here.

For pier and beach and bank sites, the field coordinator assigned two interviewers to visit a site in pairs. Occasionally a third interviewer was assigned as needed. Attempts were made to match assignments with anticipated language requirements (e.g., Chinese speaking interviewers for San Francisco sites). The protocol required interviewers to conduct a census at the start of the shift and attempt to interview all anglers present at a site. If no anglers were present upon arrival, interviewers were required to stay on-site for one hour before leaving. Interviewers surveyed anglers in a sequential fashion. For example, interviewers worked one side of a pier at a time. If new arrivals appeared in areas where they had already interviewed, interviewers surveyed them only if they could keep track of all new arrivals (possible in relatively contained areas) in order to avoid selective interviewing.

For private boat sites, two interviewers were assigned to stay at a designated boat launch site for a preset number of hours. Interviewers screened boat anglers for whether or not they had been fishing or planned to go fishing and their designated fishing location. Only those who reported fishing or planning to fish at least half of their time in the Bay were interviewed.

At the conclusion of all pier, beach and bank, and private boat interviews, the interviewer read a summary of the health advisory for SF Bay and asked the respondent if he or she wanted to receive written information on the health advisory, which was available in six different languages.

For interviewing party boat anglers, the designated field interviewer contacted party boat captains who fish predominantly in SF Bay and had previously indicated their willingness to allow an interviewer to ride their boats. If the captain planned to fish in SF Bay, space was available, and the captain was willing, the interviewer accompanied the boat on the fishing trip. On the party boat survey form (see Appendix F), the interviewer recorded the marina from which the boat left, the boat name, and target species. If the captain took the boat outside the Bay during the trip, the interviewer also recorded the approximate amount of fishing activity that occurred outside SF Bay. While on board, the interviewer attempted to interview all anglers on the trip. Health advisory questions and information were excluded from interviews with party boat anglers in order to improve cooperation from party boat captains.

A revised protocol was implemented in April 1999 as party boat captains became less willing to let interviewers board their boats. Interviewers were assigned to interview party boat anglers after they exited the party boat. Determination of whether the boat planned to go inside or outside the Bay and the estimated time of return was made prior to sending interviewers out. Only party boats fishing in SF Bay at least some of the trip were included. Interviewers attempted to interview all exiting anglers who were at least 18 years old. Questions and information about health advisories were omitted from the interview.

If problems arose during a shift, field interviewers contacted the field coordinator. A cell phone was provided to the interviewers for this purpose. For example, interviewers contacted the field coordinator when an additional interviewer was needed because a site was particularly busy, or when a shift had to be terminated due to bad weather. Interviewers reviewed all questionnaires used for interviews they had conducted for completeness and clarity at the end of their shift.

E. Field Activities Summary

At the conclusion of each sampling shift, the interviewer completed the Site Summary Form and returned the form and completed interview forms to the field coordinator. The field coordinator created a monthly summary of field activities. Appendix H contains copies of the monthly summaries as well as a 12-month summary.

We completed 89 days of field surveying at shore-based sites, and 59 survey days at private boat sites. There were 47 weekday days and 42 weekend/holiday days at shore-based sites, and 28 weekday days and 31 weekend/holiday days at private boat sites. As documented in the field summaries, about a fifth of all shore-based and private boat sampling days needed to be rescheduled. Reasons for rescheduling included bad weather, conflict with a MRFSS sampling day, inability of interviewers to complete a site, or unavailability of interviewers. Rescheduled sampling days were conducted as close to the original sampling day as possible and were on the same day type (weekend or weekday).

For party boats, we originally scheduled 18 party boat sampling days. Because we had limited access to party boat anglers, we made 22 total attempts to board a party boat and 10 attempts to interview party boat anglers as they exited the boat. We were able to conduct interviews for about a third of all party boat attempts. Party boat interviews were conducted with anglers on boats departing from Pt. San Pablo Yacht Harbor, Emeryville Marina, and San Francisco Fisherman's Wharf. Party boats were mainly sampled on weekend days.

III. Data Management, Quality Assurance and Control, and Data Analysis

A. Data Management

As interviewers returned completed survey questionnaires, the field coordinator manually reviewed and corrected them as needed. Using Teleform, trained staff scanned the forms and visually reviewed each scanned page of the survey instrument. Categorical responses were optically read and coded. All handwritten entries (e.g., numbers and text) were visually reviewed and manually corrected as needed. After all pages were verified, the data was committed to a Microsoft Access database. Since each survey form was uniquely numbered, duplicate entries could be easily identified. Text entries were manually coded into predefined categories (see Appendix I). Separate Access data base files were created for each month of data collection and converted to a data file compatible with SAS version 7 (SAS 1998). After confirming that data integrity had been maintained, monthly data sets were merged to form the full data set. Data editing and data analyses using SAS were performed on the full data set.

B. Verification of Interviews by Phone

In order for us to independently verify that the interviews actually took place, we attempted to contact by phone a subset of persons interviewed. When interviewed in the field, respondents were asked if a supervisor could contact them. Of persons agreeing to be contacted (approximately half of all respondents), we attempted to contact 94 respondents (7% of all respondents). These respondents were chosen randomly. We were able to reach 67 respondents (71% of those we tried to reach and 5% of all respondents) after making up to three attempts. All 67 confirmed that they had been interviewed at the stated day and place. No attempt was made to verify their responses to the interview.

C. Quality Assurance (QA) and Quality Control (QC) Measures

A variety of QA/QC measures were incorporated in order to minimize measurement errors or other biases.

QA procedures put into place prior to data collection included:

- Obtaining review and input on all study materials and protocols by Seafood Consumption Study Advisory Task Force members
- Field testing of survey instrument
- Thorough training of interviewers in all aspects of survey administration
- Incorporating visual cues and tools to maximize recall during the interview

QC measures undertaken throughout the data collection phase included:

- Self-review of all forms completed by interviewer at end of shift
- On-site field audits of interviewing activities by the field coordinator or other project staff on 49 sampling days (31% of all sampling days).
- Manual review of all completed survey questionnaires by field coordinator for completeness and correct coding
- Regular verbal and written feedback to interviewers individually as needed
- Scheduled group meetings to provide periodic updates and to review procedures
- Phone calls to 5% of all respondents to verify that the interviews did take place
- Data review and editing to detect inadmissible and out-of-range values
- Inclusion of redundant questions worded differently to check consistency of answers

D. Data Analysis

1. Avidity Bias

How frequently anglers go fishing (i.e., their avidity) can vary widely among anglers. Some may fish daily while others may fish only once per year. In on-site surveys such as this study, how often an angler goes fishing determines how likely he or she will be included in the survey. Generally, avid anglers will be over represented in the sample and infrequent anglers will be under represented. Several authors have described this bias, called avidity bias (ATES/OEHHA 2000, Ossiander 1999, USEPA 1997, Pollock 1994, Price 1994, Thomson 1991).

Avidity bias presents a concern when an angler's avidity is correlated with important parameters that are being studied, such as consumption rate. If no correlation exists, there is no bias and data adjustments will not change the results. However, if correlation exists, the sample will not accurately reflect the overall angler population. Because one of the main goals of the study is to characterize exposures of the general population of San Francisco Bay anglers, adjusting for avidity bias allows for the results to more closely reflect this general population.

In this study, sample data were adjusted for avidity bias by weighting the respondents in proportion to the inverse of their sampling probability. This type of adjustment is a common and standard practice in the field of survey sampling (Stuart *et al.* 1976, Snedecor and Cochran 1989)). To estimate sampling

probability, we used the angler's fishing frequency, i.e., the number of times the angler reported fishing in the four week prior to the interview.

The fishing frequency response was used to adjust consumption rates of recent consumers (anglers who reported consuming SF Bay fish in the four weeks prior to the interview, see Appendix J), as well as other consumption rate variables such as meal frequency and portion size. Consumption rates based on consumption in the 12-month period prior to the interview could not be adjusted for avidity bias because information on fishing frequency over the same time period was not obtained. We also adjusted categorical variables such as mode, ethnicity and income for avidity bias. For these variables, the avidity bias adjustment was applied to the overall proportions of the variable subgroups.

In the equation below, we describe how the avidity bias adjustment was applied to an estimate of a mean consumption rate:

Weighted mean, $cw = \frac{\sum i \, wi \, \chi i}{\sum i \, wi}$ (SAS 1988)

The weighting factor, *w*, is the inverse of the angler's fishing frequency, and *x* is the angler's consumption rate. The angler's fishing frequency value was increased by one to include the trip during which the interview took place. Thus, an angler who did not fish in the 4 weeks prior to the interview would have a fishing frequency of 1 (zero fishing trips in the last 4 weeks plus one trip when interviewed). The weighting factor used for an angler who had a fishing frequency of 1 would be 1/1, or 1 in the equation above. Also, we limited the maximum fishing frequency value to 28 times (1 time per day over the last 4 weeks). Thus, anglers who reported fishing 27 or more times in the last 4 weeks were recorded as having fishing frequencies of 28. The weighting factor used for an angler with a fishing frequency of 28 would be 1/28 in the equation above.

The avidity bias adjustment does not change an individual angler's consumption rate. The adjustment increases or decreases the weight given to anglers' responses in the aggregated sample based on their fishing frequency. For example, the adjustment reduces the contribution of avid angler's consumption to the total consumption rate to compensate for oversampling this group.

Adjusting for avidity bias may introduce additional error by using one random variate (fishing frequency) to adjust another (consumption). However, to the extent that higher consumers are actually oversampled in a survey (which cannot be determined from the data themselves), sampling theory tells us that reweighted estimates should be more accurate than unweighted ones (Snedecor and Cochran 1989). Note that, as with all sampling efforts, the true population averages remain unknown. The reported 95% confidence intervals reflect the magnitude of the uncertainty, and the true population values are expected to lie somewhere within those intervals.

Because not all variables could be adjusted, results that have been adjusted for avidity bias are described as "adjusted" in this report. However, the tables in Appendix K include both the adjusted and unadjusted data, where appropriate.

2. Calculation of Fish Consumption Rate

Consumption rate was determined by multiplying the respondent's reported portion size by meal frequency, and converting to grams per day. Portion size (in ounces) refers to the amount of fish eaten at one time. Respondents were shown a cast plastic model, representing an 8-ounce raw fish fillet. They were then asked if the model represented the amount they ate at one time, regardless of its source (SF Bay, outside SF Bay, store or restaurants). Respondents could report a portion size amount equal to the

8-ounce model, a fraction of the model (e.g., one half, one third, etc.), or a multiple of the model (e.g., two times, three times, etc.). Respondents were asked the portion size question only one time during the survey. This single response was used to estimate all fish consumption rates used in this study. Meal frequency refers to the number of times the respondent consumed fish over a specified time period. We asked about meal frequency of SF Bay fish for two different time periods to derive two different consumption rates. First, we asked respondents for the number of times they ate specific species of SF Bay fish in the four weeks prior to being interviewed; we then summed these answers for the specific species to give the total number of times the respondent ate SF Bay fish. Second, in a single question we asked respondents for the total number of times they consumed SF Bay fish in the last 12 months. Appendix J contains a more detailed discussion of how consumption rates were derived for this study.

Although we also asked respondents to report meal frequency for three types of shellfish, due to resource constraints, no portion size was obtained for shellfish. Therefore, we could not derive consumption rates for SF Bay shellfish.

Descriptive statistics for consumption rates are presented in Section IV.D, including arithmetic and geometric means, standard deviations, minimum and maximum values, and 50th (median), 90th, and 95th percentile values. Appendix K contains tables displaying more complete percentile distributions, from the 10th to 95th percentile.

3. Shape of the Consumption Rate Distribution

The procedures used to provide confidence intervals around estimates of population means, and to conduct statistical tests of consumption differences between subgroups, assume that the population distribution follows the so-called "normal," or Gaussian, distribution. Previous studies have reported that fish consumption rates tend to be lognormally distributed (Hill 1995, Hill and Lee 1995, Murray and Burmaster 1994, Ruffle *et al.* 1994). We examined the mean, median, standard deviation, skewness, kurtosis, histograms, and normal quantile plots of consumption rates derived for SF Bay anglers (recent consumers). As will be further discussed in Section IV.D.1, we found the unadjusted median and geometric means to be identical (about 16 grams/day), and the unadjusted arithmetic mean to be about 28 g/day. The extreme skewness of the distribution produced an arithmetic mean falling near the 72nd percentile, rather than near the median (50th percentile) as in a normal distribution. Citing an arithmetic mean from a non-normal sample not only conveys a misleading "mean" value, but attempting to estimate a population's arithmetic mean from a non-normal population produces confidence intervals that are far below their stated accuracy. As expected from this analysis and the previously cited experience of others, the logarithmic transformation, common in biological and medical applications (Armitage and Berry 1987), produced a more normal distribution. Thus, we primarily refer to geometric means and medians for describing measures of central tendency (USEPA 1996, Sokal and Rohlf, 1981). The geometric mean is obtained from the mean of the log transformed values, back transformed to their original units. Further discussion on the shape of the consumption rate distributions can be found in Appendix J. More detailed information about consumption rates is also presented in Section IV.D.1.

4. Statistical Methods

The type of statistical test used in the data analysis is dependent on the type of variable being examined. For categorical variables we performed chi-square tests to measure the associations of different angler characteristics such as fishing mode and ethnicity. We used the Mantel-Haenszel chi-square statistic to test for trends in demographic variables representing ordered categories, such as income, education, and

age. In all chi-square analyses, we excluded missing, don't know, and refused to answer responses. Chi-square tests could only be performed on data unadjusted for avidity bias. Thus, discussion of statistical significance of chi-square results applies only to the unadjusted data. Also, chi-square tests could not be performed on some categorical responses where the possible responses were not mutually exclusive.

Because consumption rates were lognormally distributed, we used geometric means and 95% confidence intervals to compare among different groups. We considered two groups with non-overlapping confidence intervals to be significantly different. Consumption rate differences were also tested non-parametrically by the Wilcoxon signed rank test as an alternative way of dealing with non-normally distributed consumption rate data.

Statistical analyses were performed with SAS software, version 7 (SAS 1998).

IV. Results

The information presented in this section of the report serves to address the goals and objectives defined for the overall study (Section I.D). We have attempted to keep tabular data to a minimum in this section, relying more on figures and graphs for illustration. More extensive tabular data are included in Appendix K. Figures and tables that appear in the text are numbered sequentially. Tables that appear in Appendix K are prefaced by an upper case K, for example, Table K1.

For clarity, the following terms, which we use in this report, are defined:

- *Mode* refers to the type of fishing site where anglers were interviewed. Modes included in the study were: 1) public piers, 2) beach and bank sites, 3) private boat launch sites, and 4) party boat sites. Shore-based sites refer to pier sites and beach and bank sites.
- *Decliners* refer to anglers who declined to be interviewed.
- *Respondents* refer to anglers who agreed to be interviewed. This group includes both consumers and non-consumers of SF Bay fish.
- *Consumers* are anglers who report consuming fish caught from SF Bay (no time period specified). This group also includes a small number of anglers who reported fishing for the first time in the Bay and who planned to consume their catch. Further description of how consumers are defined is included in Appendix J.
- *Recent consumers* are defined as anglers who reported consuming fish caught from SF Bay in the four weeks prior to the date they were interviewed. Recent consumers are a subset of consumers. Further description of how recent consumers are defined is included in Appendix J .
- For presenting information on ethnic groups, we refer to the following major ethnic groups: *Black/ African American, Latino/Hispanic, Caucasian, Asian, and Other* (which included Russians, Middle Easterners and individuals of unspecified mixed ethnicity). Included in the Asian group are anglers who are *Filipino, Chinese, Vietnamese, Pacific Islander, and Other Asian* (which included Japanese, Southeast Asian other than Vietnamese, Korean, and mixed Asian). Additional tables and figures are also provided which delineate the Asian subgroups separately.

A. Sampling Success

As shown in Table 2, we attempted 1,868 interviews, 5% more than we had originally targeted. Of the 1,868 attempted interviews, 130 anglers had previously been interviewed and were not reinterviewed.

Table 2. Sampling Success by Mode

	Total		Mode							
			Piers		Beach and Bank		Private Boats		Party Boats	
	N	%	n	%	n	%	n	%	n	%
Target Attempts[1]	1774		1151[2]				407		216	
Actual Attempts	1868		1052		136		557		123	
Interviewed Before[3]	130		69		9		41		11	
Net Attempts[4]	1738	100	983	100	127	100	516	100	112	100
Interviewed (Respondents)[5]	1331	77	695	71	99	78	433	84	104	93
Decliners	407	23	288	29	28	22	83	16	8	7

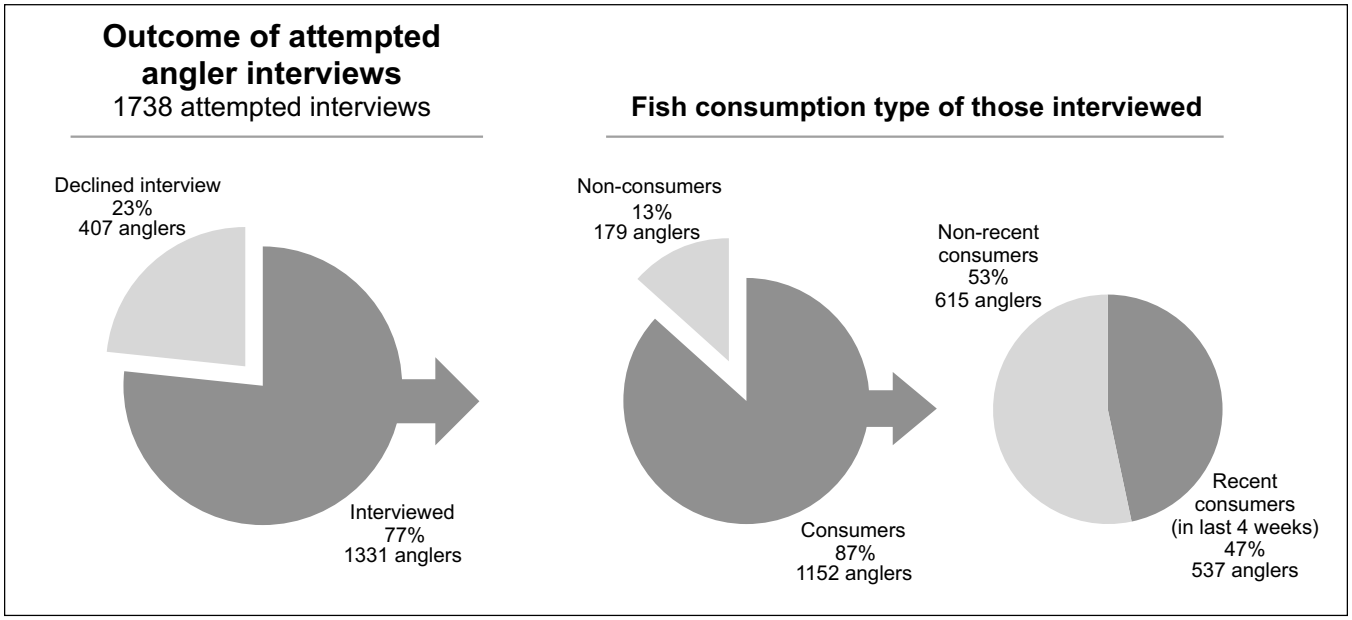
	Total		Mode							
			Piers		Beach and Bank		Private Boats		Party Boats	
	n	%	n	%	n	%	n	%	n	%
Interviewed (Respondents)[5]	1331	100	695	100	99	100	433	100	104	100
Consumers of SF Bay Fish[6]	1152	87	583	84	81	82	390	90	98	94
Non-Consumers of SF Bay Fish[7]	179	13	112	16	18	18	43	10	6	6

	Total		Mode							
			Piers		Beach and Bank		Private Boats		Party Boats	
	n	%	n	%	n	%	n	%	n	%
Consumers[6]	1152	100	583	100	81	100	390	100	98	100
Recent Consumers of SF Bay Fish[8]	537	47	277	48	39	48	181	46	40	41
Non-Recent Consumers[9]	615	53	306	52	42	52	209	54	58	59

	Total		Mode							
			Piers		Beach and Bank		Private Boats		Party Boats	
	n	%	n	%	n	%	n	%	n	%
Recent Consumers of SF Bay Fish[8]	537	100	277	100	39	100	181	100	40	100
Recent Consumers with Defined Consumption Rate[10]	501	93	255	92	37	95	172	95	37	93

1 Target Attempts–as defined in the original sampling plan reflect the relative amount of fishing activity by mode within SF Bay.
2 Number refers to total target attempts for shore-based sites, which included pier and beach and bank sites.
3 Interviewed before includes anglers who initially agreed to be interviewed but were later identified to have been previously interviewed. Interviews with these individuals were subsequently terminated.
4 Net Attempt equals actual total attempts (1868) minus interviewed before (130).
5 Respondents refer to anglers who agreed to be interviewed and who had not been previously interviewed for this study.
6 Consumers are anglers who report consuming fish caught from SF Bay.
7 Non-consumers are defined as anglers who reported they do not consume fish caught from SF Bay.
8 Recent consumers are defined as anglers who report consuming fish caught from SF Bay in the four weeks prior to the date they were interviewed. Recent consumers are a subset of the overall consumer group.
9 Non-recent consumers are consumers of SF Bay fish who did not consume any in the four weeks prior to the interview.
10 Recent consumers with defined consumption rate indicated a portion size and a frequency of consumption within the last four weeks.

Figure 4



Anglers approached but found to be previously interviewed by this study not included (130 anglers). Not adjusted for avidity bias.

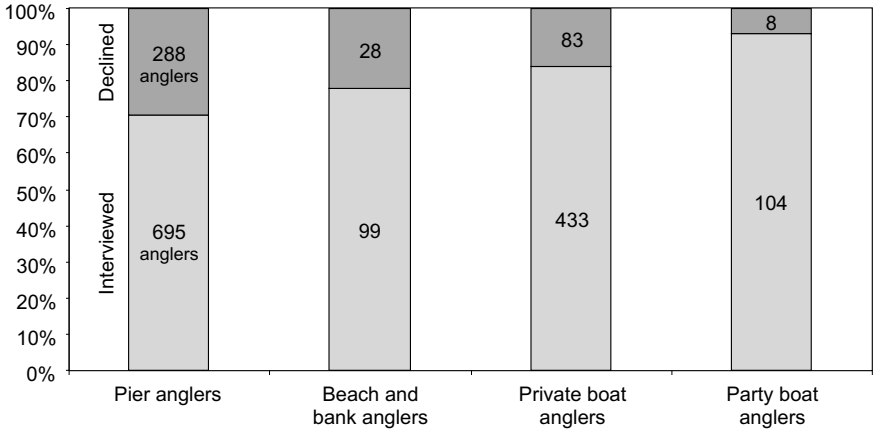
Figure 4 also shows that of those eligible to be interviewed (n = 1738), 77% agreed to be interviewed, a group we refer to as respondents. Consumers of SF Bay fish represented 87% of respondents.

An important indicator of sampling success was the total number of interviews achieved with recent consumers. As described in Section II.B., based mainly on data from the SMB study, we determined a sample size of 500 recent consumers would be needed to derive a reasonably precise mean consumption rate (i.e., 95% confidence interval of +/- 10% around the geometric mean consumption rate and 95% confidence interval of +/-15% around upper percentiles). We identified 537 recent consumers (see Figure 4 and Table 2). However, only 501 of these individuals provided adequate information for deriving a consumption rate based on a four week recall period, which still allowed us to meet our defined target.

Although consumption rate results will be discussed in later sections of this report, the precision of the geometric mean consumption rate in this study was +/-9% for the 501 recent consumers. This level of precision was within our target range. The confidence interval of +/-28% around the upper percentiles was wider than our target range (see Figure 2).

Figure 5

Proportion of interviews by fishing mode

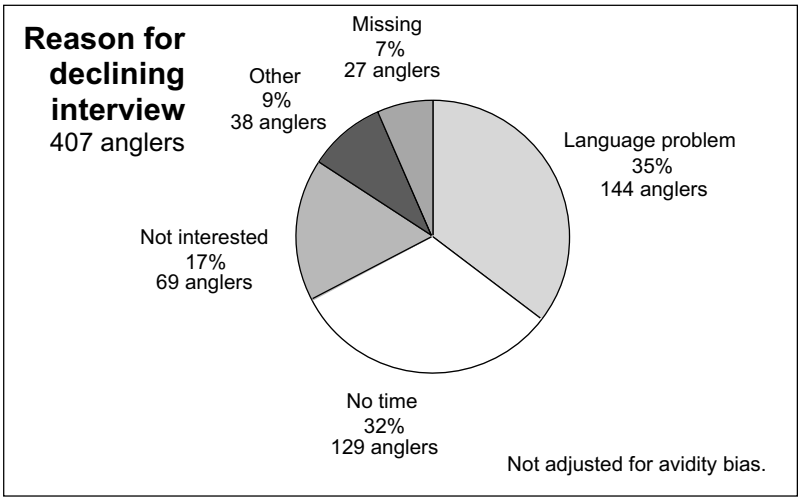


Not adjusted for avidity bias.

Our sampling plan (see Section II.B.) also identified target numbers of attempted interviews by mode, that were based on an estimate of the relative amount of fishing activity in SF Bay by mode. Table 2 and

Figure 5 show sampling results by four modes, pier, beach and bank, private boat, and party boat. (Separate codes assigned to (1) pier and, (2) beach and bank sites allowed for differentiation among the shore-based sites.) Proportionately, we had slightly less shore-based attempted interviews, more private boat attempts, and less party boat attempts than originally targeted. The resistance we encountered from party boat captains, which restricted our access to party boat anglers, accounted for our inability to reach our target for party boat interviews. As shown in Figure 5, we experienced greater cooperation among private and party boat anglers, as compared to pier and beach and bank anglers. Of pier and beach and bank anglers, 72% agreed to be interviewed, as compared to 84% of private boat anglers and 93% of party boat anglers.

Figure 6



B. Decliners

Twenty-three percent of anglers declined to be interviewed (see Table 2). Among the 407 individuals who declined to be interviewed, language problems and lack of time or interest were cited as the main reasons for declining (see Figure 6). Pier anglers were the most likely to decline an interview; they most commonly cited language problems as the reason (see Table K1). Among private boat anglers, no time was the main reason for declining to be interviewed.

Interviewers recorded observed ethnicity for 88% of anglers declining to participate. As shown in Figure 7, half of those declining were of Asian ethnicity (Chinese, Vietnamese, Filipino, Southeast Asian, Korean, and unknown Asian), whereas Asians represented one third of anglers who participated

Figure 7

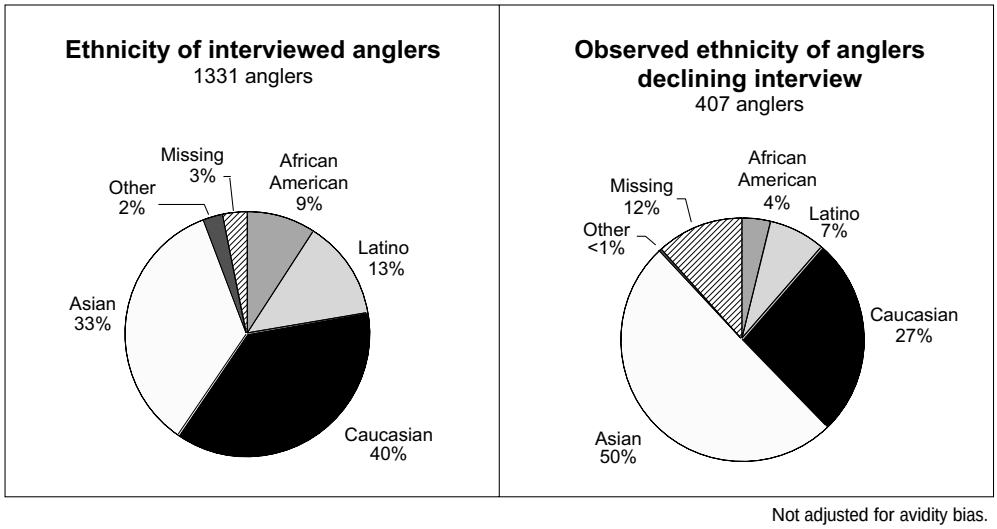
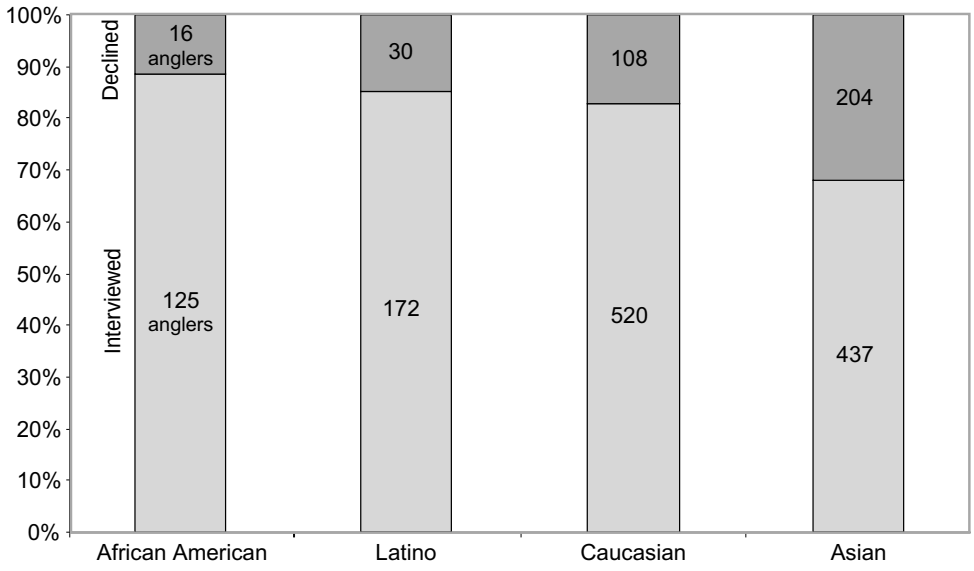


Figure 8

Proportion of interviews by ethnicity



Not adjusted for avidity bias.

in the survey. Figure 8 also shows that compared to other ethnic groups, a higher proportion of Asians declined to be interviewed. Generally, higher proportions of non-Caucasian ethnic groups were represented among pier and beach and bank anglers who declined to be interviewed than among private boat and party boat anglers who declined (see Table K1).

Interviewers were only able to note observed language spoken for 71% of decliners (see Table K1). Among those observed to be Vietnamese, Chinese, or Other Asian, language problems were noted as the most likely reason for declining (see Table K2). Interviewers generally encountered more languages other than English being spoken by pier and beach and bank anglers as compared to private and party boat anglers.

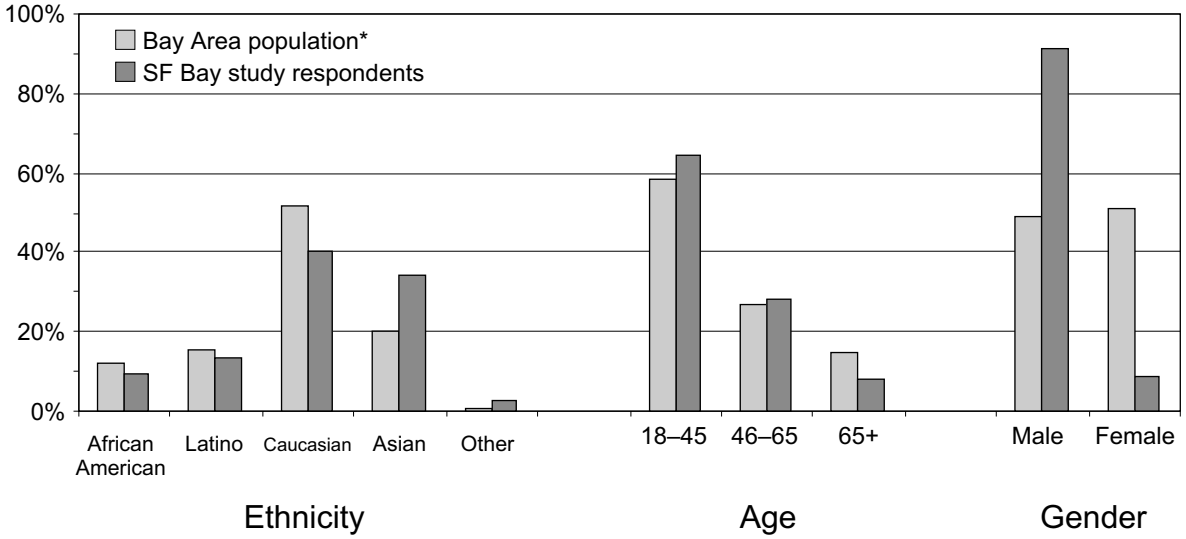
C. Angler Characteristics

One of the primary objectives of this study was to describe demographic characteristics of anglers who consume SF Bay fish. We present information regarding ethnicity, income, education, gender, and age for consumers of SF Bay fish by mode in this section. Information about the number of years consumers have been eating Bay fish, what they usually do with Bay fish, seasonal differences, household members consuming SF Bay fish, and household members who prepare or cook SF Bay fish is also included. Tables in Appendix K usually contain information for respondents, consumers, and recent consumers. The three groups are not mutually exclusive (e.g., 47% of consumers were recent consumers and 87% of respondents were consumers). The demographic characteristics of respondents, consumers, and recent consumers were largely similar. The tables in Appendix K also display data both unadjusted and adjusted for avidity bias. With respect to demographic characteristics, the overall proportions were largely unaffected by the avidity bias adjustment. The percentages given in the text below generally refer to adjusted values unless noted.

Figure 9 compares demographic variables for respondents and the aggregated population in the six Bay Area counties where the study was conducted. As shown, the study population was younger, had a

Figure 9

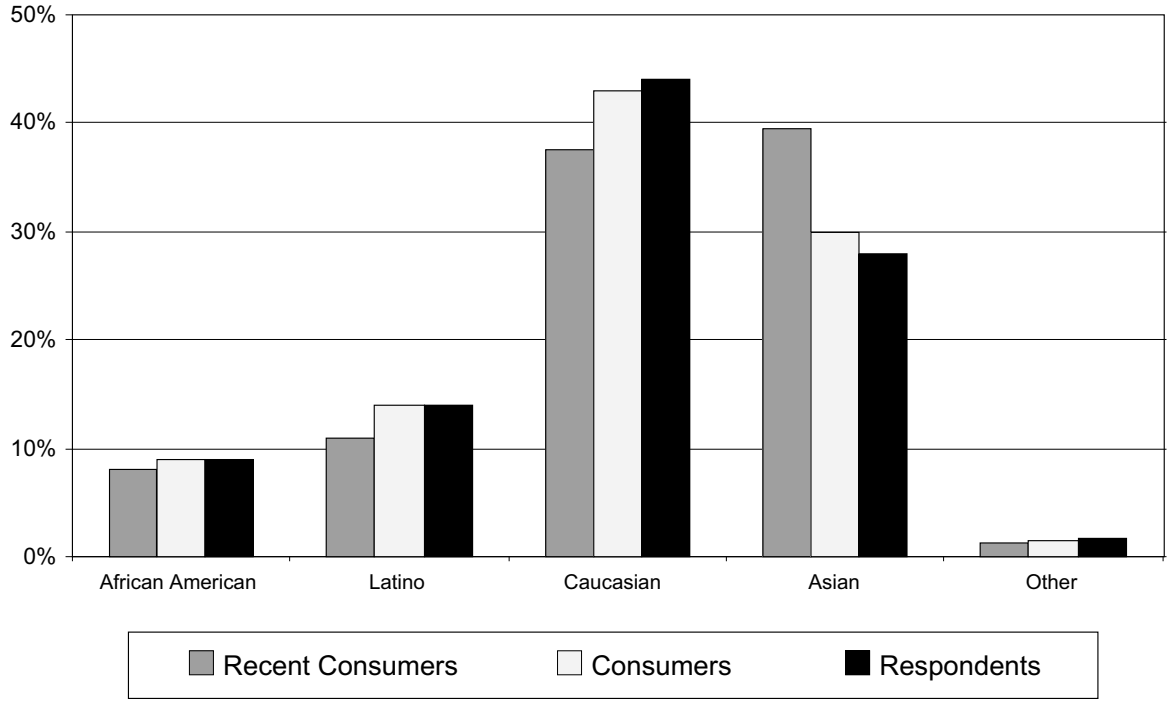
Demographic comparison of study respondents with Bay Area population



* Based on 1998 census data for the six Bay Area counties (Marin, Alameda, Contra Costa, San Francisco, Solano, and San Mateo) where the study was conducted. Not adjusted for avidity bias.

Figure 10

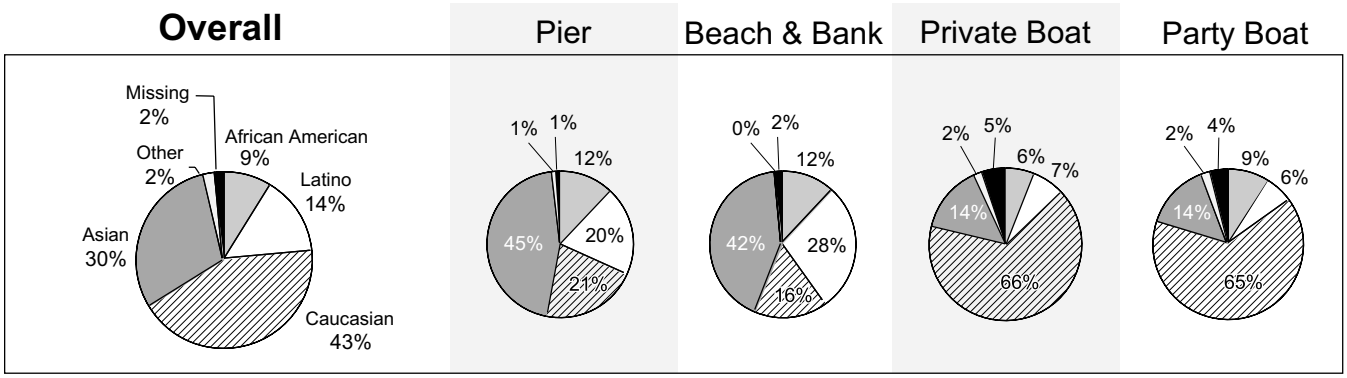
Comparison of ethnicity among recent consumers, consumers, and respondents



Adjusted for avidity bias.

Figure 11

Ethnicity of consumers by fishing mode



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

higher proportion of males and Asians, and a lower proportion of African Americans, Latinos, Caucasians, and females, as compared to overall Bay Area demographics.

Figures 10 through 20 present specific demographic information for consumers of SF Bay fish. Caucasians comprised the largest group of anglers who consumed Bay fish, followed by Asians, Latinos, and African Americans. Overall, more than half of the anglers consuming fish from SF Bay were non-Caucasian. Among recent consumers, Asians comprised the largest group, followed by Caucasians, Latinos, and African Americans. The overall fishing population was predominately male.

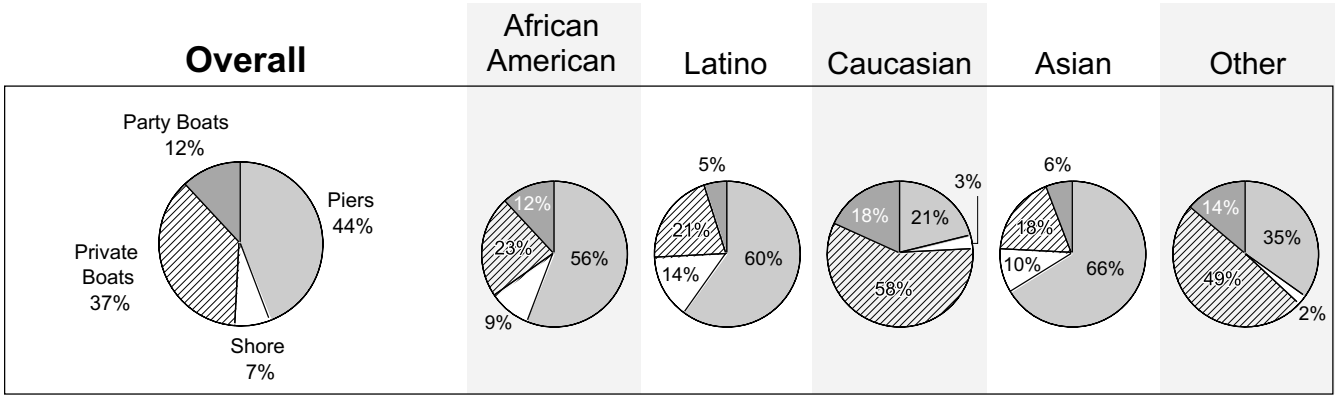
For all demographic characteristics except age and gender, we found differences by mode for consumers of SF Bay fish. Shore-based anglers tended to be non-Caucasian, whereas boat anglers were predominately Caucasian. Asians were the largest group fishing from piers and beach and bank sites, with Filipinos comprising the largest Asian group. A higher proportion of shore-based anglers reported household incomes less than $20,000/year, and also had lower education levels than boat anglers. Although the majority of interviews were conducted in English, 8% (106, unadjusted) were conducted in a language other than English and a much higher proportion of non-English interviews were conducted at piers and beach and bank modes compared to private and party boat modes.

Seasonal differences by mode were evident; the highest number of interviews for all modes was conducted during the summer months. Although 41% of consumers have been consuming SF Bay fish five years or less, about a fourth have been consuming Bay fish more than 20 years. A larger proportion of Caucasians and African Americans consumed Bay fish over the longest time period compared to other groups, while a majority of Latinos and Asians had consumed Bay fish five years or less. Ninety percent of consumers reported that they usually eat the fish they catch from SF Bay. Slightly less than half of all consumers reported they also give fish or shellfish they have caught to family or friends. Nearly one half (46%) of consumers reported that women of childbearing age (18-45 years) and 12% of consumers reported that children under six in their households ate SF Bay fish. About two thirds of consumers usually prepare or cook the fish they catch from the Bay themselves.

More specific information on angler characteristics is provided below and in tables found in Appendix K.

Figure 12

Fishing mode of consumers by ethnicity



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

1. Ethnicity

As shown in Figure 10 and Table K3, ethnic differences can be noted among respondents, consumers, and recent consumers. Overall, 55% of consumers were non-Caucasian, with Caucasians representing 43% of all consumers. For recent consumers, the proportion of non-Caucasians rises to 60%, with Asians surpassing Caucasians as the largest group.

Asian subgroups are also shown separately for consumers and recent consumers in Tables K4A and K4B. Caucasians represented the largest proportion of consumers, followed by Latinos, Filipinos, African Americans, Vietnamese, Other Asian, Chinese, Pacific Islander, and Other. Among recent consumers, Caucasians were followed by Vietnamese, Filipinos, Latinos, African Americans, Other Asians, Chinese, Pacific Islanders, and Other.

As shown in Figures 11 and 12 and Tables K3-K5, there were ethnic group differences by fishing mode. Among consumers, Caucasians were the dominant group fishing from private boats and party boats, whereas Asians comprised the largest group fishing from piers and beach and banks.

Table K6 shows ethnic differences by each site for respondents. For shore-based sites, Caucasians were the dominant group at Martinez Shoreline Park. Over 50% (unadjusted) of the respondents interviewed at Fort Point Pier, Point Pinole Shoreline Park, Alameda Rockwall, Candlestick Point Recreation Area, Coyote Point, and San Francisco Municipal Pier were Asian, with Filipinos representing the largest Asian subgroup (see Table K7). McNear's Beach had the highest number of Latinos; 35% (unadjusted) of interviews at this site were conducted with Latinos. African Americans were the dominant group at Port View Park. Caucasians were the largest ethnic group of all private boat and party boat sites. The proportion of Asians using Richmond Marina and Oyster Point Marina was higher compared to other private boat sites. Vallejo Marina and Oyster Point Marina had the highest proportion of Filipino private boat anglers while San Leandro Marina had the highest proportion of Vietnamese.

2. Language Spoken During Interview

The majority (87%) of all interviews with consumers were conducted in English (see Table K8). The proportion of non-English interviews conducted at piers and beach and bank sites was four times higher than at private boat sites. At McNear's Beach, Pt. Pinole Shoreline Park, San Francisco Muni Pier, and Coyote Point, over 20% of the interviews were conducted in a language other than English (see Table K9).

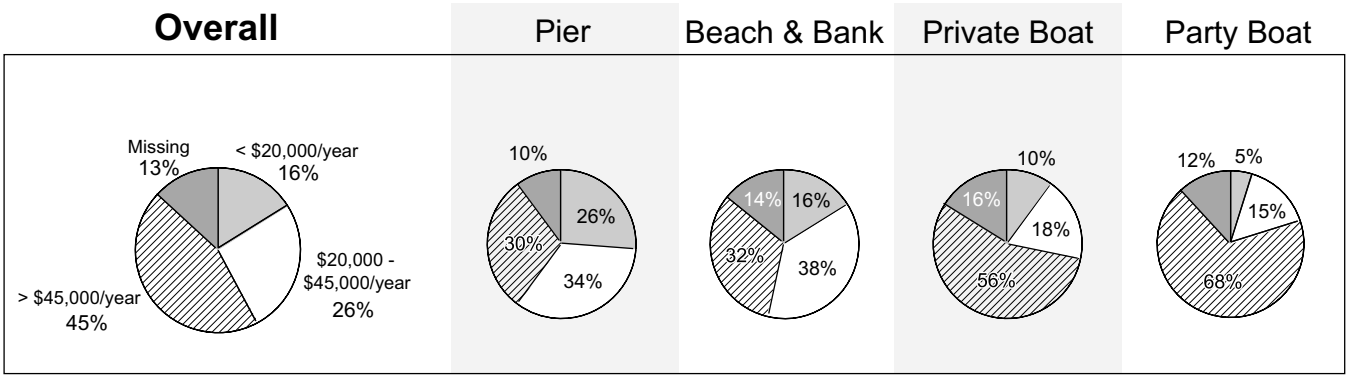
3. Income

To determine income, we asked respondents if their total household income was greater than $20,000/year. For those who indicated yes, we then asked if their household income exceeded $45,000/year.

Of all the demographic information gathered, we had the highest proportion of missing information for income (see Figure 13 and Table K10). Income information was missing for 13% of consumers as compared to 4% to 7% for the other demographic characteristics. Overall, 45% of consumers reported a total household income greater than $45,000/year (see Figure 13). The proportion of boat anglers reporting household incomes greater than $45,000/year was nearly two times the proportion of shore-based anglers.

Figure 13

Income of consumers by fishing mode

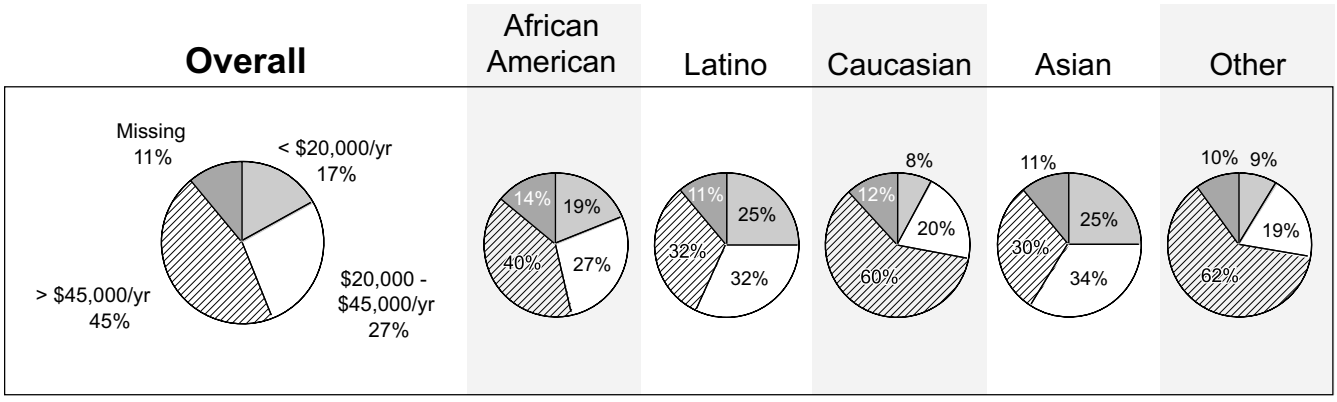


Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

Figure 14 and Table K11 show ethnicity by income for consumers. Within non-Caucasian groups a higher proportion reported annual household incomes less than $20,000 compared to Caucasians.

Figure 14

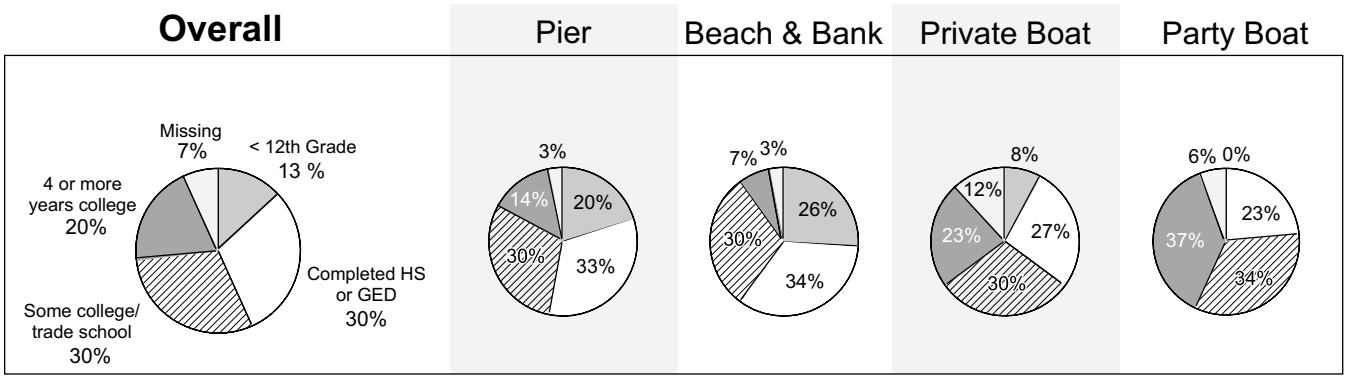
Income of consumers by ethnicity



"Overall" values differ from previous graphic due to exclusion of anglers missing ethnicity data.
Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

Figure 15

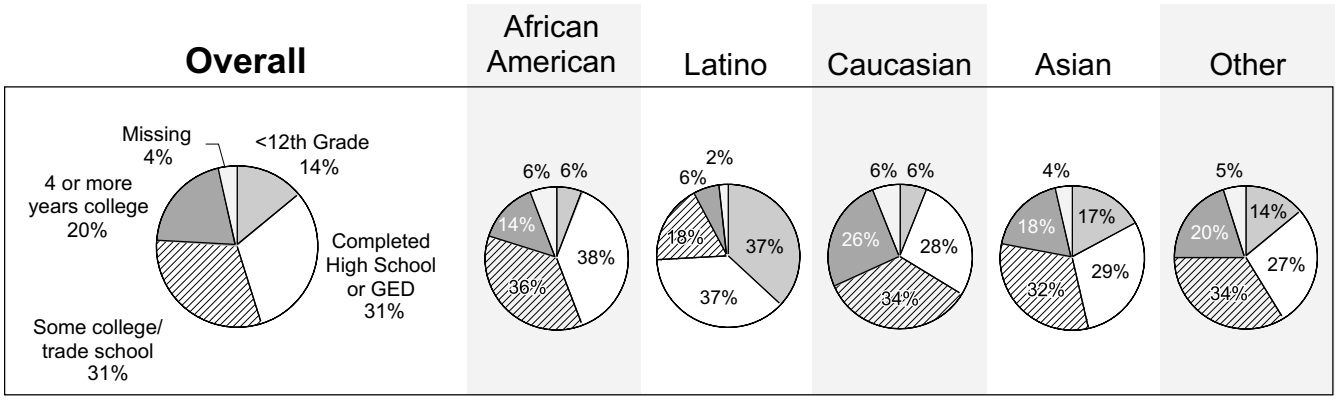
Education of consumers by fishing mode



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

Figure 16

Education of consumers by ethnicity



"Overall" values differ from previous graphic due to exclusion of anglers missing education data.
Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

4. Education

Education is usually highly correlated with income (Liberatos *et al.* 1988). Information on education was missing for only 7% of consumers. Among consumers, 50% reported some college level education or higher. Similar to income, there were differences in level of education by mode. A higher proportion of party boat and private boat consumers reported higher education levels than pier and beach and bank anglers (see Figure 15 and Table K12).

Education levels also varied by ethnicity, as shown in Figure 16 and Tables K13A and K13B. Among the different groups, 74% of Latino and 66% of Vietnamese consumers reported high school level or less. More than half of all the other groups reported some college level education or higher.

5. Gender

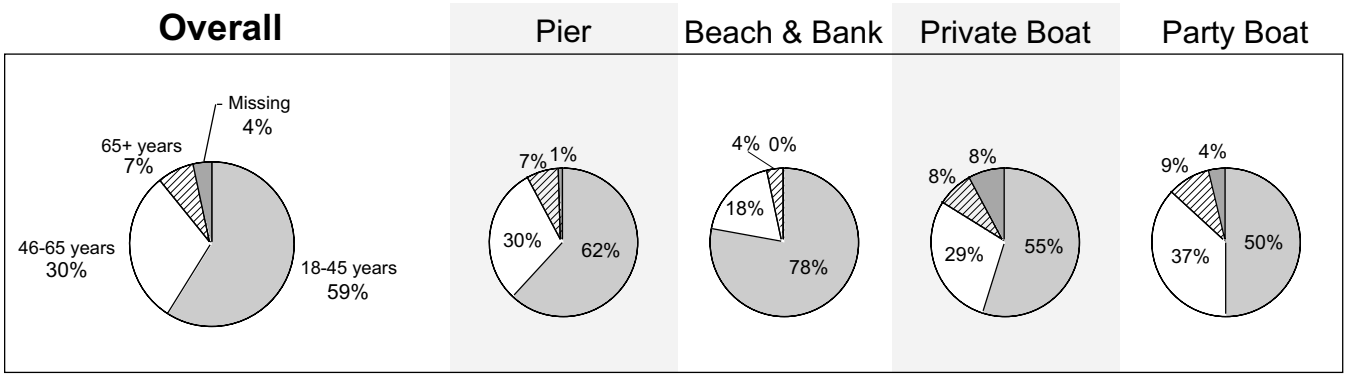
As shown in Table K14, 86% of all consumers were male. Differences by mode were not apparent.

6. Age Structure

Although interviewers recorded the number of anglers who appeared to be less than 18 years of age during the census at shore-based sites, these individuals were not included in the survey. About 20% of all anglers counted in the census at shore-based sites were observed to be younger than 18 years of age (see Appendix H).

Figure 17

Age of consumers by fishing mode



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

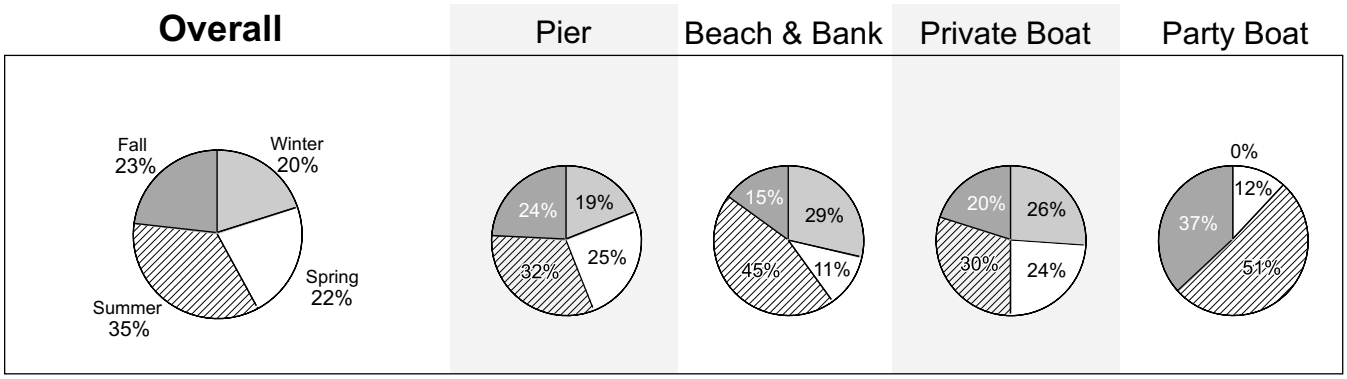
As shown in Figure 17 and Tables K15 and K16, 89% of all consumers fell within the 18 and 65 year range. Fifty-five percent of all female consumers were of child bearing age (18-45 years). A higher proportion of party boat anglers was in the age range above 46 years, as compared to anglers fishing from the other modes. More consumers over 65 years of age fished on weekdays than on weekends, in contrast to those less than 65 years of age (see Table K17).

7. Season of Interview

To define seasons, summer included all interviews conducted from July through September, fall included October through December, winter included January through March, and spring included April through June. Overall, the highest number of interviews was conducted during the summer due to the higher level of fishing activity (see Figure 18 and Table K18). Summer was also the dominant season within all

Figure 18

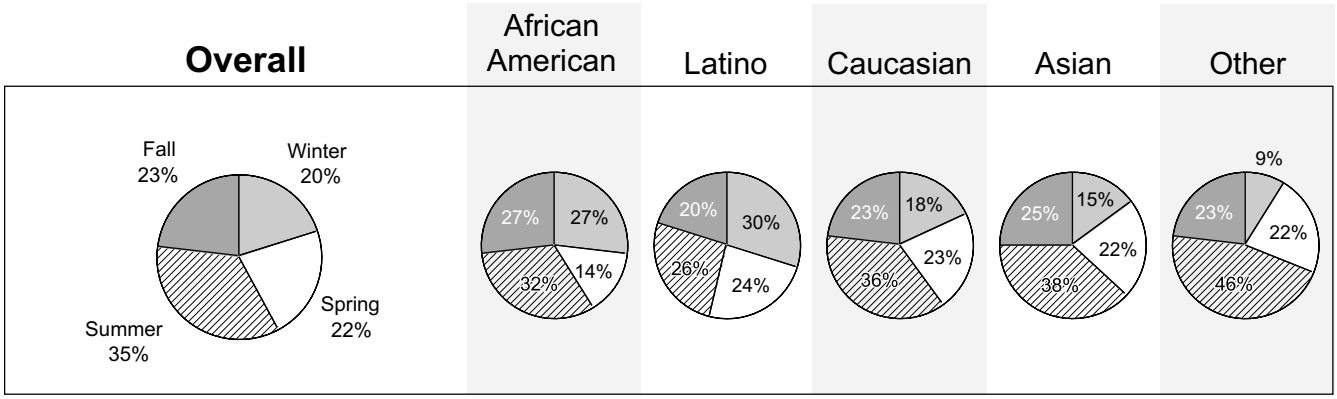
Season interviewed among consumers by fishing mode



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

Figure 19

Season interviewed among consumers by ethnicity



Anglers that reported no Bay fish consumption excluded. Adjusted for avidity bias.

modes and ethnic groups (see Figure 19), except for Latinos, Chinese and Pacific Islanders. More Latinos were interviewed during the winter, and more Chinese and Pacific Islanders were interviewed during the spring than other seasons (adjusted percentages, Table K19).

8. Years Eating Bay Fish

As shown in Table K20, 41% of all consumers have been consuming SF Bay fish 5 years or less and 27% have been consuming it for greater than 20 years. Among ethnic groups, Caucasians and African-American consumers reported eating Bay fish over a longer time period as compared to Latinos and Asians. Over 50% of Vietnamese, Chinese, Filipino, Pacific Islander, and Latino consumers reported consumption of Bay fish for five years or less compared to 25% of Caucasian consumers.

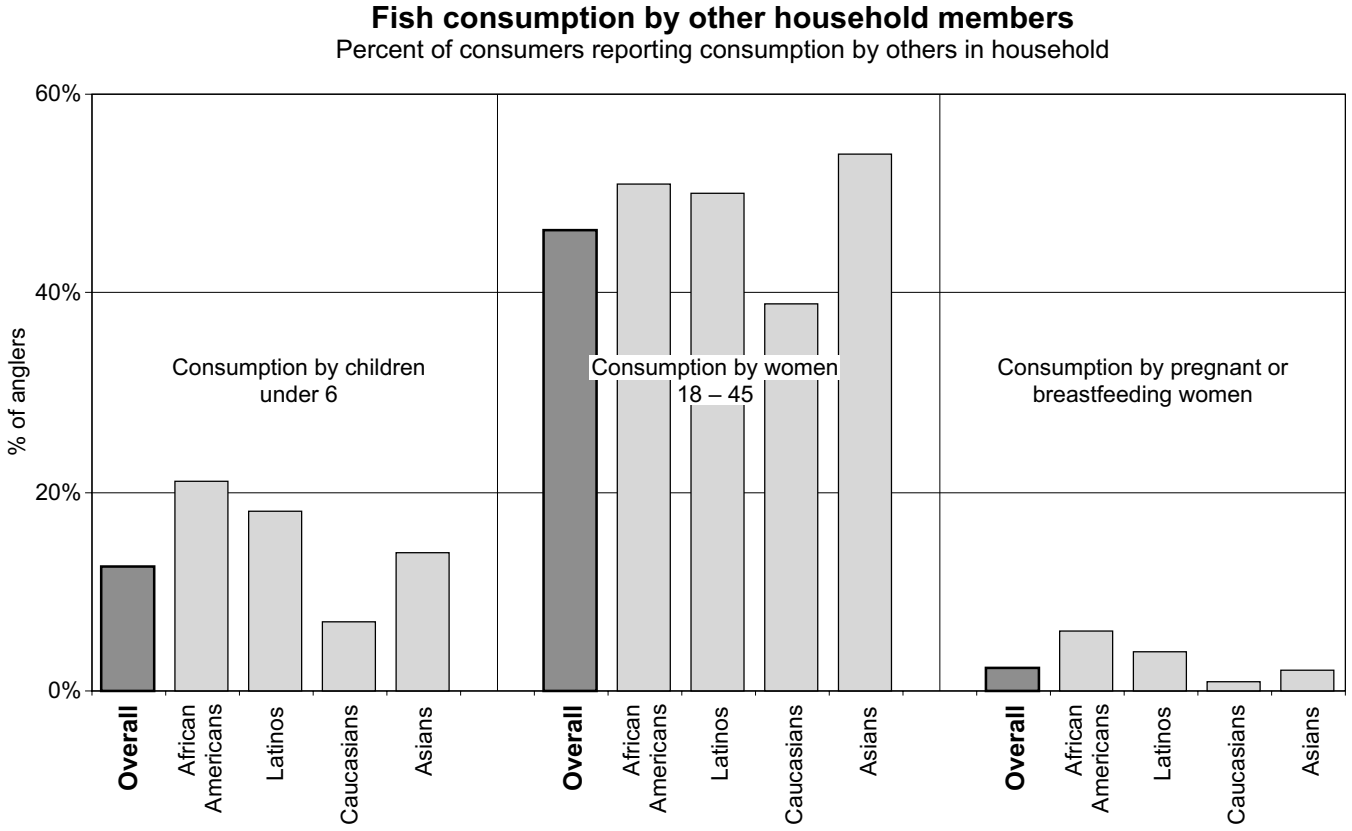
9. Fish Fate

Respondents were queried as to what they usually did with the fish or shellfish they caught from the Bay. The two most common responses were “eat it” or “give it to family or friend” (Table K21, unadjusted values). For consumers, most reported they usually ate the fish or shellfish they caught from SF Bay. A little less than half indicated they also give fish or shellfish to family or friends. As expected, non-consumers reported eating Bay fish much less frequently but gave it to family or friends. Responses to this question were not used to define whether the angler was a consumer or not (see Appendix J).

10. Household Members Who Eat Bay Fish

Because pregnant and breastfeeding women, women who are of childbearing age, and young children face increased risks from eating Bay fish, we asked respondents who else in their household eats Bay fish. As shown in Figure 20 and Table K22 (unadjusted values), only 2% of consumers reported pregnant or breastfeeding women in their household who ate SF Bay fish. However, 46% of consumers reported that women of childbearing age (18-45 years) in their household ate Bay fish, and 13% reported that children younger than six years of age ate Bay fish. By mode, consumers fishing at piers or beach and bank sites reported a higher proportion of pregnant women, women of childbearing age, and young children than consumers fishing from boats. Although non-consumers reported they do not consume SF Bay fish, many non-consumers reported women of childbearing age and young children in their households do consume Bay fish (see Table K22).

Figure 20



Anglers reporting no fish consumption not included. Not adjusted for avidity bias.

Comparing by ethnic group (see Table K23, unadjusted), about half of Asian, Latino, and African American consumers reported women of childbearing age in their household ate Bay fish. About a fifth of African Americans reported children under the age of six, compared to 7% of Caucasians.

11. Who Prepares or Cooks SF Bay Fish

We also asked respondents who in their household usually prepares or cooks the fish they catch and eat from the Bay. The majority of consumers (64%, unadjusted) reported they usually prepare or cook the fish they catch themselves and about one-fourth reported that their spouse usually prepares or cooks their catch (see Table K24). About a third of Latinos and Asians also reported spouse as the person who usually prepares or cooks Bay fish (see Table K25).

D. Fish Consumption Characteristics

As described in Section I.D., the primary goals of the study were to gather information for characterizing anglers' exposures to chemicals from eating Bay fish and to use that information to identify highly exposed subpopulations. In this section, we describe how much Bay fish anglers eat, and use consumption information to identify highly exposed groups. Next, we describe which species of SF Bay fish anglers consume, what parts are consumed, and how fish are prepared. In addition, consistent with the

specific study objectives, we quantified consumption of fish from sources other than SF Bay. We also quantified how frequently anglers ate three types of Bay shellfish (crabs, clams, mussels).

In general, the fish consumption data presented in the figures in this section have been adjusted for avidity bias, when this adjustment could be made (see Section III.D.1 for further discussion of avidity bias). The data tables in Appendix K, however, provide both unadjusted and adjusted data, as well as more detailed descriptions of anglers' responses.

1. Bay Fish Consumption Rates

To describe how much Bay fish anglers eat, we estimated fish consumption rates based on the amount of fish consumed over a given time period. As discussed in Section III.D.2, consumption rates were derived by multiplying two variables, portion size and meal frequency, and converting to grams per day (g/d). The portion size question was asked only once during the interview and was used to calculate all fish consumption rates in this study. However, we asked anglers to report meal frequency for two different time periods. The primary time period used was a four-week recall. We asked anglers how many times they ate Bay fish in the four weeks prior to being interviewed. When multiplied by portion size, we derived a consumption rate for the four-week recall period. Although less reliable than the four week recall, we also asked anglers to report the number of times they ate Bay fish in the past 12 months. When multiplied by portion size, a consumption rate over the 12-month recall period was derived.

In the following sections we describe portion size, meal frequency, and consumption rate responses. Consumption rates are described primarily for two populations, consumers and recent consumers. Consumers are anglers who eat Bay fish. Recent consumers are a subset of consumers who reported consuming Bay fish in the last four weeks. More detailed definitions of consumers and recent consumers can be found in Appendix J. We also derived "per angler" consumption rates, based on all respondents, to allow for comparisons with other studies.

a. Portion Size

Portion size responses characterize the amount of fish anglers reported consuming at one time. Figure 21 shows how consumers of Bay fish responded to the portion size question. In general, anglers gave portion size responses in multiples or fractions of the fish fillet model. Just over half (54%, adjusted) of consumers reported that the 8-ounce model was equal to the amount they eat at one time. Portion size responses of respondents and recent consumers were similar to consumers. Table K26 shows portion size responses for recent consumers, consumers, and respondents for common responses. Figure 22 shows the portion size responses among consumers as a distribution. Similar to Figure 21, responses are grouped around 8 ounces, (one model) 4 ounces (one half the model), 12 ounces and 16 ounces (one and a half and two times the model). The overall mean (adjusted) portion size for consumers was 7.7 ounces

Figure 21

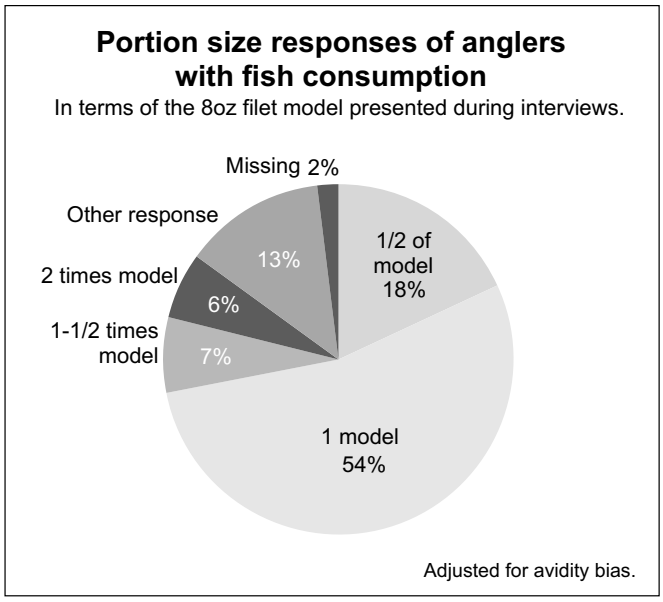
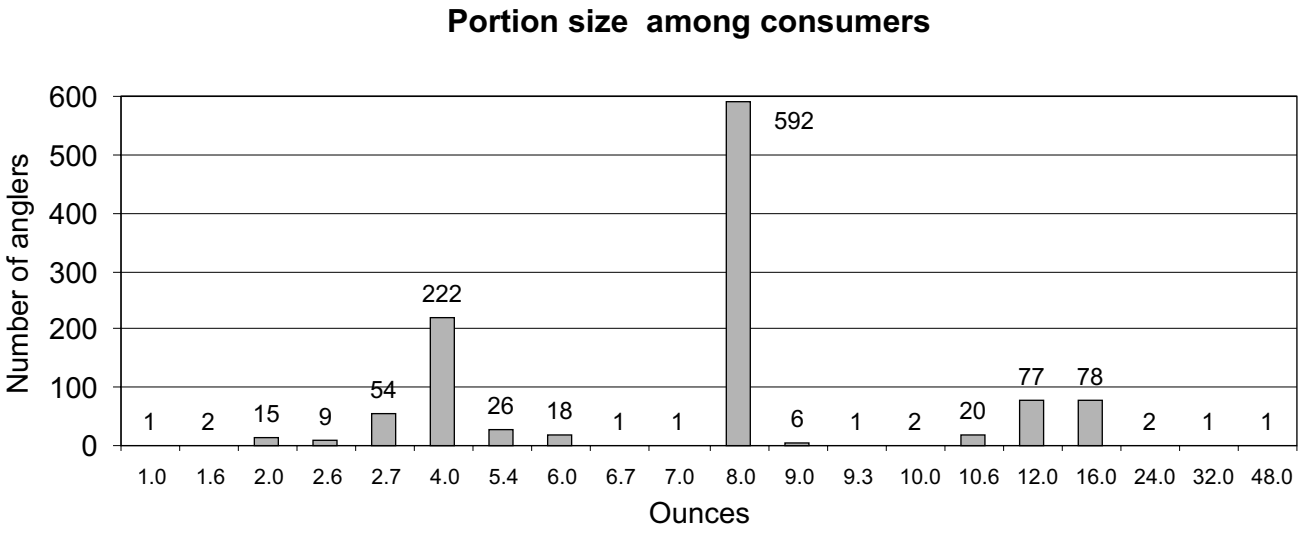


Figure 22



Not adjusted for avidity bias.

(217 grams), slightly less than the 8-ounce model. Tables K27a and K27b show the full distribution of portion size responses for consumers and recent consumers.

b. Meal Frequency among Recent Consumers

Meal frequency describes the number of times that anglers reported consuming Bay fish over a specified time period. In this section, we describe meal frequency responses for recent consumers based on a four-week recall. Table 3 summarizes meal frequency for recent consumers, both unadjusted and adjusted for avidity bias. The adjusted geometric mean meal frequency was slightly lower than the unadjusted meal frequency, although the medians were the same (two times in the last four weeks). Table K28 provides the complete meal frequency distribution (from the 10th to 95th percentile) for recent consumers.

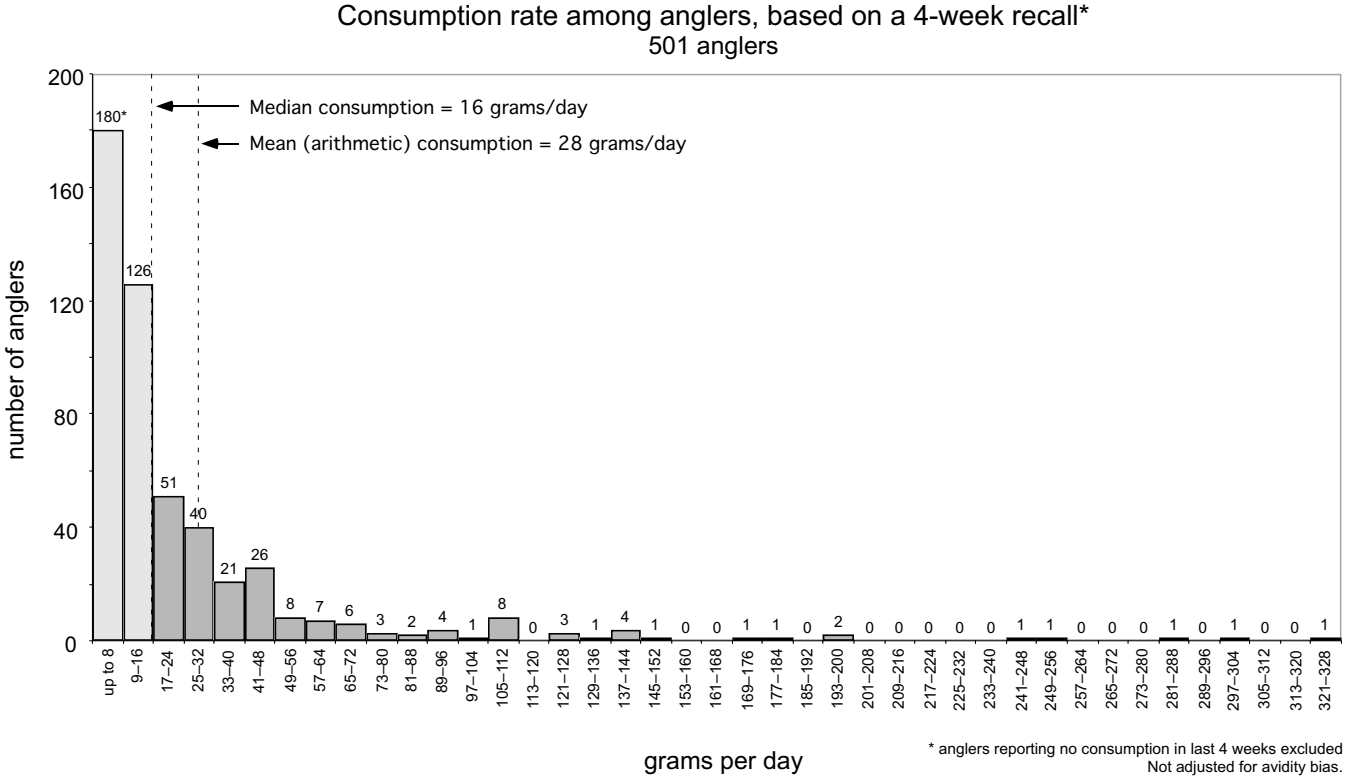
Table 3. Meal Frequency for Recent Consumers Based On Four Week Recall

Number of Times Bay Fish Was Consumed in the Last Four Weeks	Recent Consumers (Unadjusted for Avidity Bias) n=512[a]	Recent Consumers (Adjusted for Avidity Bias) n=473[a,b]
Mean (Standard Deviation)	3.5 (4.3)	2.9 (3.4)
Minimum Value	1	1
Maximum Value	32	32
Geometric Mean	2.4	2.0
Median (50th Percentile)	2	2
90th Percentile	7	6
95th Percentile	11	8

[a] For 25 recent consumers, meal frequency information was missing.

[b] For an additional 39 anglers, fishing frequency was not reported. Thus, meal frequency could not be adjusted for avidity bias. See Section III.D.1 for further discussion of avidity bias.

Figure 23



Although we identified 537 recent consumers in our sample, meal frequency information was missing for 25 recent consumers. Thus meal frequency could only be derived for a slightly smaller group of recent consumers (n = 512). In addition, not all recent consumers provided information on fishing frequency, which was needed to adjust for avidity bias. Thus, meal frequency (adjusted) was derived from 473 recent consumers (n = 473).

c. Consumption Rates among Recent Consumers

By multiplying portion size by meal frequency responses, we derived consumption rates for recent consumers. Figure 23 shows the consumption rate distribution for recent consumers using the raw (untransformed) data. The raw data show a skewed distribution that required a log transformation. (Further discussion of the shape of the consumption rate distribution can be found in Appendix J.)

In Table 4 we provide a summary of the consumption rate distribution for data unadjusted and adjusted for avidity bias. Table K29 displays the complete consumption rate distribution (from 10th to 95th percentile) for recent consumers. Similar to the meal frequency results in Table 3, consumption rate results could only be provided for a slightly smaller subset of recent consumers because information needed to estimate consumption rate or adjust for avidity bias was missing.

Tables 4 and K29 show the geometric mean to be much closer to the median value, whereas the arithmetic mean falls near the 70th percentile of the full distribution for both adjusted and unadjusted data. Median consumption rates for recent consumers were 16.0 g/d for both unadjusted and adjusted data. This amount is equal to consuming two eight-ounce meals over a four-week (28 day) period. Adjusting the data for avidity bias resulted in only a slight lowering of the arithmetic and geometric means.

The values reported in Table 4 represent overall consumption rates of recent consumers that apply across fishing modes. In the sampling plan, as discussed in Section II.B.3, we set sampling targets that were weighted by the relative amount of fishing activity in each mode. As discussed in Section IV.A, our estimate of the relative proportions by mode in the sample of anglers we interviewed was slightly different than our targets. However, re-weighting the sample proportions by mode to reflect these differences did not change the consumption rate estimates in Table 4 (see Appendix J for further discussion).

Table 4. Consumption Rates in Grams/Day (g/d) for Recent Consumers Based On Four Week Recall

Consumption Rate (g/d)	Recent Consumers (Unadjusted for Avidity Bias) N=501[a]	Recent Consumers (Adjusted for Avidity Bias) N=465[a,b]
Mean (Standard Deviation)	28.1 (39.6)	23.0 (32.0)
Minimum Value	2.0	2.0
Maximum Value	324.0	324.0
Geometric Mean	16.5	14.0
Median (50th Percentile)	16.0	16.0
90th Percentile	56.0	48.0
95th Percentile	108.0	80.0

[a] For 36 recent consumers, there was insufficient information for deriving a consumption rate
[b] For an additional 36 recent consumers, fishing frequency was not reported. Thus, their consumption rate could not be adjusted for avidity bias.

d. Consumption Rates among Consumers

In order to gain a better understanding of the larger population of anglers who consume Bay fish, we present in this section consumption rate results for all consumers of Bay fish. We estimated consumption rates for consumers based on both a four-week and a 12-month recall. Table 5 shows values that characterize consumption rates for consumers of Bay fish for these two recall periods.

Table 5. Consumption Rates in Grams/Day (g/d) for Consumers Based on Four Week and 12 Month Recall

Consumption Rate (g/d)	Four Week Recall (adjusted for avidity bias) N=1080[a]	12 Month Recall (unadjusted for avidity bias [b]) N=1019[c]
Mean (Standard Deviation)	6.3 (19.6)	11.0 (35.7)
Geometric Mean	0.0	1.2
Minimum Value	0.0	0.0
Maximum Value	324.0	638
Median (50th Percentile)	0.0	2.5
90th Percentile	16.0	22.1
95th Percentile	32.0	44.2

[a] For 36 anglers, there was insufficient information for deriving a consumption rate. For an additional 36 anglers, fishing frequency was not reported. Thus, their consumption rate could not be adjusted for avidity bias. See Section III.D.1 for further discussion of avidity bias.
[b] Twelve month recall data could not be adjusted for avidity bias.
[c]Consumption rate data for 133 respondents (12%) was missing.

Consumption rates based on a four-week recall have been adjusted for avidity bias (the full distribution and unadjusted data can be found in Table K30a). Because about half of consumers (53%) did not consume any fish in the four weeks prior to being interviewed (i.e., their consumption rate in the last four weeks was zero), the geometric mean and median are zero.

Most consumers reported some consumption of Bay fish in the last 12 months. However, as noted by USEPA (1998), the accuracy of a survey respondent's recall decreases as the time period over which the recall is made increases. Thus, the consumption rate results based on the 12-month recall may be less reliable than the responses based on a four-week recall. Among consumers who reported consumption of Bay fish in the last 12 months, 14% (n=142) said that the number of times they had eaten fish was zero. Because zero was a valid response, these zero values were included in the calculation of the consumption rate values in Table 5. Missing values, however, were excluded. The median consumption rate for consumers was 2.5 g/d. This amount is equal to consuming about one 8-ounce portion every three months. The consumption rate based on a 12-month recall period could not be adjusted for avidity bias because we did not ask anglers how frequently they fished in the past 12 months. The full distribution can be found in Table K30b.

e. Per Angler Consumption Rates

Some angler studies report per angler consumption rates that are based on all survey respondents including non-consumers (i.e., anglers who do not eat any fish). In Table 6 we present per angler consumption rates based on both four-week and 12-month recall periods so that comparisons to other studies can be made. These estimates include a significant number of anglers who reported consumption rates of zero. In fact, similar to results presented in the previous section, the majority of consumers and respondents based on a four-week recall had consumption rates of zero; thus the median is zero. Also, as noted in the previous section, consumption rates based on a 12-month recall may be less reliable than those based

Table 6. Consumption Rates in Grams/Day for Respondents Based on a Four Week and 12 Month Recall

Consumption Rate (g/d)	Four Week Recall (adjusted for avidity bias) N=1259[a]	12 Month Recall (unadjusted for avidity bias[b]) N=1198[c]
Mean (Standard Deviation)	5.3 (18.2)	9.3 (33.1)
Geometric Mean	0.0	0.4
Minimum Value	0.0	0.0
Maximum Value	324.0	638
Median (50th Percentile)	0.0	1.8
90th Percentile	16.0	18.4
95th Percentile	24.0	36.8

[a]For 36 anglers, there was insufficient information for deriving a consumption rate. For an additional 36 anglers, fishing frequency was not reported. Thus, their consumption rate could not be adjusted for avidity bias. See Section III.D.1 for further discussion of avidity bias.
[b] Twelve-month recall data could not be adjusted for avidity bias.
[c]Consumption rate data for 133 consumers (10%) was missing; non-consumers were assigned a consumption rate of zero.

on a four-week recall. The median consumption rate of 1.8 g/d based on a 12-month recall is equivalent to consuming about one eight-ounce portion every four months. The full distribution of these consumption rates for respondents can be found in Tables K31a and K31b.

2. Differences Among Demographic Subgroups

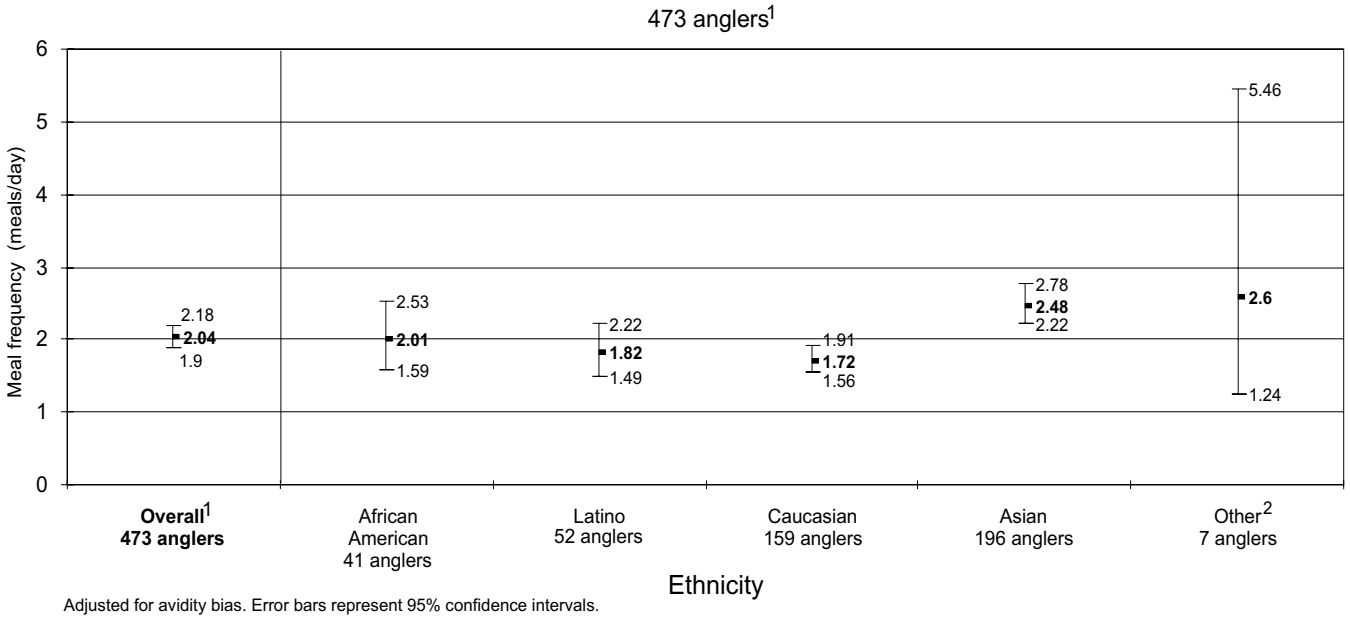
In addition to estimating overall fish consumption rates for anglers who consume SF Bay fish, another primary goal of the study was to identify highly exposed subpopulations. One way to identify a highly exposed subpopulation is to compare consumption rate variables (i.e., portion size, meal frequency, and consumption rates) within demographic subgroups and look for differences among these subgroups.

When we compared the arithmetic mean (adjusted) portion sizes among consumers of Bay fish, we found differences for ethnicity, season interviewed, and gender (see Table K32). Among ethnic groups, African Americans reported the largest portion size (9.0 ounces); their portion size was significantly larger than Caucasians and Asians. Asians reported the smallest portion size (6.7 ounces). Their portion size was significantly smaller than Latinos and Caucasians, as well as African Americans. Portion sizes differed by season of interview, with larger portion sizes reported during the fall (8.1 ounces) than the spring (6.6 ounces). Also, female anglers reported a smaller portion size (6.6 ounces) than male anglers (7.8 ounces).

For meal frequency and consumption rates in this study we compared the geometric means (adjusted). Comparisons of meal frequency based on a four-week recall for recent consumers showed no differences among demographic subgroups except among ethnic groups (see Table K33). Figure 24 shows adjusted geometric mean meal frequencies with 95% confidence intervals by major ethnic groups. Asians had a higher meal frequency (2.5 times in the last four weeks) than Caucasians (1.7 times). As shown by the non-overlapping confidence intervals, these differences were statistically significant. Among Asian subgroups, shown in Figure 25, Filipinos had the highest meal frequency (3.1 times). The

Figure 24

Geometric mean meal frequency by ethnicity (major groups) among recent consumers

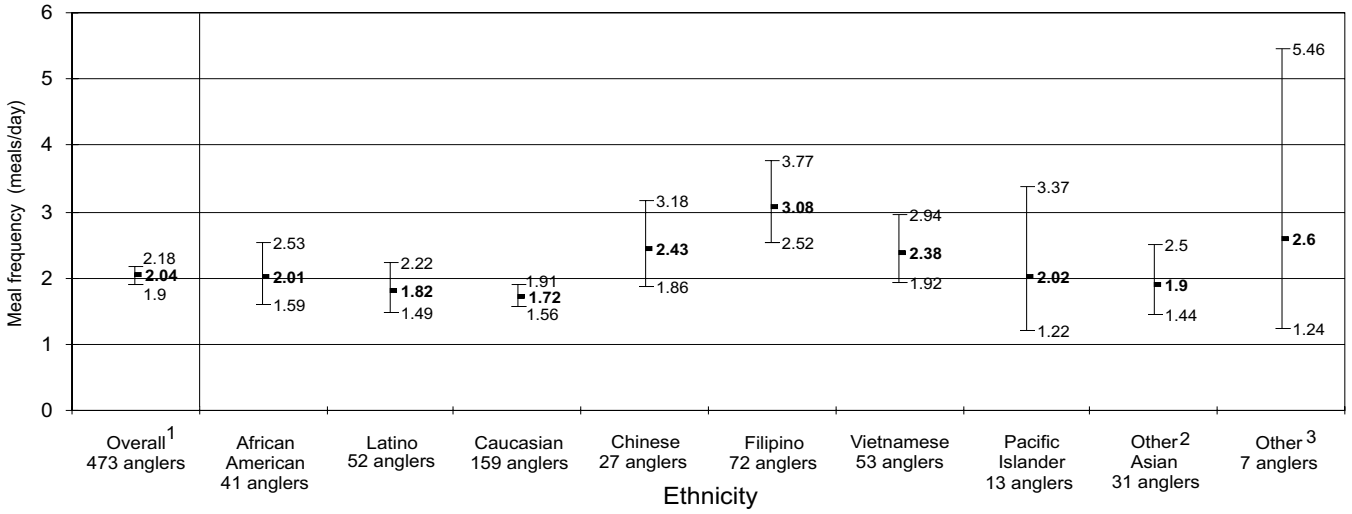


Adjusted for avidity bias. Error bars represent 95% confidence intervals.

1 Ethnicity was missing for 18 Recent Consumers.
2 "Other" includes Russian, Middle Eastern, and individuals of unspecified mixed ethnicity.

Figure 25

Geometric mean meal frequency by ethnicity (including Asian subgroups) among recent consumers
473 anglers[1]



Adjusted for avidity bias. Error bars represent 95% confidence intervals.

1 Ethnicity was missing for 18 Recent Consumers.
2 "Other Asian" includes Korean, Japanese, Southeast Asian (either than Vietnamese), and individuals of mixed Asian or unspecified Asian ethnicity.
3 "Other" includes Russian, Middle Eastern, and individuals of unspecified mixed ethnicity.

complete distribution of meal frequency responses by demographic factors can be found in Tables K34a and K34b.

Comparisons of consumption rates among subgroups of recent consumers showed differences for ethnicity but not for other demographic characteristics (see Table K35). Figure 26 shows adjusted geometric mean consumption rates by major ethnic groups. The geometric mean consumption rates for African Americans were roughly 50% higher than Caucasians, the ethnic group with the lowest consumption rate. Figure 27 includes Asian subgroups. Filipinos also had consumption rates approximately 50% higher than Caucasians. These differences were statistically significant. Pacific Islanders and anglers whose ethnicity was described as "Other" (Russian, Middle Easterners, and individuals of unspecified mixed ethnicity) had the highest consumption rates of all ethnic groups, approximately double the rate for Caucasians. However, anglers in these two groups were very small in number (Pacific Islanders, n=12 and Other, n=7), and differences in the geometric means between these two groups and Caucasians were not significant. Tables K36a and K36b describe the geometric mean and full distribution of consumption rates among recent consumers by demographic variables for unadjusted and adjusted data.

Because consumption rate data were not normally distributed, we also used a non-parametric test, the Wilcoxon signed rank test, to compare consumption rates within demographic variables. Using this test, ethnicity showed significant differences ($p<0.05$) between subgroups with consumption rate. No statistically significant differences with consumption rates existed based on mode, income, education, age, gender, or season of interview.

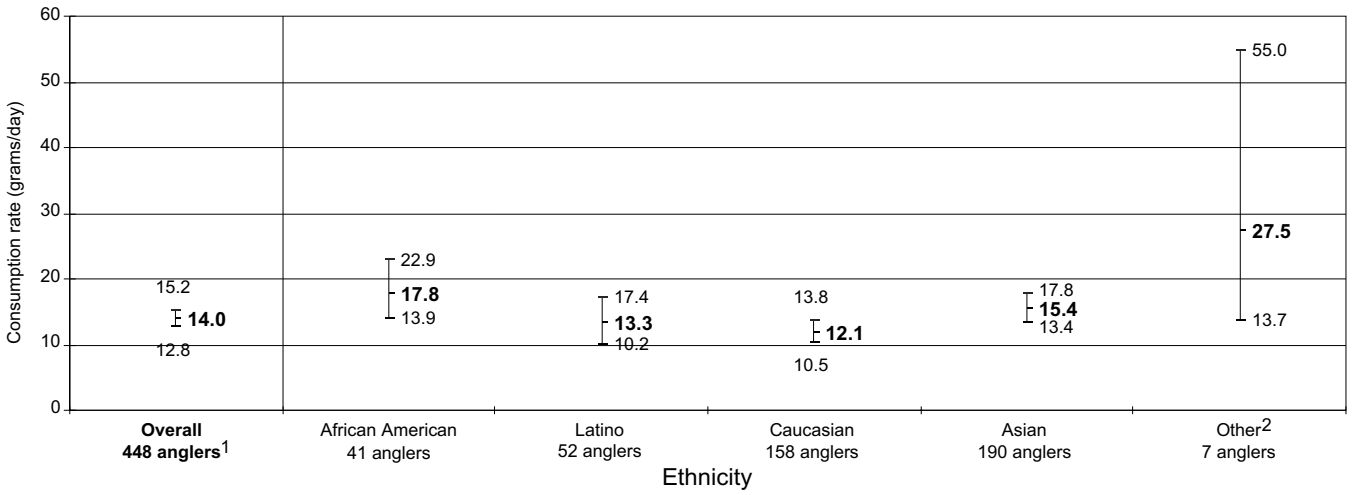
3. Highly Exposed Consumers

As discussed in the previous section, one way to identify highly exposed subpopulations is to compare consumption rate variables among subgroups and look for differences. In this section, we discuss another way to identify highly exposed anglers by describing the demographic characteristics of the group of anglers with the highest consumption rates. We characterize two highly exposed groups, those who eat

Figure 26

Geometric mean consumption rate by ethnicity (major groups) among recent consumers

448 anglers



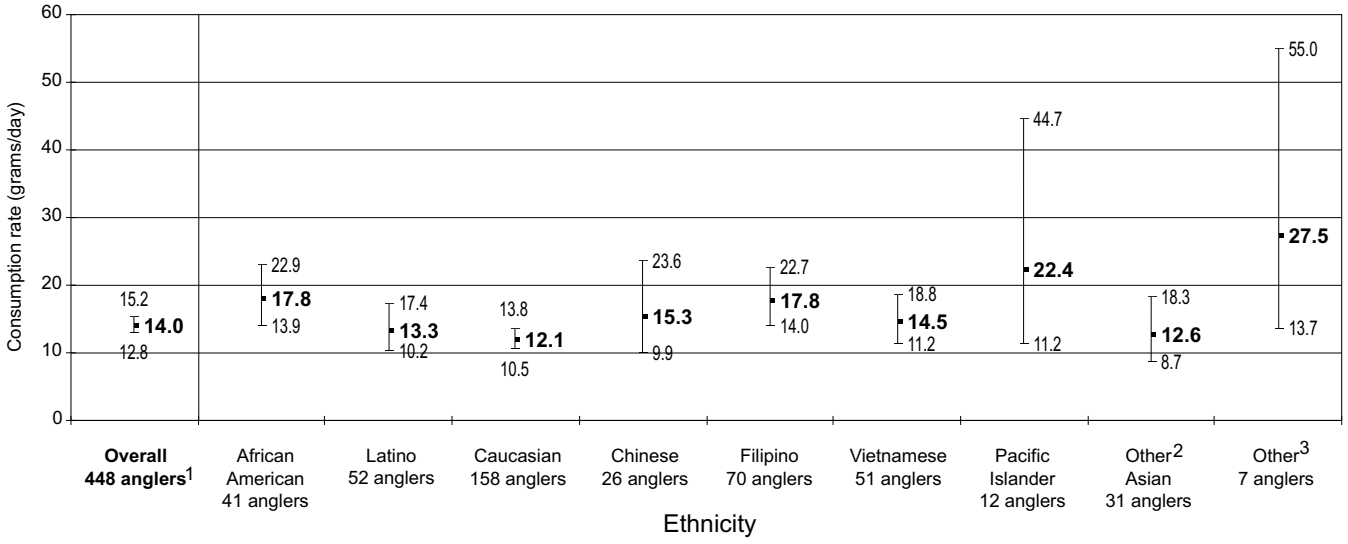
Adjusted for avidity bias. Error bars represent 95% confidence intervals.

1 "Overall" excludes 17 recent consumers with missing ethnicity data.
2 "Other" includes Russian, Middle Eastern, and individuals of unspecified mixed ethnicity.

Figure 27

Geometric mean consumption rate by ethnicity (including Asian subgroups) among recent consumers

448 anglers



Adjusted for avidity bias. Error bars represent 95% confidence intervals.

1 "Overall" excludes 17 recent consumers with missing ethnicity data.
2 "Other Asian" includes Korean, Japanese, Southeast Asian (other than Vietnamese), and individuals of mixed Asian or unspecified Asian ethnicity.
3 "Other" includes Russian, Middle Eastern, and individuals of unspecified mixed ethnicity.

above health advisory levels, and those whose overall consumption rate is above the 95% percentile. These highly exposed groups are then compared to consumers of Bay fish who are below these levels.

a. "Above Advisory" Consumers

Anglers who consume Bay fish above levels recommended by the health advisory for SF Bay can be considered a highly exposed group. The health advisory recommends that anglers limit their consumption of most species of Bay fish to no more than two meals per month, with meal size adjusted for body weight. (See Appendix A for full text of the health advisory). We defined "above advisory" consumers as those who reported consuming greater than 16 ounces (two 8-ounce meals) of advisory species in the four weeks prior to being interviewed. (Sixteen ounces consumed within a four-week period is equal to 16 g/d.) Above advisory consumers differ from anglers whose overall consumption rate is greater than 16 g/d because some commonly consumed species, such as jacksmelt and salmon, are not included in the health advisory.

In order to see how the above advisory consumers are different from other consumers of Bay fish, we compared them to consumers who did not surpass the health advisory level. We call this group the "below advisory" group. We find in Figure 28 that 9% of consumers (adjusted; 15%, unadjusted, see Table K37a) reported consuming above advisory levels (greater than 16g/day) in the four weeks prior to being interviewed. Looking only at meal frequency, we also find that 9% (adjusted; 16%, unadjusted) of consumers reported consuming greater than 2 meals of advisory fish within a four week period. Based on consumption rates, for the 9% above advisory consumers, Figure 28 also shows how far above the advisory recommendations these anglers are consuming. For example, 41% of above advisory consumers are consuming between two to four times (32 g/day to 64 g/day) above the advisory level. Only 1% are consuming 16 times (256 g/day) or more above the advisory level.

We also examined the demographic differences between the above and below advisory groups in two ways. In Figure 29, we compare how the demographic profile of above advisory consumers differs from below advisory consumers. Among fishing modes, we found that private boat anglers represented a smaller proportion of the above advisory consumers when compared to the below advisory consumers. Among ethnic groups, Asians represented a larger proportion among the above advisory group when compared to the below advisory group, whereas Caucasians represented a smaller proportion among the above advisory consumers. Within income and education levels, differences between the above and

Figure 28

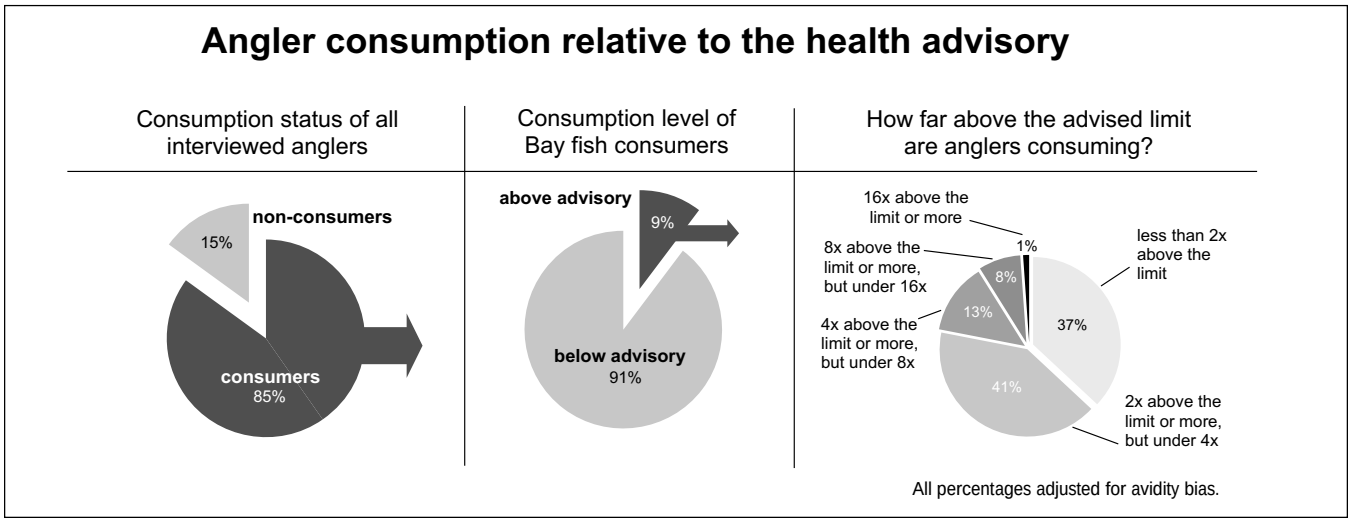
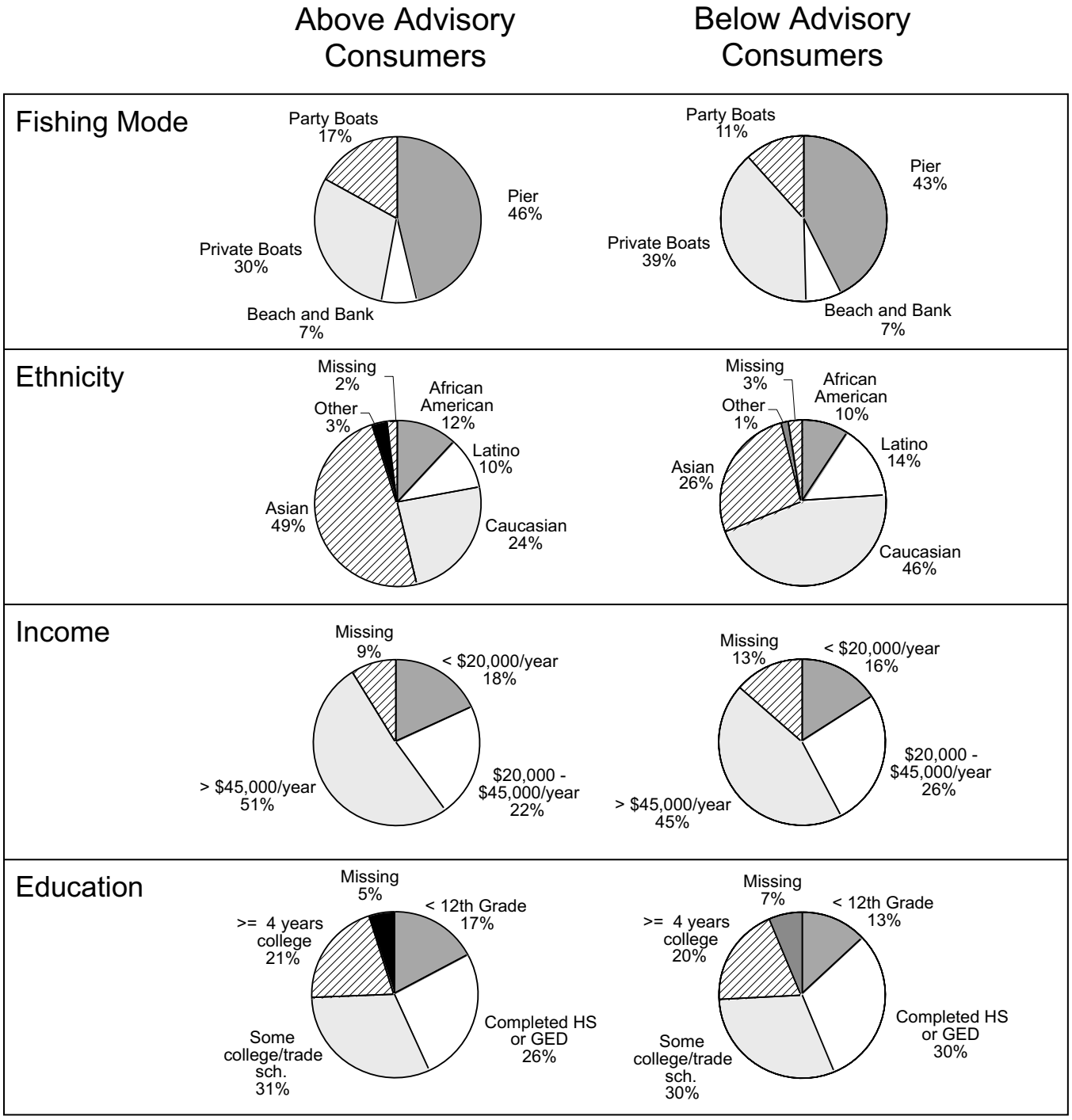


Figure 29

Demographic characteristics of anglers consuming above and below the advisory

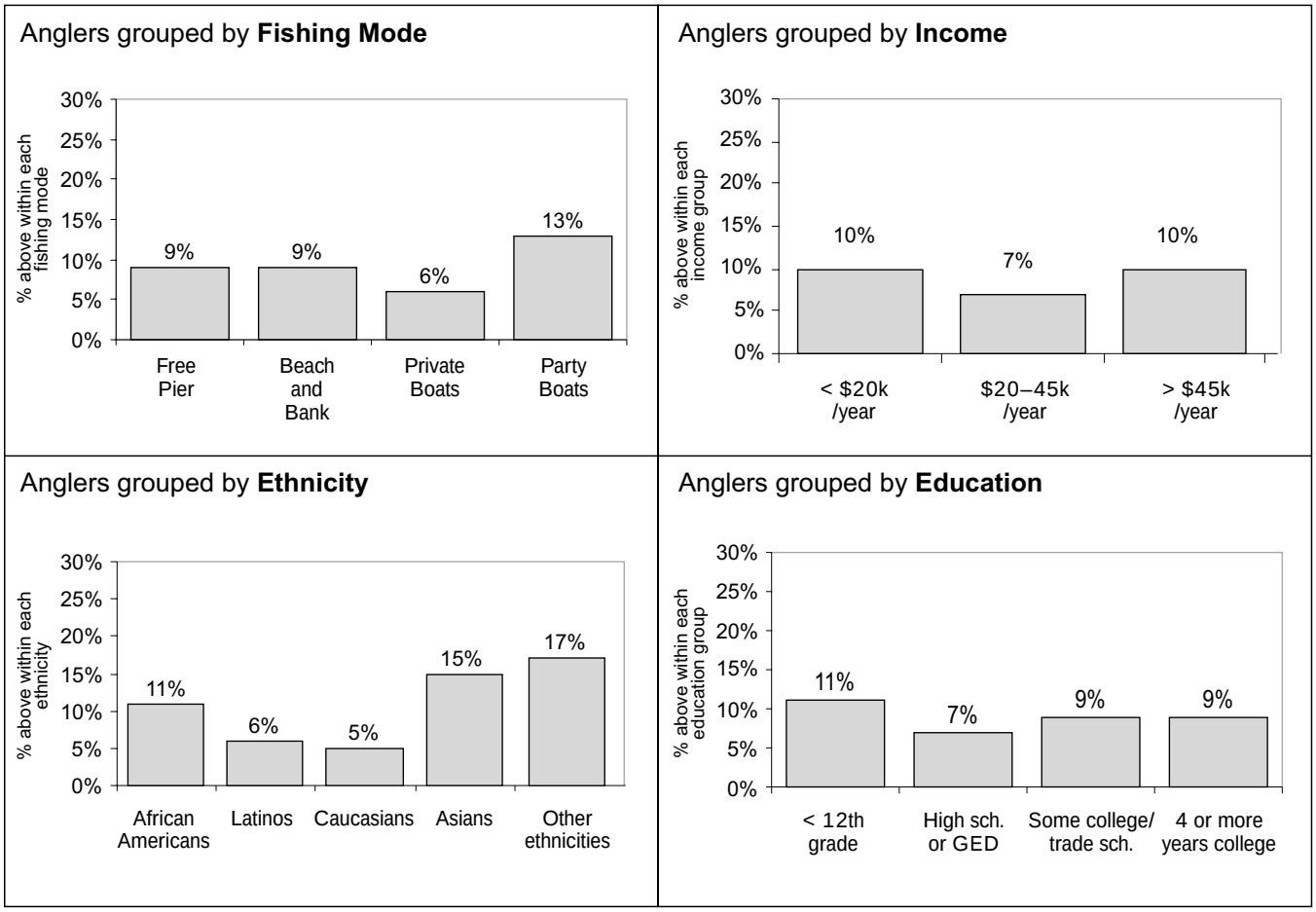


All percentages adjusted for avidity bias.

Figure 30

Percentage of anglers consuming above advisory recommendations

Anglers with Bay fish consumption



Anglers with no fish consumption excluded from percentage calculations. All percentages adjusted for avidity bias.

below advisory group were small. Tables K37a and K37b compare the above advisory groups to the below advisory group for these and other demographic variables. We also show these same data presented in a different way. Figure 30 compares the proportion of above advisory consumers within demographic subgroups. For example, within ethnic groups, Asians were three times more likely to be in the above advisory group than Caucasians (see Table K37b).

It is important to note that the health advisory is more restrictive for women who are pregnant, planning to become pregnant, or nursing, and for small children. For these groups, the health advisory recommends that consumption of Bay fish be limited to no more than one time per month. We did not interview any children, and we did not determine whether the women we interviewed were pregnant, planning to become pregnant or nursing. However, as discussed previously and shown in Table K35, consumption rates for female anglers did not differ from consumption rates for males. Thus, if consumption rates for pregnant women, women planning to become pregnant, and nursing women are similar to women we interviewed, then a much higher proportion of these women will exceed a more restrictive health advisory.

b. Consumers above the 95th Percentile

Because risk assessors often use upper percentiles of a distribution to characterize high end exposures, in Figure 31 we characterized the consumers of Bay fish whose consumption rate was among the top five percent of consumers (i.e, above the 95th percentile). We compared this group, who consumed greater than 32 g/day (adjusted), to consumers of Bay fish whose consumption rate was at or below the 95th percentile.

Figure 31 also compares these two groups by demographic variables. Similar to the above advisory consumers discussed in the previous section, we found that a larger proportion of the top five percent of consumers were Asian and a smaller proportion were Caucasian, when compared to the remaining 95% of consumers. However, unlike the above advisory consumers, a larger proportion of the top five percent group reported the highest income level (>$45,000 per year) than the comparison group. Differences by mode and education were small. Table K38 compares the top five percent to the remaining 95% of consumers for these and other demographic variables.

4. How Decliners May Affect Consumption Rates

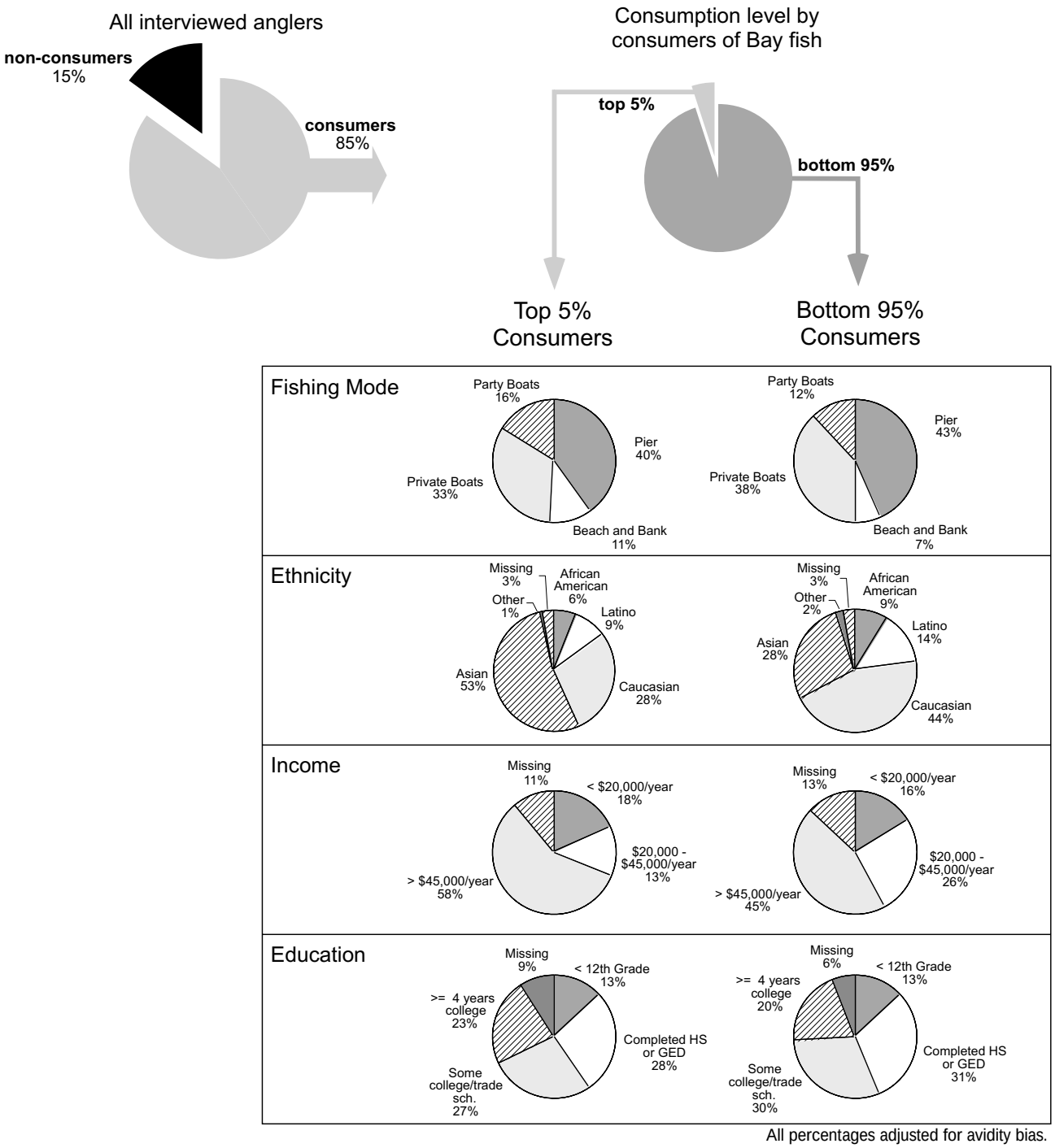
Anglers who declined to be interviewed for this study represented 23% (n=407) of net attempted interviews (see Section IV.B, Figure 4 and Table 2). Although the decline rate for this study was lower than similar studies (Wong *et al.*1997, SCCWRP/MBC 1994), lacking data on nearly one fourth of the sample may have introduced some bias. By recording observed ethnicity for anglers who declined to be interviewed, we were able to show that the ethnic profile of those who chose not to participate in the study (i.e., decliners) differed from anglers who agreed to be interviewed (Tables K1c and K3c). Decliners, for example, had a higher proportion of Asians than anglers who were interviewed. In addition, for about a third of decliners, we recorded language problems as the reason the angler declined to be interviewed. These anglers could be comprised of recent immigrants who may be less aware of health advisories and thus have higher consumption rates than the angler population as a whole.

We evaluated how consumption rates of recent consumers (based on a four-week recall) may have been influenced by the decliners. As a worst-case scenario, to ensure that we do not underestimate the influence decliners may have had on overall consumption rates, we assumed that all decliners had recent consumption (in the last four weeks) of Bay fish. (More likely, decliners included non-consumers or consumers who had not eaten Bay fish recently, as in the interviewed population). Furthermore, because ethnicity was the only demographic variable that showed a significant influence on consumption rate, we adjusted our sample to account for ethnic differences between the decliners and interviewed anglers. We did this by assuming that decliners of a certain ethnic group had the same consumption rate as recent consumers we interviewed in the same ethnic group. We found that consumption rates of recent consumers with decliners included were virtually identical to the consumption rates of recent consumers without decliners.

It is also plausible that decliners have consumption rates that are lower than anglers who were interviewed. For example, they may have declined to be interviewed because they consume very little Bay fish or do not eat Bay fish at all. If decliners have low consumption rates, the consumption rates presented in Section IV.D.1 may be biased upwards. Although any bias associated with anglers who declined to be interviewed is not quantifiable, our analysis using reasonable assumptions about this group revealed that the 23% of anglers from whom we could not directly obtain consumption data are not very likely to influence our overall derived consumption estimates.

Figure 31

Demographic characteristics of anglers with consumption rate in the top 5% (above 32 grams/day) and bottom 95%



All percentages adjusted for avidity bias.

5. Commonly Consumed Species

One of the study objectives was to determine which species of SF Bay fish were most commonly consumed by anglers. We determined the most commonly consumed species in two ways. First, for the three species of greatest health concern in SF Bay white croaker, leopard shark, and striped bass, we asked whether anglers, in general, consumed these species. Second, we asked anglers whether they had had recent consumption (in the last four weeks) of any SF Bay fish species, including these three species. Data reported in this section could not be adjusted for avidity bias, thus results are unadjusted.

a. Consumption of White Croaker, Leopard Shark, and Striped Bass

For three species of SF Bay fish—white croaker, leopard shark, and striped bass—interviewers asked respondents the general question, "Do you eat this fish?" When asking about these three species, the interviewer showed the respondent color photos of these fish (see Appendix F). Among consumers of Bay fish, about three fourths reported that, in general, they ate striped bass while much smaller proportions (28% and 20%, respectively) reported that they ate white croaker and leopard shark (see Figure 32).

We also looked at the demographic variables that describe consumers of these three species. For consumers who said they eat white croaker, there were statistically significant differences within mode, ethnicity, income, and education (see Figure 32 and Table K39). For example, a much higher proportion of consumers who fish from piers and beach and bank sites, reported that they eat white croaker, compared to boat anglers. Among ethnic groups, 46% of Asians eat white croaker compared to only 10% of Caucasians. The proportion of consumers who reported the lowest income level (<$20,000) were twice as likely to consume white croaker than consumers reporting the highest income level (>$45,000). A similar pattern was found for level of education.

For consumers of leopard shark, there were statistically significant differences within ethnicity (when Asian subgroups were included), income, and education (see Figure 32 and Table K39). A higher proportion of Vietnamese and Chinese reported consuming leopard shark compared to other ethnic groups. As with white croaker, consumers at the lowest income and educational levels had a higher proportion of leopard shark consumers than consumers at the highest income and educational levels.

Because such a high proportion of consumers eat striped bass, there were no statistically significant differences by mode, ethnicity, income and education, for consumers of this species (see Figure 32 and Table K39).

b. Commonly Consumed SF Bay Fish Species

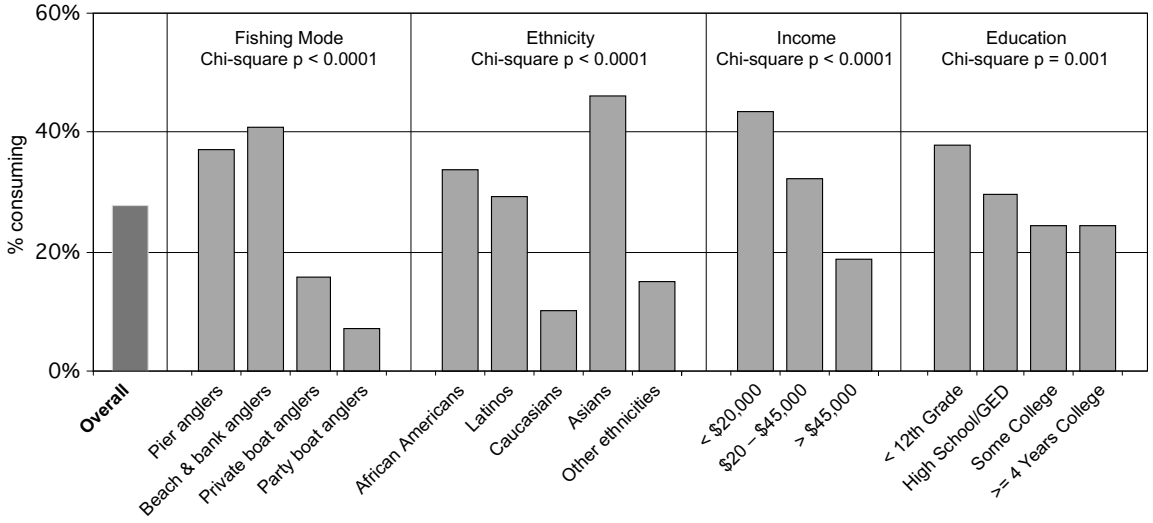
In addition to asking respondents if they, in general, eat white croaker, leopard shark, or striped bass, respondents were also asked if they had consumed any SF Bay fish species in the last four weeks. The interviewers showed respondents color pictures of 16 fish species and three types of Bay shellfish. Shellfish consumption is described in a later section (Section IV.D.8). Interviewers then asked respondents about recent consumption of other fish species for which pictures were not available.

Figure 33 shows the 14 most commonly consumed fish species among recent consumers during the twelve-month survey period. Striped bass was the most commonly consumed fish species, with slightly over half of recent consumers reporting they consumed striped bass in the last four weeks. We excluded fish species reported by less than 1% of recent consumers. Interviewers showed anglers pictures of all species in Figure 33 except salmon.

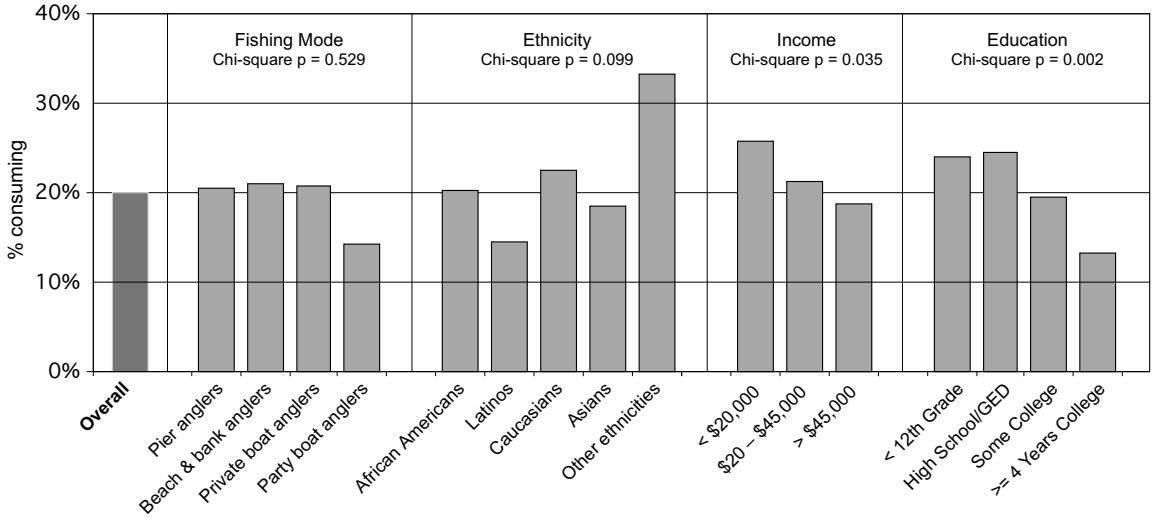
In Figure 34, we compared the demographic variables that characterize the anglers who had recent consumption of two species, halibut and jacksmelt. These two species were the second and third most

Figure 32

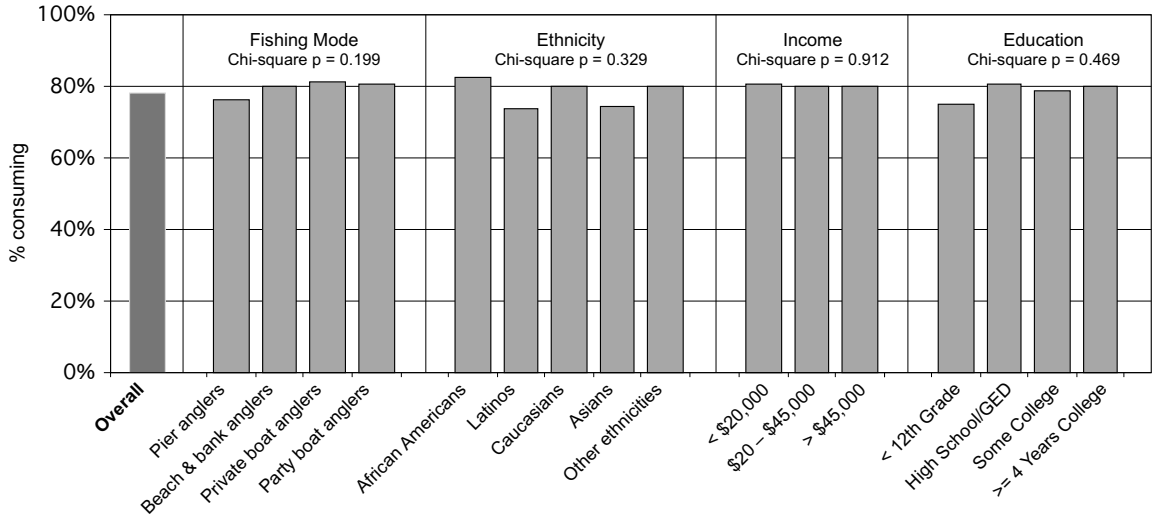
Consumption of white croaker



Consumption of leopard shark



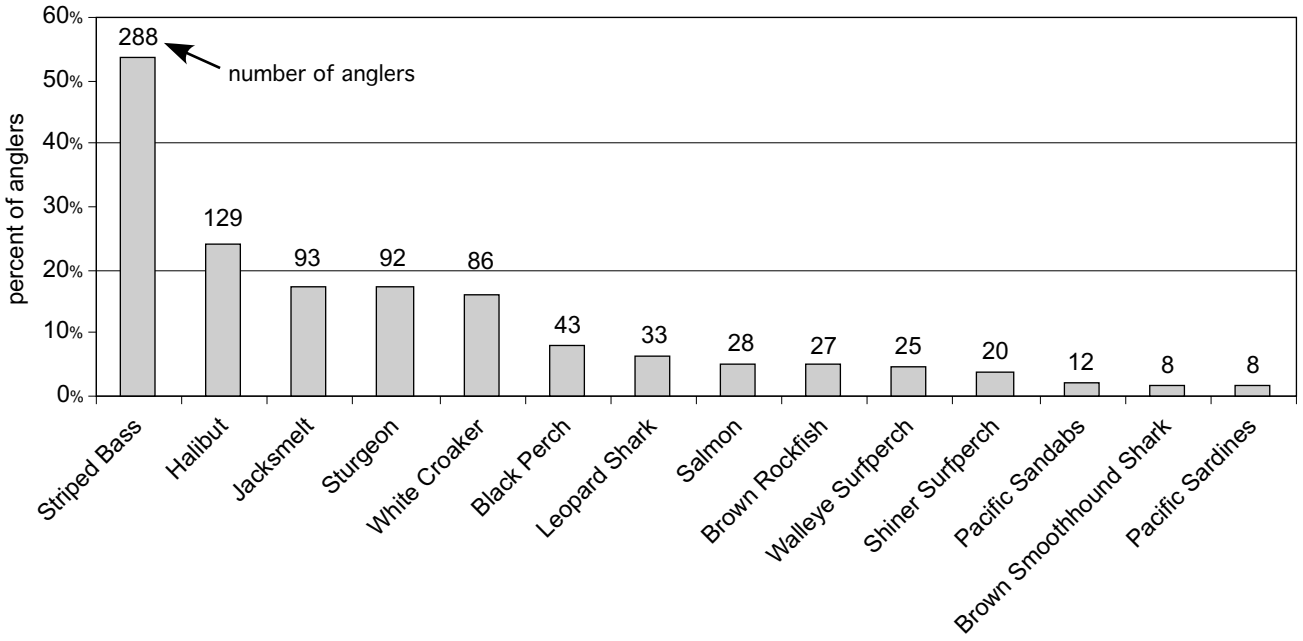
Consumption of striped bass



Anglers reporting no fish consumption not included in percentage calulations Not adjusted for avidity bias.

Figure 33

Bay fish species consumed by anglers with recent fish consumption
537 anglers



Anglers reporting no consumption in last 4 weeks not included.Not adjusted for avidity bias.

commonly consumed species (in the last four weeks) after striped bass. We do not present demographic factors that characterize recent consumers of striped bass because there were no significant differences within these factors except for season of interview (Table K40). We found statistically significant differences within mode, ethnicity, and income for both halibut and jacksmelt (see Figure 34). For example, among fishing modes, a much higher proportion of party boat anglers had recent consumption of halibut compared to shore-based anglers. In contrast, a higher proportion of shore-based anglers (especially beach and bank anglers) had recent consumption of jacksmelt compared to boat anglers.

Caucasians were more than two times as likely to have consumed halibut than Asians, although Asians were almost ten times as likely to have consumed jacksmelt than Caucasians. For recent consumers of halibut, the proportion in the highest income level was nearly three times that in the lowest income level. For recent consumers of jacksmelt, the proportion in the lowest income levels was nearly twice the highest income level.

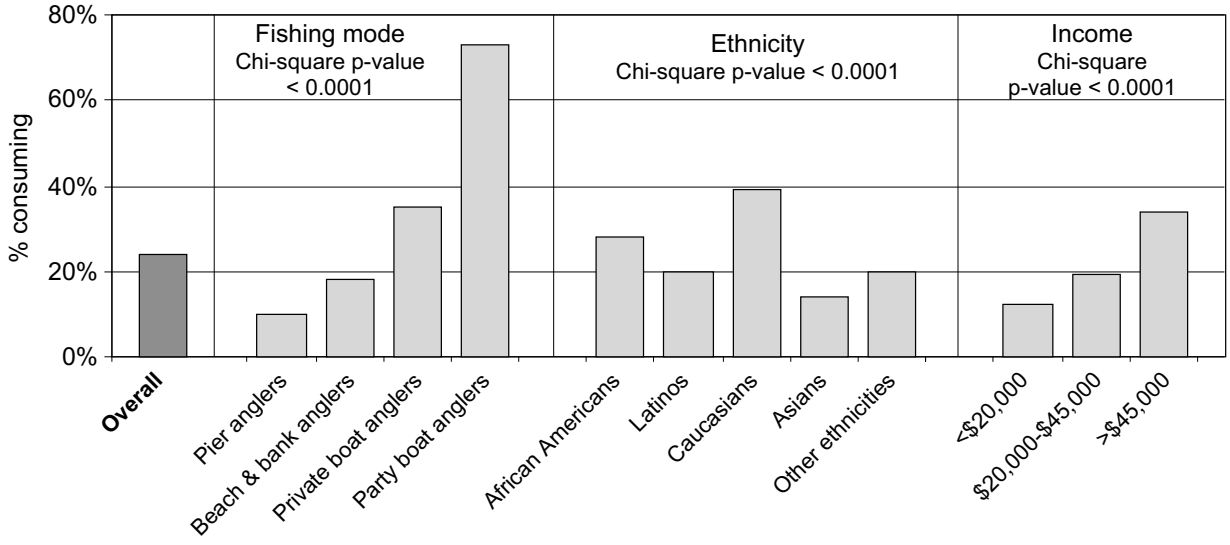
Comparison of demographic factors among recent consumers of the top seven fish species (striped bass, halibut, jacksmelt, sturgeon, white croaker, surfperch, and leopard shark) can be found in Table K40.

6. Fish Parts Consumed and Fish Preparation Practices

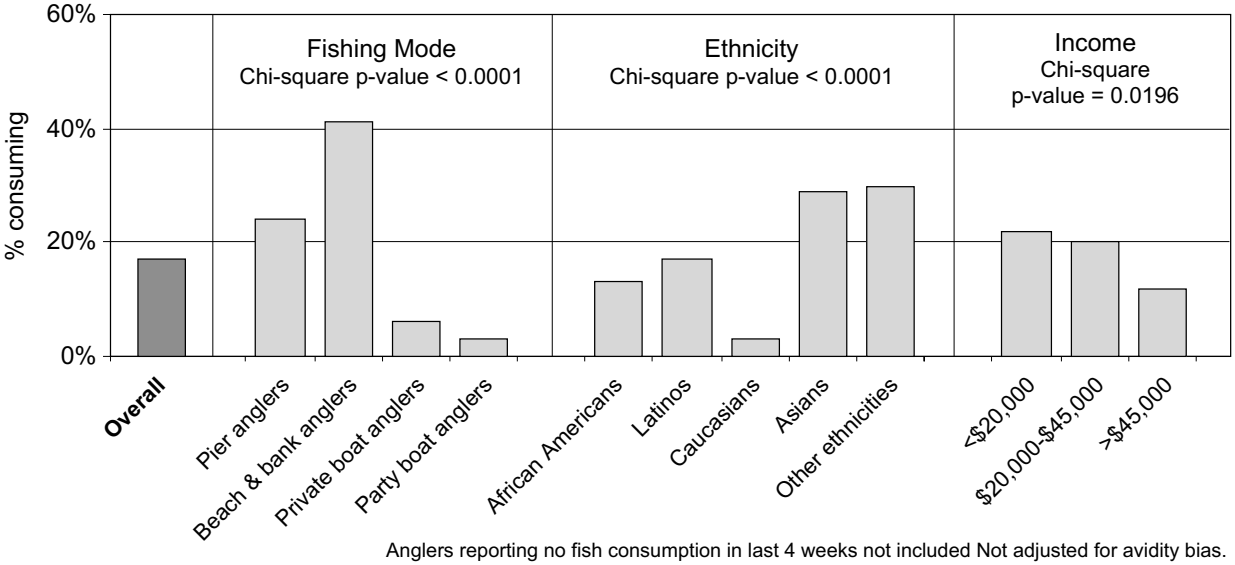
Because the parts of the fish consumed and the preparation and cooking methods used will influence an angler's exposure to chemicals in contaminated fish, another objective of the study was to characterize these consumption methods for three SF Bay species: white croaker, leopard shark, and striped bass. This information will help identify populations that are likely to be more exposed to chemical contaminants because of their consumption practices.

Figure 34

Percentage of recent consumers with halibut consumption



Percentage of recent consumers with jacksmelt consumption



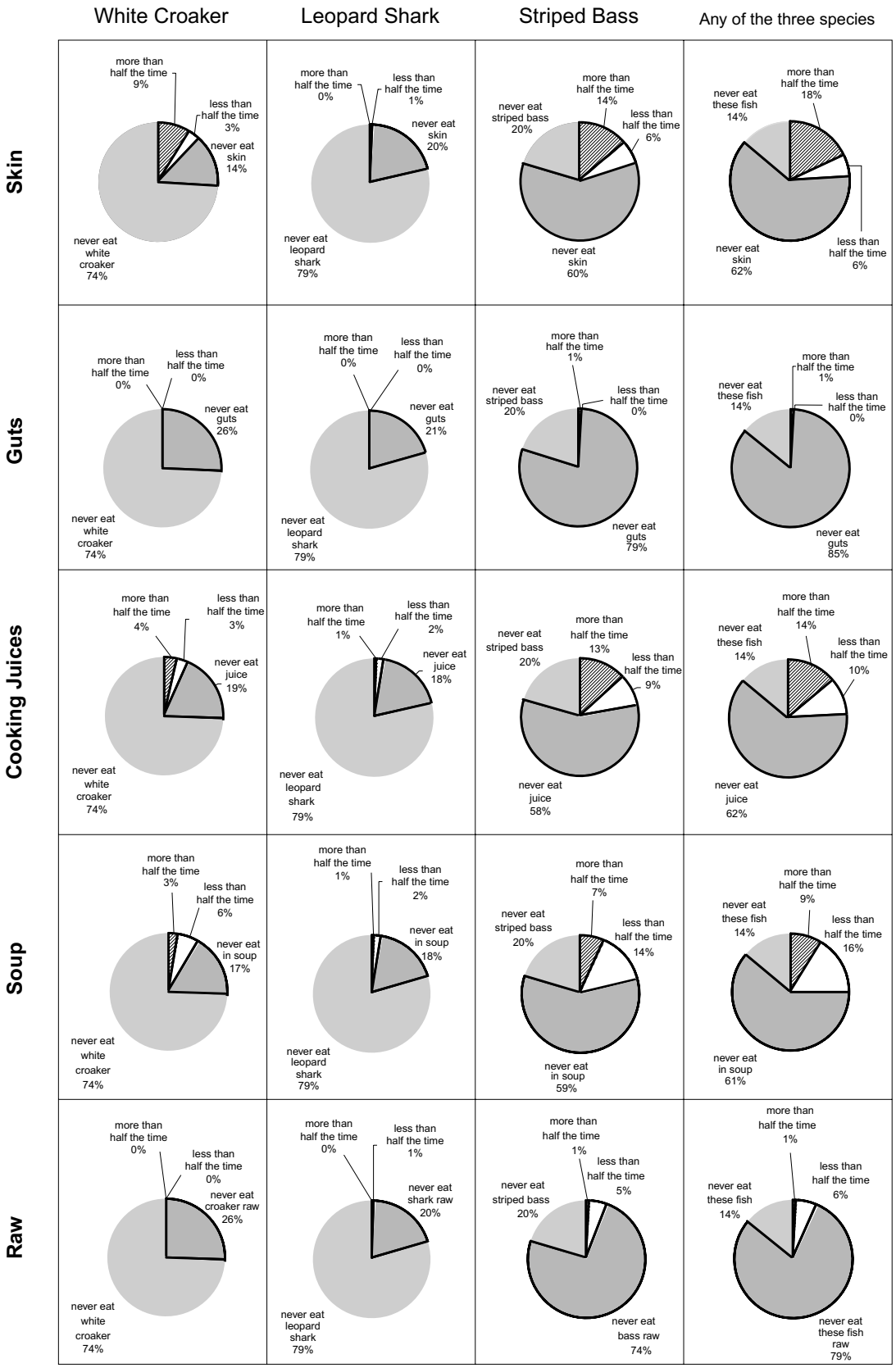
Anglers reporting no fish consumption in last 4 weeks not included Not adjusted for avidity bias.

Anglers were asked about each of the three species independently. Anglers first had to report that they, in general, ate one of the three species before they were asked about their consumption methods for that species. Specifically, interviewers asked anglers how often they ate: (1) the skin, (2) the guts, (3) the cooking juices or drippings, (4) the species in soup, (5) the species raw. In answering these questions, respondents indicated whether they followed the consumption practice more than half the time, less than half the time, or never.

The data on fish parts consumed and fish preparation methods used by anglers is summarized for the three species in Figure 35 and Table K41. Overall, we found that the majority of consumers of Bay fish never reported any of these five consumption practices for the three species. Only about one fourth

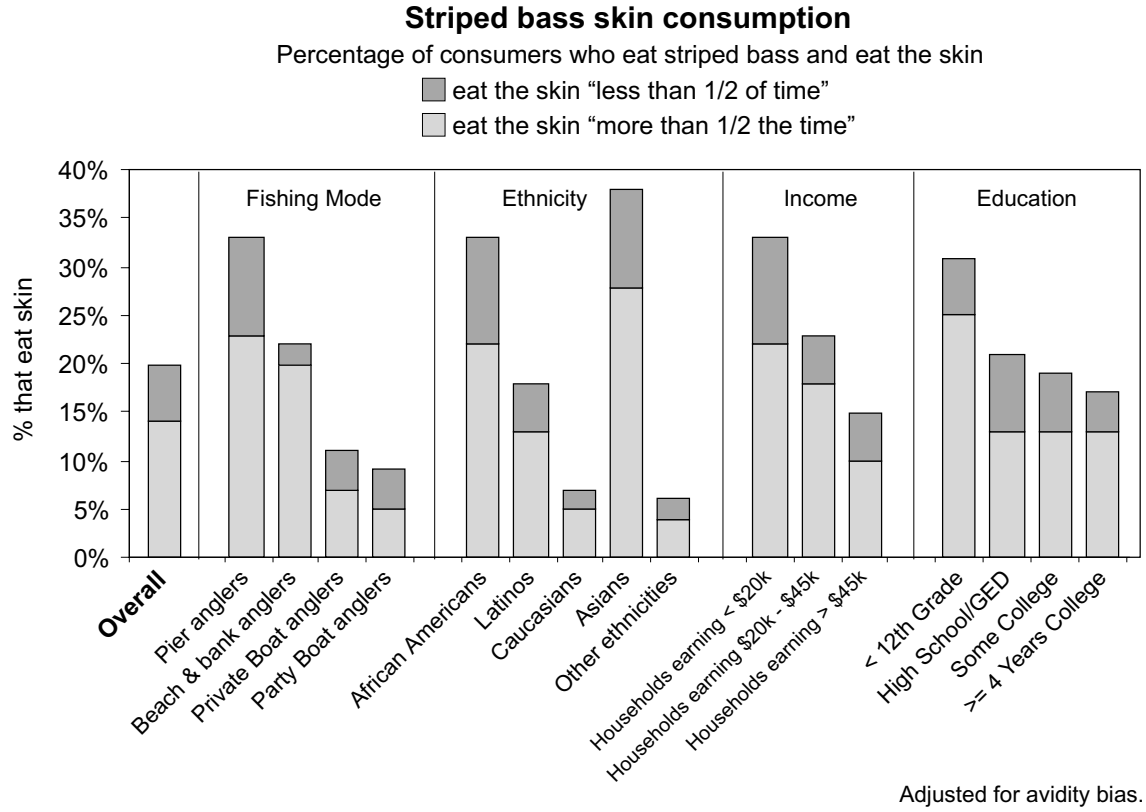
Figure 35

Fish parts consumed and fish preparation practices among consumers



Adjusted for avidity bias.

Figure 36a



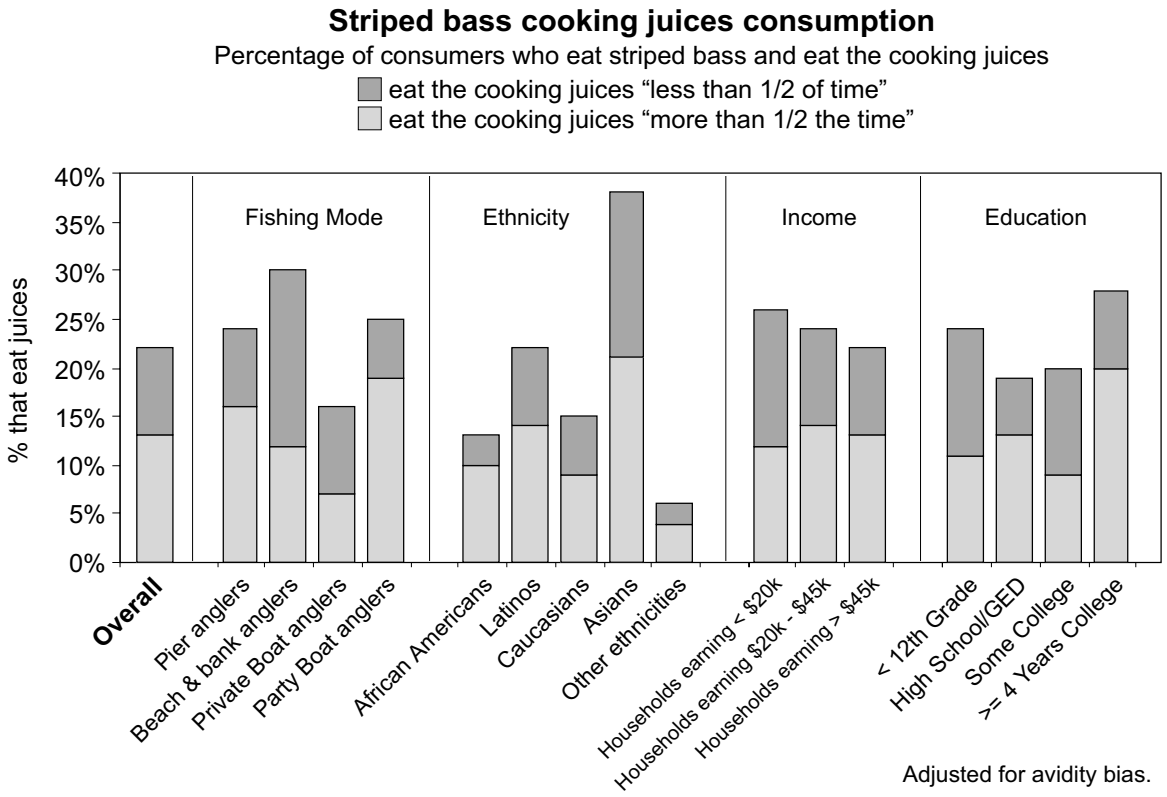
of consumers reported that they ever ate skin, cooking juices, or ate soup made from at least one of these species. Only 1% of consumers reported consumption of guts for any of the three species and only 7% reported raw consumption.

Consumers of Bay fish more frequently reported consumption of striped bass skin, guts, etc., compared to the other two species. This was due largely to the fact that a much higher percentage of consumers ate striped bass than other species (see Figure 35). However, when consumers who did not eat these species were excluded, the proportions changed. For example, among consumers of white croaker, nearly half ate white croaker skin whereas only one fourth of striped bass consumers ate striped bass skin. About one in three consumers of white croaker ate this species in soup. In comparison, only one in five striped bass consumers ate this species in soup. About one fourth of striped bass and white croaker consumers ate the cooking juices of these species at least some of the time. Raw consumption was still highest among striped bass consumers, compared to other species. These consumption methods among leopard shark consumers were uniformly lower than the other two species.

Further analysis of consumption of striped bass skin, cooking juices, and consumption of this species raw by demographic factors is presented in Figures 36a-36c. We chose to present more detailed analysis of consumption practices for striped bass because the majority of anglers in all demographic groups consumed this species, thus consumption methods were not skewed by who did or did not eat this species.

Among consumers who ate striped bass skin, shore-based anglers were twice as likely as boat anglers to eat skin of this species at least some of the time. African American and Asians were four to five times as likely as Caucasians to eat skin at least some of the time. Also, the proportion of anglers

Figure 36b



who ate striped bass skin was highest at low income and education levels. Among consumers who ate cooking juices of striped bass, private boat anglers were less likely to consume cooking juices of striped bass than anglers of other fishing modes. Asians were nearly three times as likely as Caucasians and African Americans to consume cooking juices at least some of the time. Differences by income and education were relatively small.

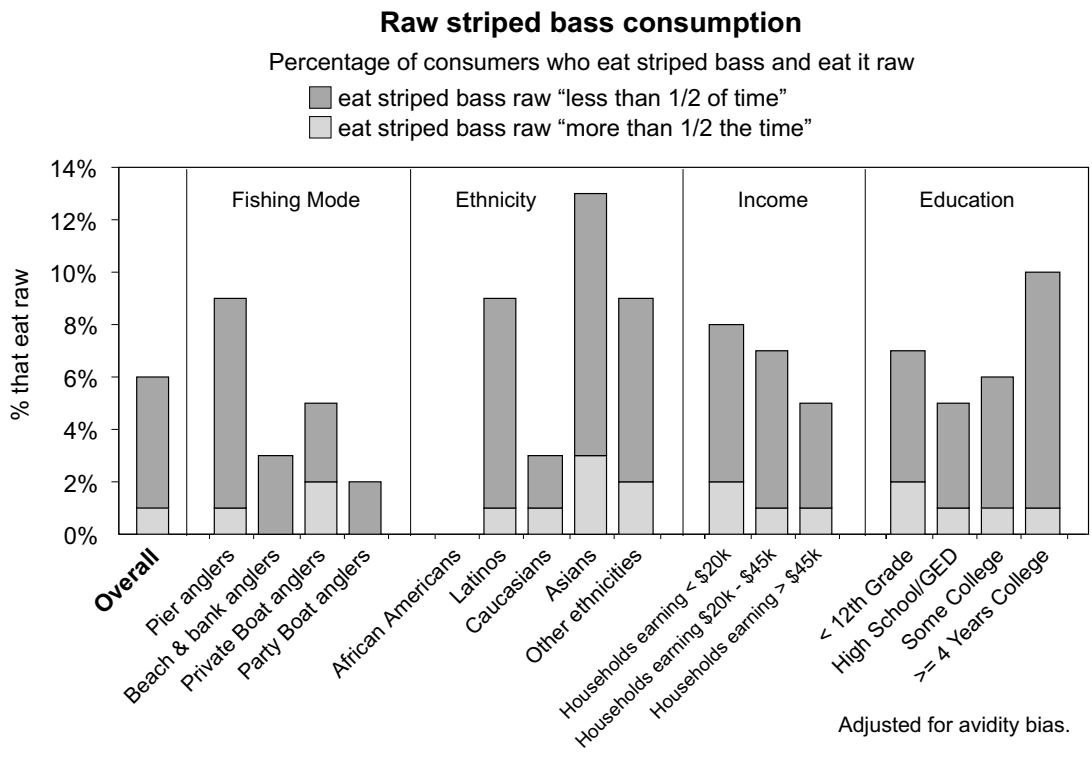
Although raw consumption of striped bass was relatively uncommon among consumers of this species (6%), pier anglers and Asians were more likely to report raw consumption than other modes and ethnic groups (see Table K42e). Tables K42a-K42e summarizes the five consumption methods for striped bass by mode, ethnicity, income, and education.

In contrast to the population that consumes striped bass, the population consuming white croaker differed markedly from the overall consumer group (see Figure 32 and Table K39). Consumption methods for consumers of white croaker for some demographic factors are presented in Tables K43a-K43e. No further analysis of leopard shark was conducted because few anglers reported any of these consumption patterns for this species.

7. Consumption of Fish Caught from Outside SF Bay and Commercial Sources

Although the primary purpose of this study was to characterize anglers' consumption of fish from SF Bay, we also characterized consumption of fish from two other sources: (1) fish caught from areas outside SF Bay, including the ocean and freshwater rivers and lakes, and (2) fish from commercial sources (i.e., fish purchased from stores or restaurants). We only asked respondents whether they had recent consumption (in the last four weeks) of fish from these sources. We found, in Figure 37, that one

Figure 36c

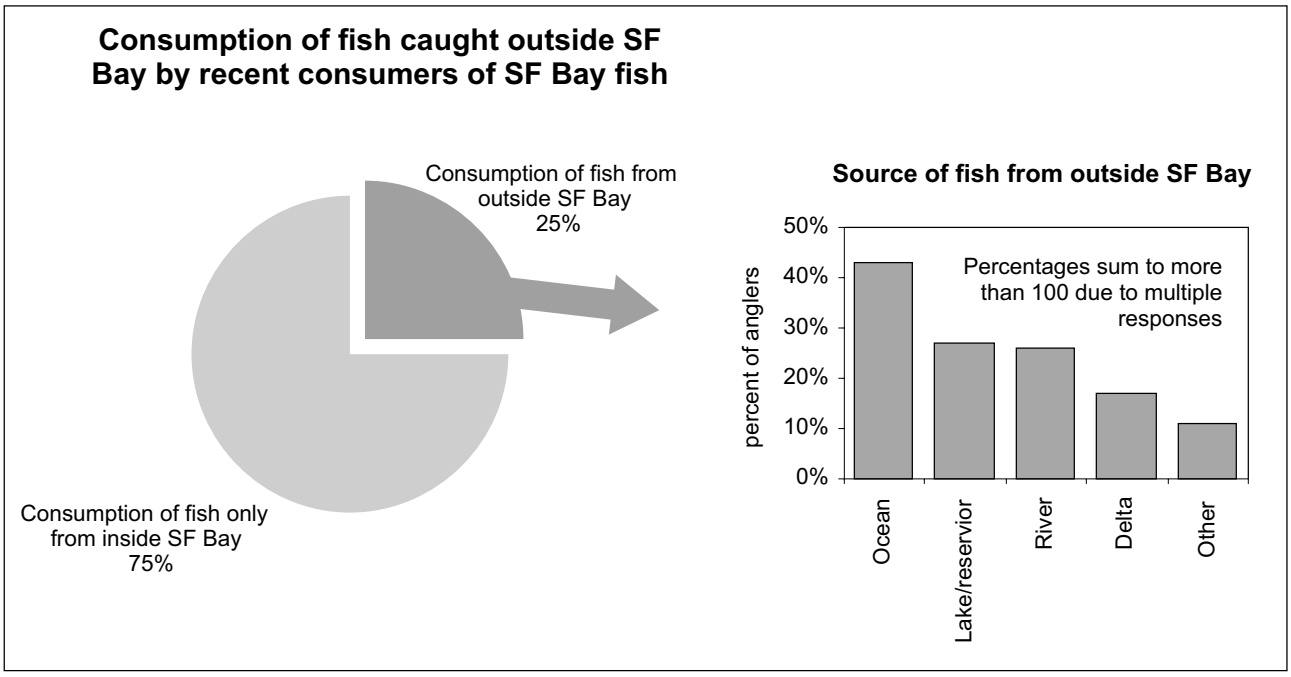


fourth of recent consumers of SF Bay fish also reported eating fish caught from areas outside of SF Bay in the four weeks prior to the interview, with the ocean being the area most often reported. In Figure 38, we show that half of recent consumers reported consumption of fish from a store or restaurant. The proportion of anglers reporting recent consumption from areas outside SF Bay and from commercial sources was very similar for two other groups, respondents and consumers (see Table K44).

In Table 7, we show how consumption rates for recent consumers of SF Bay fish increase when fish from other sources is included. The first column of Table 7 shows consumption rates of SF Bay fish only. The second column of Table 7 shows consumption rates that include all sport fish (fish from SF Bay plus fish from outside SF Bay). Consumption rates shown in the first two columns (SF Bay fish and all sport fish only) are very similar because relatively few recent consumers of SF Bay fish also had consumption of fish from outside SF Bay. The median consumption rates do not change when outside SF Bay fish is added; it remains at 16.0 g/d. The geometric mean value, however, rises slightly from 14.0 g/d to 17.1 g/d (adjusted).

The third column of Table 7 describes consumption rates that include all fish, which is the sum of fish from SF Bay, outside SF Bay, and from commercial sources. The median consumption rate that included all fish is 24.0 g/d (adjusted), equivalent to three eight-ounce meals per month. This amount is 50% higher than consumption rates for SF Bay fish only. The full distribution of consumption rates among respondents, consumers, and recent consumers, both unadjusted and adjusted, is shown in Tables K45a and K45b.

Figure 37



Adjusted for avidity bias.

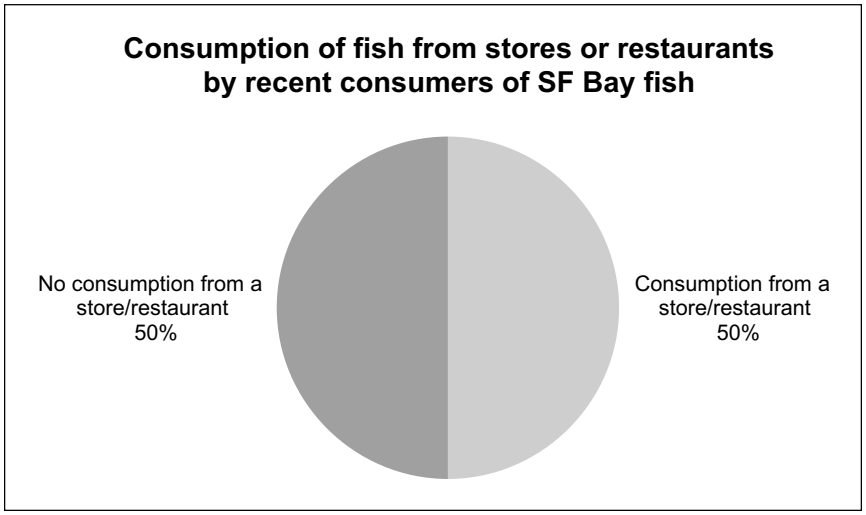
Table 7. Consumption of Fish From Outside SF Bay and Commercial Sources among Recent Consumers of SF Bay Fish (n=465, adjusted)

	Fish From SF Bay Only (g/d)	All Sport Fish (Fish From SF Bay and Outside SF Bay) (g/d)	All Fish (Fish from SF Bay, Outside SF Bay, and Commercial Sources) (g/d)
Mean (Standard Deviation)	23.0 (32.0)	27.9 (35.6)	43.4 (76.0)
Minimum Value	2.0	2.0	2.0
Maximum Value	324.0	324.0	848.0
Geometric Mean	14.0	17.1	26.0
Median (50th Percentile)	16.0	16.0	24.0
90th Percentile	48.0	56.0	80.0
95th Percentile	80.0	96.0	128.0

[a] For 36 recent consumers, there was insufficient information for deriving a consumption rate. For an additional 36 recent consumers, fishing frequently was not reported. Thus, their consumption rate could not be adjusted for avidity bias.

8. Shellfish Consumption

Figure 38



Adjusted for avidity bias.

Interviewers asked respondents about their consumption, in the last four weeks, of three types of shellfish from SF Bay: crabs, clams, and mussels. Consumption rates for shellfish could not be derived because no portion size question on shellfish was included in the survey. Only meal frequency, the number of times shellfish was eaten in the last four weeks, was recorded. In addition, these shellfish consumption data do not characterize the population of shellfish consumers in SF Bay. These data reflect the population of anglers who also had recent consumption of shellfish. Due to resource constraints, persons who were gathering shellfish but were not fishing were not interviewed. For example, many people deploy crab pots from piers in SF Bay. These persons were not interviewed unless they were also fishing at the time they were approached by the interviewer.

Overall, only a small percentage (6%) of consumers of Bay fish also had recent consumption of Bay shellfish. Among shellfish types, anglers reporting recent consumption of crab were far more numerous than those who consumed mussels or clams (see Table K46). The proportion of crab consumers differed among the respondents, consumers, recent consumers, and above advisory consumers. The proportion of crab consumers was twice as high (16%) among above advisory consumers than consumers of SF Bay fish (6%).

In Figure 39 and Table K47 we describe some of the demographic characteristics of consumers of Bay fish who also had recent consumption of crab. By mode, the highest proportion of crab consumers fished on piers. The proportion of crab consumers among Asians (especially Vietnamese) and African American was higher than other ethnic groups. Also, anglers with lower income and education levels were more likely to have consumed crab, and anglers interviewed during the summer or fall were more likely to have consumed crab than those interviewed during the winter or spring.

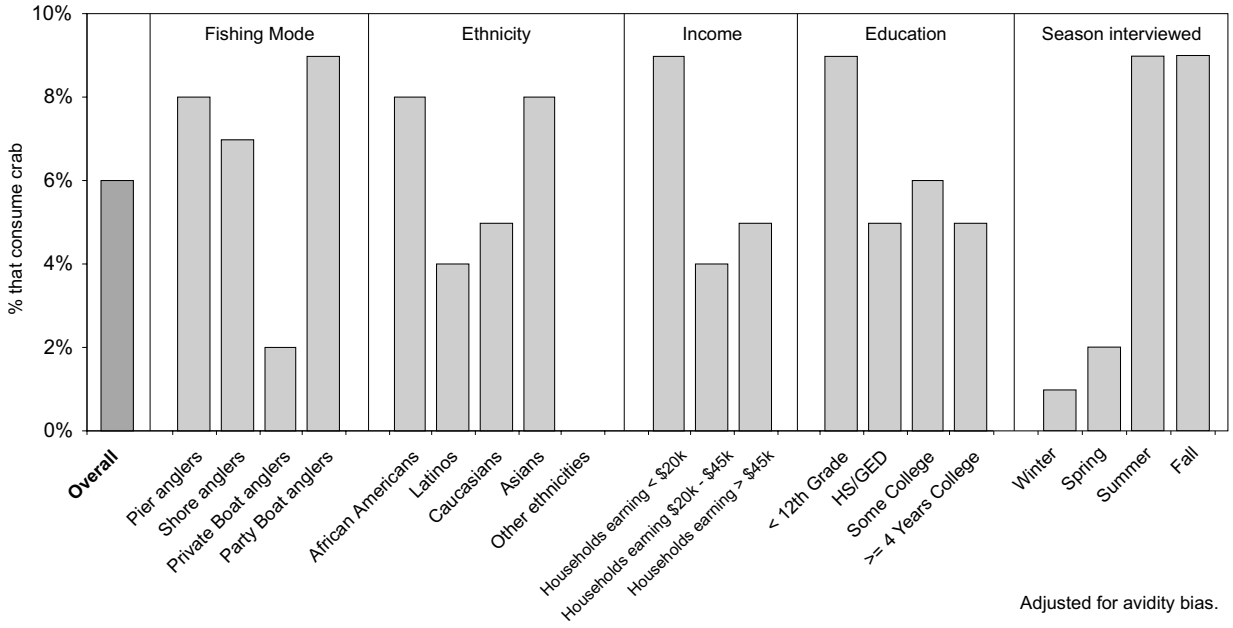
The median (adjusted) meal frequency for crab and all shellfish (sum of crab, clams, and mussels) was one time in the last four weeks for consumers of Bay fish (see Table K48).

E. Health Advisory Questions

In this section, we assess anglers' awareness and comprehension of the health advisory, and determine whether awareness and/or comprehension influenced anglers' fish consumption behavior. We also identify ways anglers preferred to receive health advisory information. Questions concerning the health advisory were not asked of party boat anglers, thus, the findings reflect only responses from shore-based and private boat anglers. Because the health advisory provides guidance that may have influenced an angler's decision to consume fish caught from the San Francisco Bay, we present information in this section for both consumers and non-consumers as noted. (The health advisory for SF Bay can be found in Appendix A.) Values adjusted for avidity bias are presented unless otherwise noted. Tables presenting

Figure 39

Percentage of consumers with recent crab consumption



data (adjusted and unadjusted for avidity bias) for respondents, consumers and non-consumers are provided in Appendix K.

1. Awareness of San Francisco Health Advisory

To determine anglers' awareness and comprehension of the health advisory we asked a two-part question. In the first part, we asked anglers "Have you heard or seen any information or health advisories about eating fish from the Bay?" For those who responded yes, we assessed the angler's comprehension of the advisory by asking them "What did the information say about fish from the Bay?" Verbal responses to the latter portion of the question were written down. These responses were later reviewed and manually coded (see Appendix I for coding categories for text responses). Responses to the first part of the question are reported in this section and responses to the second part are reported in the following section.

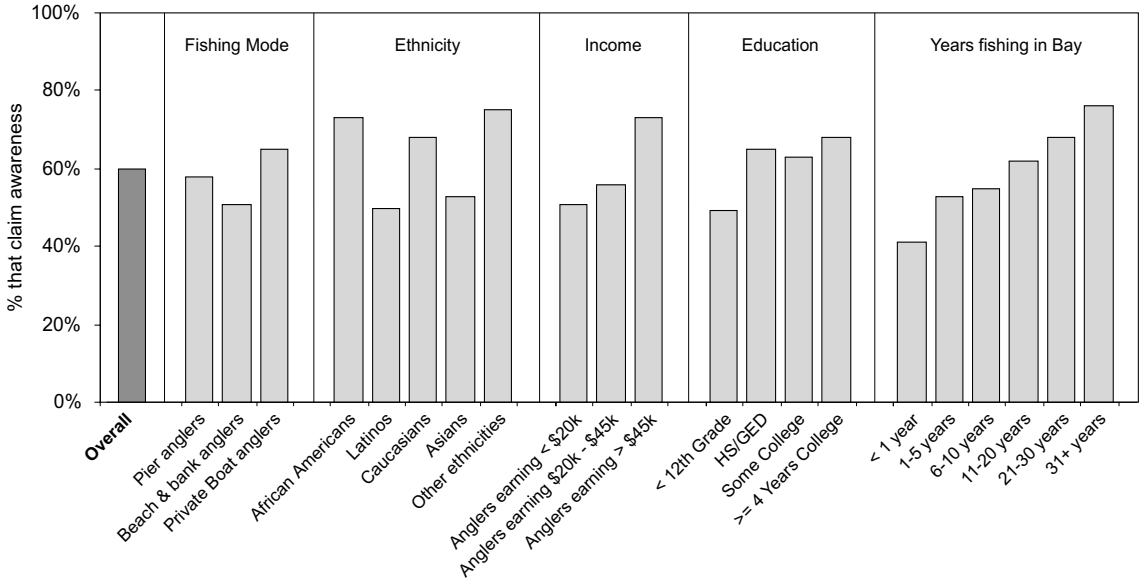
For the first part of the question, as shown in Figure 40, 60% of consumers reported awareness of an advisory. As shown in Table K49, 62% of non-consumers similarly reported awareness of an advisory. We found differences in reported awareness of a health advisory among consumers by demographic characteristics (Figure 40 and Table K49). For example, Latino and Asian consumers were less likely to report an awareness of the health advisory compared to African Americans and Caucasians. The proportion of consumers who were aware of health advisories also increased nearly 50% from the lowest income level (less than $20,000 per year) to the highest income level (greater than $45,000 per year). A similar trend was observed for education level.

The proportion of consumers reporting awareness of the advisory also increased with the length of time they had been fishing in the Bay (see Figure 40 and Table K49). Less than half of the consumers with less than a year's experience fishing in SF Bay reported awareness of the advisory, compared to over three fourths of consumers with 30+ years experience.

Figure 40

Awareness of health advisory by demographic characteristics

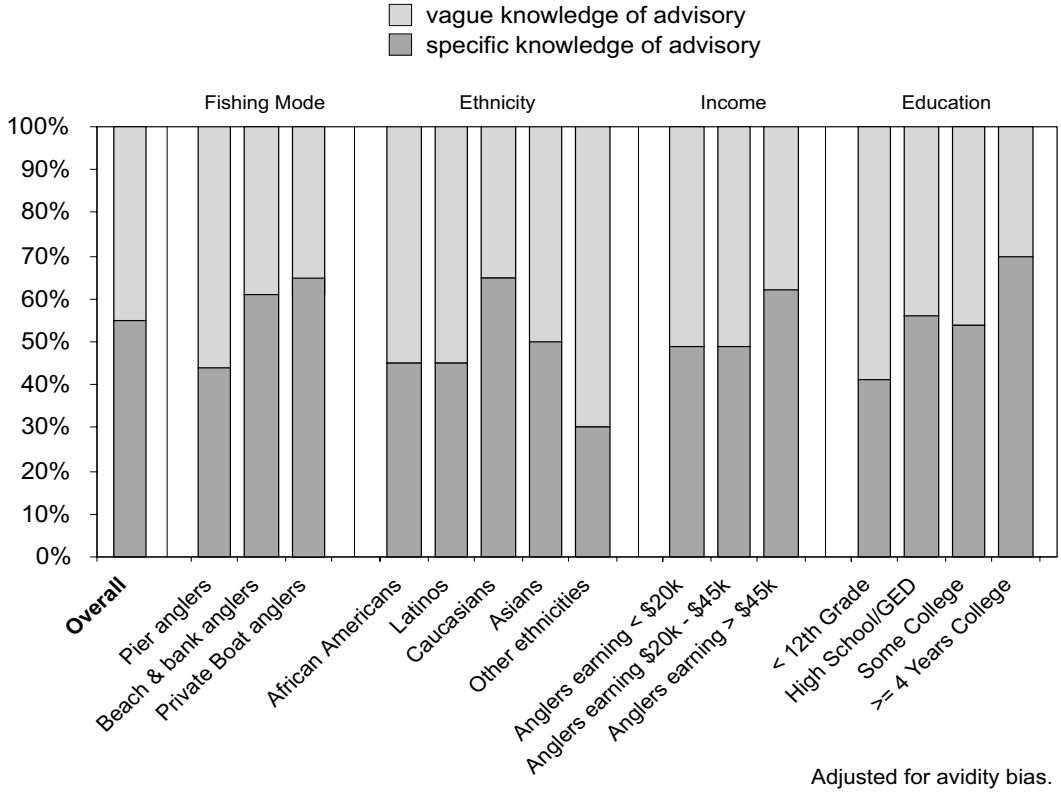
Percentage of consumers claiming awareness of advisory
Anglers reporting no consumption of Bay fish not included



Party boat anglers not asked health advisory questions Adjusted for avidity bias.

Figure 41

Comprehension of health advisory among consumers with awareness of advisory



Adjusted for avidity bias.

2. Comprehension of Health Advisory

We assessed comprehension or understanding of the health advisory only among respondents who indicated an awareness of the advisory (see Figure 41 and Table K50). We categorized their responses in one of two ways: (1) anglers who described a specific health protective measure, such as eating less fish or preparing and cooking fish in safer ways ("specific knowledge"), or (2) anglers who reported a general awareness about fish or water being contaminated ("vague knowledge"). Anglers who described specific health protective measures had better comprehension or understanding of the advisory than anglers who indicated only vague knowledge. Of consumers who reported awareness of an advisory, 55% reported a specific health protective measure.

Similar to our findings regarding awareness in the previous section, we found differences in comprehension by mode, ethnicity, income, and education (see Figure 41). Among consumers, a higher proportion of beach and bank and private boat anglers reported health protective recommendations compared to pier anglers (see Table K50). By ethnicity, a lower proportion of Filipinos, African Americans, and Latinos reported specific health protective measures compared to Caucasian and Chinese consumers (see Table K51). The proportion of consumers reporting specific health protective recommendations also increased with income and education levels (see Tables K52 and K53).

In addition to determining whether anglers understood specific health protective measures, we also looked at whether any anglers recalled the consumption recommendations from the SF Bay advisory to eat no more than two meals per month. We found that only 35 (6%) consumers who were aware of the health advisory reported the two meals per month recommendation. However, it should be noted that interviewers only recorded responses and did not prompt respondents or question their responses.

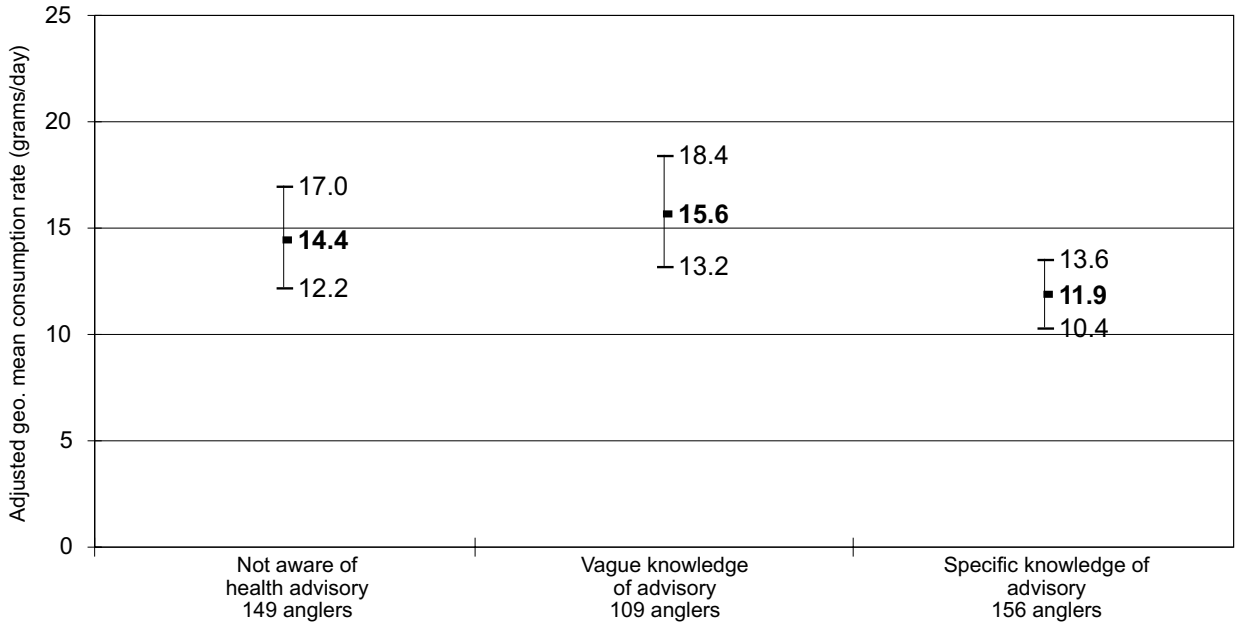
3. Awareness and Comprehension of Advisory and Consumption Rates

We also examined how awareness and comprehension of the health advisory were related to consumption rates among recent consumers (consumers who had consumed Bay fish in the four weeks prior to the interview). Firstly, we compared adjusted consumption rates for three groups of recent consumers: (1) recent consumers who indicated they were not aware of an advisory for the SF Bay, (2) recent consumers who reported awareness that fish or water is contaminated ("vague knowledge"), and (3) recent consumers who reported health protective measures. Although differences between these three groups were not statistically significant, anglers who showed specific knowledge of health protective measures had the lowest consumption rates (see Figure 42). Anglers who reported only vague knowledge had the highest consumption rate. The consumption rate for anglers who reported no awareness of health advisories fell between these two groups.

Secondly, we compared awareness and comprehension of the health advisory between two groups of consumers: (1) those who consumed above advisory levels (see Section IV.D.3.a), and (2) those who consumed below advisory levels (see Figure 43 and Table K54). We found the proportion unaware of the health advisory was similar for anglers consuming above and below the health advisory. However, above advisory consumers had a higher proportion of anglers with vague knowledge and the below advisory consumers had a higher proportion of anglers with specific knowledge. In other words, consumers who consumed above advisory limits demonstrated a poorer understanding of health advisories, and those who consumed below advisory limits showed a better understanding of advisories.

Figure 42

Geometric mean consumption rate of recent consumers* and their awareness of the health advisory



* Party boat anglers were excluded because they were not asked any health advisory questions.
Error bars indicate 95% confidence intervals.
Adjusted for avidity bias.

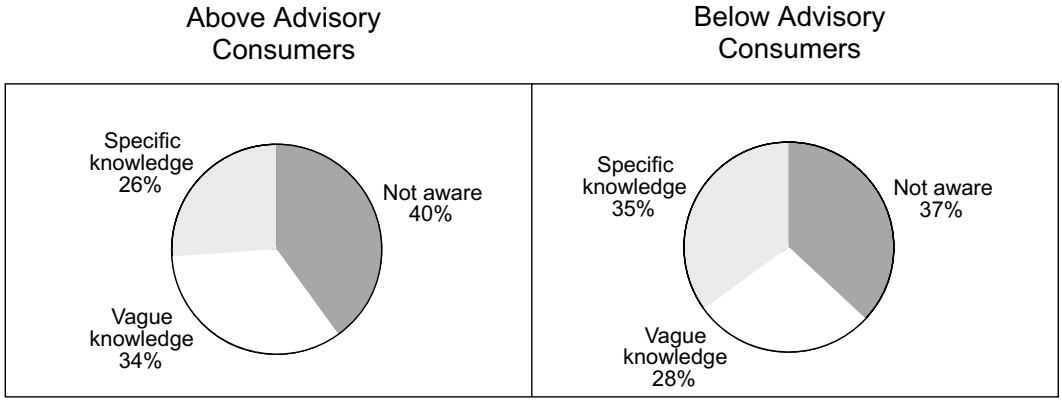
4. Behavioral Changes in Fish Eating Habits

We also assessed changes in fish consumption habits among anglers who reported that they were aware of an advisory. If anglers reported awareness of health advisories, they were asked if the information did or did not cause a change in their fish-eating habits. Next, if anglers reported changing their fish-eating habits, they were asked how they changed their habits. If they reported that they had not changed their fish eating habits, they were asked why not. The anglers' verbal responses were written down and later reviewed and manually coded (see Appendix I for coding categories for text responses). Anglers who adopted a behavioral change reported they either: (1) engaged in protective measures (i.e., prepared and cooked fish using safer methods); (2) stopped eating Bay fish entirely, or (3) ate only uncontaminated fish. Anglers who reported no change in behavior reported they either: (1) already consumed below the limit, (2) believed contamination did not pose a health problem, or (3) did not elaborate on why. (For the group reporting no behavior change, we did not attempt to verify whether their responses to this question matched their responses to other survey questions, for example, whether their consumption rate was actually below the advisory level.)

Of the consumers who indicated awareness of the advisory, 37% said they had changed their consumption habits (Figure 44). Out of this group, 71% reported to have engaged in health protective measures since hearing the advisory, and 16% reported they had stopped eating Bay fish entirely (see Figure 44 and Table K55). Consumers who said they had not changed their habits represented about one-third of all consumers who indicated being aware of a health advisory. Among this group, 60% said

Figure 43

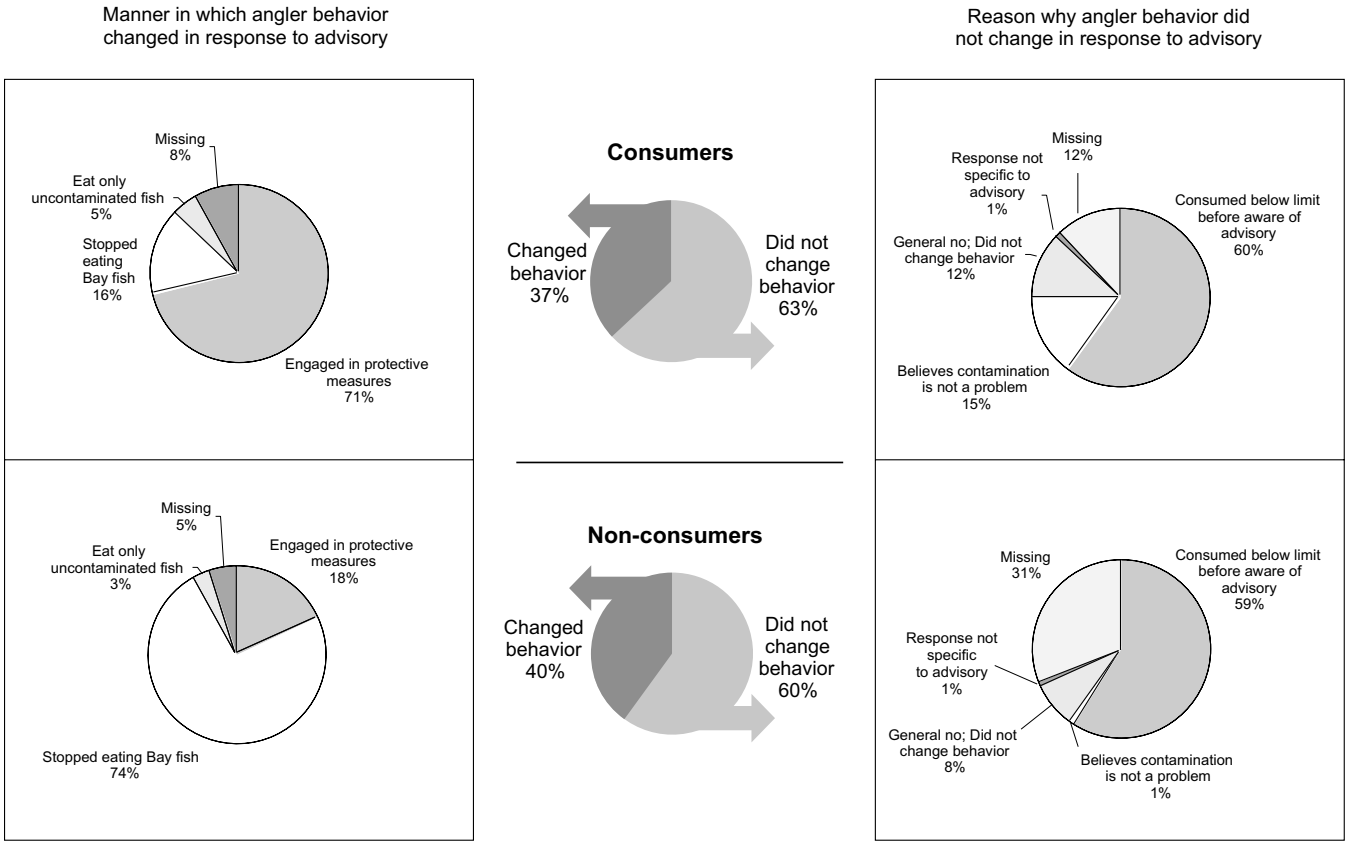
Health advisory awareness of above and below advisory consumers



Party boat anglers not asked health advisory questions. Adjusted for avidity bias.

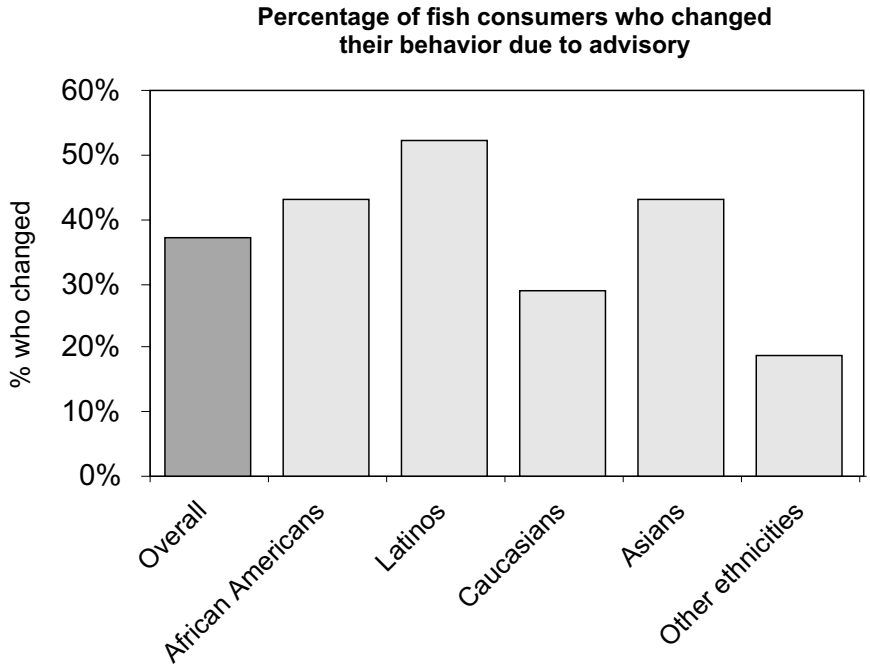
Figure 44

Anglers' behavior changes in response to health advisory



Adjusted for avidity bias.

Figure 45



Party boat anglers not asked health advisory questions.
Adjusted for avidity bias.

they already consumed below the advisory limits (as they understood it) prior to learning of the advisory, and 15% said that fish contamination was not a health problem.

For non-consumers who indicated they had changed their behavior, 74% indicated they stopped eating Bay fish (see Table K55). As expected for non-consumers, when asked why they had not changed their habits upon learning of the advisory, most indicated they already consumed below the limit before they were aware of the advisory.

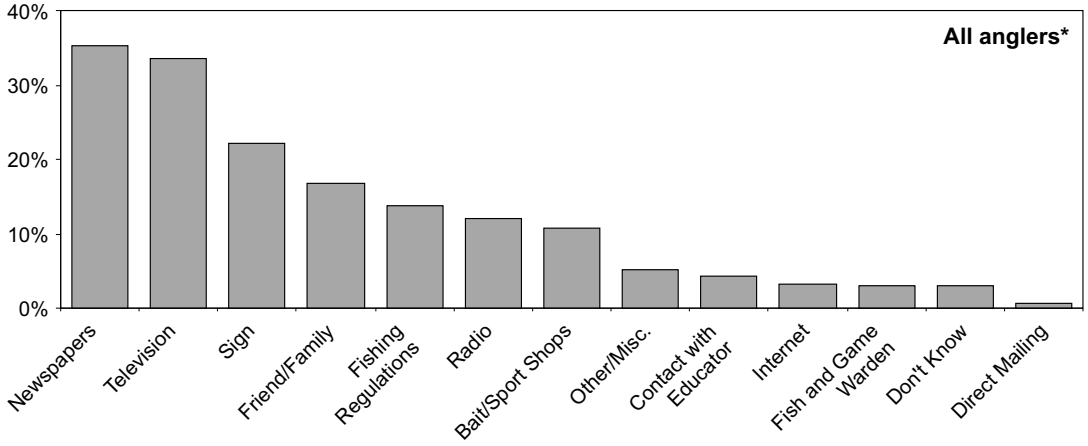
There were only slight differences between those who changed their behavior or not within demographic groups (see Tables K56 and K57). However, a larger proportion of African American, Latino, and Asian consumers reported changes in their fish consumption habits compared to Caucasians (see Figure 45 and Table K56). Responses for non-consumers by demographic characteristics are shown in Table K57.

5. How Anglers Prefer to Receive Information about Fish

One of the study objectives was to identify ways anglers preferred to receive information about health advisories. All respondents were asked: "What is the best way for you to get information about catching and eating fish from the Bay?" Figure 46 and Table K58 show that among respondents the three most frequently mentioned responses were newspapers, television, and signs. Private boat anglers preferred newspapers, but shore-based anglers mentioned television and newspapers, about equally. Among the different ethnic groups, Caucasians were the only group to prefer newspapers to television. Responses for consumers were similar (see Table K59).

Figure 46

Preferred methods for receiving fishing information
Percentage of anglers indicating each method



*except party boat anglers, who were not asked health advisory questions. Not adjusted for avidity bias.

6. Discussion Groups

We also conducted four discussion groups with anglers. The purpose of the discussion groups was to further our understanding of anglers' awareness of the health advisory and to explore ways to reach anglers with health information. After reviewing preliminary study results, the project staff identified three groups of shore-based anglers and one group of boat anglers to invite to participate in discussion groups. The shore-based angler groups were: (1) Filipino anglers (the largest group of Asian anglers), 2) anglers who were unaware of the advisory, and (3) anglers who were aware of the advisory but had not changed their consumption habits.

Although we carried out extensive efforts to contact and recruit eligible participants for these discussion groups, only 17 of the 217 anglers we contacted actually participated. Due to the small number of anglers who participated in the discussion groups, generalizations about the findings to the overall fishing population cannot be made. However, those participating in the groups raised pertinent concerns and questions regarding advisory messages and educational strategies that merit further consideration. For example, during discussion over terms used in the health advisory, participants indicated that they did not interpret the term "sport fish" to mean the fish they caught from the SF Bay. Additionally participants indicated preferences for graphics and wording to be used for health advisory recommendations and signs, such as specifying pounds and number of fish meals, rather than grams or ounces, that can be safely consumed. Appendix L contains a more detailed description of the efforts to organize and conduct the discussion groups and content of the discussion groups.

V. Discussion and Conclusions

Our study design, field survey methods and procedures, and data analyses and presentation contained in this report provide documentation that the study goals and objectives have been achieved. We have gathered quantitative data on anglers fishing in SF Bay. This information can be used to characterize anglers' exposure to chemical contaminants. Although we found that the majority of SF Bay anglers consume below health advisory limits, we found that some anglers are highly exposed, and we described

these highly exposed populations in several ways. Finally, we gathered information that can be used to develop educational messages to target specific groups of SF Bay anglers.

In order to gain a better understanding of the results of this study, we compared our findings to results from similar studies where valid comparisons could be made. In particular, we made most of our comparisons to the Santa Monica Bay study (Allen *et al.* 1996, SCCWRP/MBC 1994) and Save San Francisco Bay Association's Save the Bay study (Wong *et al.* 1997). Overall, our findings and methodology were consistent with these studies, who likewise were based on angler interviews at fishing locations. We compared our findings on consumption practices to two community-based studies, one conducted by the Asian Pacific Environmental Network (Chiang 1998) and the other by Sechena *et al.* (1999). These studies drew participants from specific Asian ethnic groups who were recruited through community-based organizations, although participants were not necessarily anglers. We also compared health advisory responses to an angler survey conducted at a single location by the Office of Environmental Health Hazard Assessment (Russell *et al.* 1997). A survey of pier anglers in SF Bay by Communities for a Better Environment (Karras 1998) could not be compared because adequate documentation on this study's methodology was not available.

In addition to comparing our results with other studies, we also describe some of the limitations of how these results should be interpreted. Despite our efforts, we were not able to address all possible sources of bias in this study. These limitations are discussed further at the end of this section.

A. Sampling Success and Angler Characteristics

Overall, we achieved a higher response rate when compared to the Santa Monica Bay and Save the Bay studies (see Table 8). Because Save the Bay's study included only pier anglers, we compared their response rate to pier anglers from our study. Although, in both studies the proportion of decliners, due to language barriers among total interview attempts was similar, we still found a lower rate of decliners among pier anglers in this study.

Table 8. Comparison of Decliners among San Francisco Bay Seafood Consumption Study, Santa Monica Bay Study, and Save the Bay Study

	SF Bay Seafood Consumption Study (unadjusted)		Santa Monica Bay Study (Allen *et al.* 1996, SCCWRP/MBC 1994)	Save the Bay Study (Wong *et al.* 1997)
	All Fishing Modes	Pier Only	All Fishing Modes	Pier Only
Total Attempts	1738[a]	983 [a]	1740	379[a]
Total Decliners	407 (23%)	288 (29%)	496 (29%)	145 (38%)[b]
Decliners due to language barrier	144 (8%)	125 (13%)	---[c]	53 (14%)

[a] based on net attempts, anglers interviewed before were excluded
[b] incomplete interviews excluded from declines but included in total attempts
[c] not recorded

We also compared the ethnic composition of respondents from this study with the Santa Monica Bay and Save the Bay studies in Table 9. This study and the Santa Monica Bay study found that Caucasians comprised the largest group of respondents. However, after Caucasians, Asians were the largest group in this study, while Latinos were the largest group in the Santa Monica Bay Study, which reflects the ethnic differences of anglers in the two regions.

Our finding of a high proportion of non-Caucasians among pier anglers in our study population was very similar to Save the Bay's results. Both studies found that Asians were the dominant group

Table 9. Comparison of Ethnic Groups among Respondents for San Francisco Bay Seafood Consumption Study, Santa Monica Bay Study, and Save the Bay Study

Ethnic Group	SF Bay Seafood Consumption Study (unadjusted)		Santa Monica Bay Study (Allen *et al*. 1996, SCCWRP/MBC 1994)	Save the Bay Study (Wong *et al.* 1997)
	Respondents (%)	Pier Only (%)	Respondents (%)	Pier Only (%)
Number of respondents	n=1331	n=695	n=1243	n=228
African American	9	11	10	12
Latino	13	16	25	14
Caucasian	40	25	43	24
Asian (includes Pacific Islander)	33	43	18	40
Other	2	3	2[a]	9
Missing	3	2	2	3
Asian Subgroups				
Chinese	6	7	2	9
Filipino	13	18	6	16
Vietnamese	7	9	1	5
Pacific Islander	2	2	[b]	4
Other Asian	5	7	9[c]	7

[a]includes Middle Easterners, Samoans, and Cambodians
[b]Pacific Islanders were included under the "Other" category
[c]includes Japanese and Koreans

fishing from piers in SF Bay, with Caucasians representing only about one-fourth of respondents. Filipinos were the largest Asian subgroup in both studies.

B. Fish Consumption Rates

Comparisons of consumption rates between studies are inherently difficult to make. Study methodologies are rarely identical and differences in methods can greatly affect the results. Consumption rates from different studies cannot be compared without a clear understanding of how the rates were derived. Most importantly, it is essential when comparing consumption rates to describe both the population to which the consumption rates applies, and the recall period over which the estimate was made.

1. Consumption Rates Among Recent Consumers

Table 10 summarizes consumption rates from this study, the Santa Monica Bay study (ATES/OEHHA 2000, Allen *et al.* 1996, SCCWRP/MBC 1994), and the Save the Bay study (Wong *et al.* 1997). The consumption rates for recent consumers (based on a four week recall) reported in this study were lower than consumption rates reported in the comparison studies, although these differences can probably be explained by differences in methodology.

The unadjusted geometric mean consumption rate from the Santa Monica Bay study is about 50% higher than the rate derived in this study, and this difference is statistically significant. Although consumption rates in both studies were derived from recent consumers based on a four-week recall, there were important differences in the way the studies calculated consumption rate that can explain the differences in their results. In the Santa Monica Bay study, when calculating the fish consumption rate of a consumer within the last four weeks, fish that an angler had caught—but not yet eaten—was observed by the interviewer and included in the fish consumption rate data. Interviewers attempted to identify

Table 10. Comparison of Consumption Rates (g/d) for San Francisco Bay Seafood Consumption Study, Santa Monica Bay Study, and Save the Bay Study

	SF Bay Seafood Consumption Study (unadjusted)	Santa Monica Bay Study (Allen *et al.* 1996, SCCWRP/MBC 1994) (Unadjusted)	SF Bay Seafood Consumption Study (adjusted)	Santa Monica Bay Study (adjusted) (ATES/OEHHA 2000)	Save the Bay (Wong *et al.* 1997)
Respondents	n=1331	n=1244	n=1152	[b]	n=222
Population used to derive consumption rate (% of respondents)	n=501 (38%)	n=555 (45%)	n=465[c] (40%)	[b]	n=62 (27%)
	Consumed fish in last 4 weeks	Consumed fish in last 4 weeks	Consumed fish in last 4 weeks	Consumed fish in last 4 weeks	Consumed fish in last 7 days
Mean (Standard Deviation)	28.0 (39.5)	49.6 (111.1)	23.0 (32.1)	30.5 (45.)	[b]
Geometric Mean	16.5	23.6 [a]	14.0	[b]	[b]
Median (50th Percentile)	16.0	21.4	16.0	15.0	32
Upper 95% Confidence Limit of the Geometric Mean	18.0	25.8 [a]	[b]	[b]	[b]
Lower 95% Confidence Limit of the Geometric Mean	15.2	21.5 [a]	[b]	[b]	[b]

[a] Derived from Hill and Lee (1995b).
[b] Not reported
[c] For 36 anglers there was insufficient information for deriving a consumption rate. For an additional 36 anglers, fishing frequency was not reported, thus their consumption rate could not be adjusted for avidity bias.

and record all fish that the angler had caught at the time of the interview. For example, if the interviewer observed white croaker in the angler's bucket, the number of times the angler ate fish in the last four weeks was increased by one to account for future consumption of the white croaker. In this study, only fish that had already been consumed (in the past four weeks) was included. Fish that the angler caught on the day of the interview that had not yet been consumed when the interview took place was not included in any consumption rate calculation. This additional factor may explain why Santa Monica Bay estimates were higher than SF Bay estimates.

Furthermore, other differences between the two studies may have contributed to differences in the results, for example, the way sampling effort was allocated across modes in the two studies and the use of different portion size models. In this study, sampling effort was based on the relative amount of fishing activity in each mode (see Section II.B.3 for further discussion). In the Santa Monica Bay study, sampling effort was not explicitly allocated by fishing activity. How this difference would affect consumption rates is not known, because the relative amount of fishing activity by mode in the Santa Monica Bay study was never estimated. The Santa Monica Bay study also used a 150 gram (5.3 ounce) portion model while this study used an 8 ounce (227 gram) portion model. The model size appeared to influence the

responses in both studies. (This will be discussed further below.) Whether the different model sizes would widen or narrow the consumption rate difference between the two studies is not known.

It is likely that other factors unrelated to methodology contributed to the different findings of the two studies. These factors include (1) avidity differences due to climate which could result in anglers in Southern California spending more time fishing than the average angler in SF Bay (as discussed in Section III.D.1, avidity is generally correlated with consumption), (2) differences in how productive the two fisheries are, (3) the different years the studies were conducted, and (4) differences in demographic characteristics of anglers in the two populations.

Staff from the Air Toxics Epidemiology Section within OEHHA adjusted the data from the Santa Monica Bay study for avidity bias (ATES/OEHHA 2000) using methods similar to ours. This adjustment lowered their results significantly so that they are closer to the adjusted data from this study than comparisons of the unadjusted data. For example, the adjusted median is very similar to the one derived from this study.

We also compared the results of this study with Save the Bay's study of pier anglers in SF Bay (Wong *et al.*1997). Save the Bay found a median consumption rate of 32 g/d, which was two times the median consumption rate of 16.0 g/d found in this study (see Table 11). However, the target population and recall period used in the Save the Bay study differed from this study. This may explain the difference in results. Save the Bay derived a consumption rate from the subset of anglers who had reported consuming fish in the last seven days. In this study, a seven-day recall was never used. The primary consumption rate was derived from anglers who had reported consuming fish in the last four weeks. Anglers who consumed fish in the past seven days represent an even smaller subset of all anglers than those who consumed fish in the last four weeks. This smaller subset selectively includes anglers with the highest consumption rates. Thus, these two groups cannot be directly compared. In fact, the group that was used to derive a consumption rate in the Save the Bay study represented 27% of respondents. In this study, the group (recent consumers) used to derive a consumption rate represented 38% of respondents.

Other factors could also have contributed to the different results. Save the Bay used a 150 g (5.3 ounce) portion size model while this study used an 8-ounce (227 g) model. As noted earlier, while the model size is likely to influence consumption rate estimates, the direction and magnitude of this influence is not known. Save the Bay also conducted interviews only during the fall, while interviews in this study were conducted over a full year. We found that consumption rates of anglers in the fall were higher compared to other seasons, although differences among seasons were not statistically significant (see Tables K35 and K36). Finally, the two studies were conducted several years apart. Many factors during the years between the two studies could have influenced the consumption patterns of the population that fishes in the Bay. These factors include (1) changes in the fishery or variability in fish abundance over time (in fact, an El Niño occurred in 1998), (2) better knowledge of fish contamination issues among anglers (e.g., SFEI released a report on contaminants in fish in 1998 that was widely covered by the press), and (3) changes in the fishing population due to immigration, since many anglers report having fished in the Bay for a relatively short amount of time (See Table K20).

2. Consumption Rates Among Consumers

Although one of the study goals was to gather information for characterizing exposures to the population that consumes Bay fish, comparisons of consumption rates based on all consumers could not be made. Neither of the comparison studies reported consumption rates based on the whole population of consumers, rather than a subset comprised of recent consumers. Both studies only reported consumption rates for a subset of consumers (recent consumers based on a four-week or seven-day recall).

3. Per Angler Consumption Rates

We compared the per-angler consumption rate based on a 12-month recall in this study (see Table K31) to a consumption rate derived by the USEPA (1997) for marine recreational anglers. Both studies reported low consumption rates. USEPA estimated an average consumption rate of 2.0 g/d of marine fish for Northern California recreational anglers. This value is higher than both the geometric mean value of 0.4 g/d and median of 1.8 g/d reported in this study for respondents based on a 12-month recall. It should be noted, however, that the methodologies used in these two studies were very different. The USEPA value was derived using estimates of recreational catch from the National Marine Fisheries Service's Marine Recreational Fisheries Statistics Survey (NOAA/PSMFC 1997) and assumptions about the fraction of the catch that was consumed and the number of anglers who consumed the catch. In addition, the two consumption rates represent different types of fish; the USEPA estimate includes all marine fish and this study includes only SF Bay fish. Also, the USEPA value was adjusted for avidity bias while the value in this study (based on a 12-month recall) was not.

4. Influence of the Portion Size Model

This study used an eight-ounce portion size model to help respondents describe the amount of fish they consume at one time. Multiplying portion size by meal frequency, we derived a consumption rate. Most respondents reported that they ate an amount equal to the model, and many respondents reported that they ate an amount equal to a fraction (e.g., one half of the model) or multiple (e.g., two times) of the model. As a result, the consumption rate distribution did not follow a smooth and continuous shape, but was peaked around multiples of the model (see Figure 22). These results appear to confirm that the model influences consumption rate responses and introduce a degree of bias in the results.

Portion size responses were not reported in the comparison studies so they could not be compared to results from this study. Although not explicitly discussed in either study, the portion size model appears to have influenced results in both the Santa Monica Bay and Save the Bay studies. In the Santa Monica Bay study, the consumption of an amount of fish equal to their model of 150 grams over the 28-day recall period is equal to a consumption rate of 5.36 g/d. Their median consumption rate of 21 g/d was equal to four times the model. Other consumption rate results they report are multiples of their model. For example, consumption rates for individual species are typically 11 g/d (two times the model), 16 g/d (three times the model), etc. A similar pattern can be found in the Save the Bay study.

5. Avidity Bias Adjustment

One of our study findings (discussed in Section IV.D.1) was that the adjustment for avidity bias resulted in only a slight change in the results. For consumption rates of recent consumers, the geometric mean, 16.5 g/d, dropped to 14.0 g/d (adjusted) with the avidity bias adjustment, although the median value did not change. This difference is much smaller than has been observed in other studies such as Price *et al.* (1994). The small effect of an avidity bias adjustment in this study can be explained by the weak correlation between consumption rate and angler avidity ($r = 0.23$). This weak correlation might result from two related factors. Firstly, we limited this consumption rate calculation to only recent consumption (the last four weeks). If a longer recall period was used, the consumption rate responses would likely show greater variation. Secondly, we also limited the angler avidity (fishing frequency) response to the same relatively narrow time range (number of times fishing in the last four weeks). The minimum fishing frequency that could be recorded in our study was one-time fishing in the last four weeks (including the trip during which the interview occurred) and the maximum number of times was 28 (one time per day). The range from one to 28 times in the last four weeks is relatively narrow compared to a longer time

period such as one year. With a longer time period we would expect a wider range of consumption rates and fishing frequencies, a much stronger correlation between these variables, and a much stronger avidity bias effect. In fact, studies finding a strong avidity bias effect, such as Price *et al.* (1994), used a one-year recall to estimate consumption rate and fishing frequency.

C. Consumption Rate Differences Among Ethnic Groups

One important finding of this study was that we were able to show consumption rate differences between ethnic subgroups. In general, we did not find significant differences for other demographic characteristics. Although the planning of this study focussed on obtaining a sample of anglers that reflected the population by mode, ethnic differences appear to be far more important in influencing consumption rates among SF Bay anglers than mode.

Among the comparison studies, only the Santa Monica Bay study described consumption rates by ethnic groups, although the statistical significance of differences between these groups was not described. Table 11 compares geometric mean and median consumption rates for major ethnic groups from this study and the Santa Monica Bay study. Overall, there were only a few similarities between the two studies. For example, both studies found that African Americans had higher rates than other groups, although these differences were not large. In the SF Bay study, we found that Caucasians had the lowest geometric mean consumption rates of all groups and the Santa Monica Bay study found Latinos had lower rates than other groups. Geometric mean consumption rates for Asian subgroups were not available for the Santa Monica Bay study. Based on arithmetic means, the Santa Monica Bay study found Pacific Islanders to have consumption rates considerably higher than other groups, similar to findings from this study. However, these results were based on very small samples in both studies.

Table 11. Comparison of Geometric Mean Consumption Rates (g/d) by Ethnicity (unadjusted) for San Francisco Bay Seafood Consumption Study and Santa Monica Bay Study

Ethnic Groups	SF Bay Seafood Consumption Study (g/d)		Santa Monica Bay Study (g/d)[a]	
	Geometric Mean	Median	Geometric Mean	Median
African American	19.4	16	26.8	24
Latino	16.6	16	17.9	16
Caucasian	14.4	16	26.3	21
Asian	17.8	16	26.1	21

[a] Derived from Hill and Lee 1995a.

Other angler studies have also reported consumption rate differences among ethnic groups (Burger *et al.* 1999, Shatenstein *et al.* 1999, Shubat *et al.* 1996, West *et al.* 1992 and 1989). However, direct comparisons to this study could not be made due to differences in sampling and data analysis methods.

As discussed in Section II.B., this study was designed to obtain a highly representative sample of the population fishing in SF Bay. The study design best suited for obtaining a representative sample, however, is not the optimum study design for making comparisons between subgroups. In the absence of specific subgroup variance information, the optimal design for testing subgroup differences would have deliberately sampled equal numbers of persons in each subgroup to be compared (Levy and Lemeshow 1999). Nevertheless, we were able to show some statistically significant differences between subgroups.

In order to help assess whether consumption rate differences between subgroups could be replicated in other studies, we also considered the statistical power of these subgroup comparisons. We found that

the standard deviation of the log consumption rate for most demographic subgroups was about 1.0. This value can be useful in planning future studies, or for calculating the sample size needed to detect specific differences in consumption rate (Armitage and Berry 1987). In Table 12, we show the sample sizes needed to detect differences in consumption rates using a standard deviation of the log consumption rate of 1.0. We assumed 80% power to detect a statistically significant difference (a=0.05, two-sided) between a consumption rate of 16 g/d (the overall study unadjusted geometric mean) and alternatives 100% to 33% higher. Groups of 30 to 60 were sufficient to detect 1.5 to 2-fold increases in consumption rate with 80% power. Thus, the statistical power was adequate in many of the subgroups we compared to detect 1.5 to 2-fold differences in consumption rates had they been observed.

Table 12. Minimum Sample Sizes Needed for Detecting Consumption Rate Differences Between Two Groups of San Francisco Bay Anglers

Difference to be Detected	Minimum Sample Size per Group
16 g/d vs. 32 g/d	33
16 g/d vs. 24 g/d	60
16 g/d vs. 21 g/d	212

D. Interpretation of Above Advisory Consumers

Our conclusion that about one in ten consumers of SF Bay fish exceeded the health advisory limit should be considered approximate, as a precise determination of above advisory consumers was not possible. Several factors highlight the lack of precision in the above-advisory estimate. In general, these factors indicate that we may have underestimated the number of above-advisory consumers.

Firstly, the definition of an above-advisory consumer is very sensitive to how the consumption recall period is defined. The health advisory recommends that anglers limit their consumption of Bay fish to no more than two meals per month. If we assume that a month has 30 days, and each meal is equivalent to 8 ounces, the health advisory limit is equal to 15 g/d. However, this study used a 28-day recall period, to be comparable with the Santa Monica Bay study, not one month. Two 8-ounce meals per 28 days are equal to 16 g/d. Although a one-gram difference, between 15 g/d and 16 g/d, appears to be insignificant, it is not. Many SF Bay anglers reported consuming 16 ounces in the last four weeks. This amount is equal to 16 g/d, and thus these anglers are right at the health advisory limit. This lack of precision is also compounded by the use of a portion size model (see Section V.B.4). We define anglers as exceeding the health advisory limit if they consume greater than 16 g/d. If the 15 g/d day level were used to identify above-advisory consumers, the proportion of consumers exceeding the advisory would nearly double, from 9% to 16% (adjusted).

Secondly, the health advisory recommends using body weight to determine a person's meal or portion size. The 8-ounce portion size is based on an angler with a body weight of 154 pounds (70 kilograms). For anglers who weigh more or less than this amount, the portion size should be adjusted up or down. We did not attempt to ascertain body weights of the anglers we interviewed, so we do not know if the reported portion sizes are proportional to the anglers' body weights.

Thirdly, the health advisory recommends no consumption of large striped bass (greater than 35 inches). Although over three-fourths of consumers of Bay fish reported that they consume striped bass, no effort was made to determine if this advice for striped bass was being followed. Thus, we do not know whether this size restriction for striped bass is significant or not in determining who is above the health advisory.

Finally, the health advisory recommends more restrictive limits for women who are pregnant or breastfeeding, planning to become pregnant, and for young children. For these groups the health advi-

sory recommends that consumption of Bay fish be limited to no more than one meal per month. In this study, we did not interview any children and we did not determine whether the women we interviewed were pregnant, breastfeeding, or planning to become pregnant. If consumption rates for these groups of women are similar to the women we did interview, a higher proportion will exceed the more restrictive advisory.

E. Consumption Patterns

In addition to recommending limits on the amount and types of Bay fish that can be eaten, health advisories for SF Bay recommend that anglers consume only the skinned fillet and that the fish be cooked so that the juices drain away and are discarded (see Appendix A). These practices can reduce one's exposure to the contaminants in fish. We have shown that these practices are not always followed, particularly among Asians. This finding is generally consistent with other studies.

Similar to the findings in this study, Save the Bay found consumption of skin of two species—striped bass and white croaker—to be common among pier anglers in SF Bay (Wong *et al.* 1997). They found that 49% of consumers of striped bass ate the skin and 36% of white croaker consumers ate the skin in the previous 30 days. They did not report skin consumption by ethnic group, however. In this study, among pier anglers, we found that consumers of striped bass and white croaker ate skin 40% and 52% (unadjusted) of the time respectively. However, these rates were slightly higher, 49% and 56% (unadjusted), respectively, for Asians who consumed these species.

The Santa Monica Bay study did not report whether skin was eaten. However, a higher proportion of Asians in that study did report eating fish whole/gutted, compared to other ethnic groups.

APEN's community-based study of Laotians in West Contra Costa County, which borders SF Bay, found that among respondents who had ever eaten Bay fish, 76% eat the skin of the fish and 86% eat fish in soup or stews. We interviewed only a very small number of Laotians (<1% of respondents). APEN's findings are higher than the rates we reported for all Asians. This may be due to the fact that APEN asked respondents about consumption patterns for all fish, not by specific species. The higher rates in APEN's study could also be due to Laotians consuming skin and soup more frequently than other Asians groups. Sechena's (1999) community-based study of Asians and Pacific Islanders in King County, Washington, found that 55% of their respondents ate skin of fish; however, the primary source of fish in this study was the grocery store.

F. Consumption of Fish From Other Sources

Few studies of fishing populations have looked at total sport fish and commercial fish consumption. We are aware of no such studies for California populations. Using data collected by West *et al.* (1989), Murray and Burmaster (1994) estimated consumption rates of sport fish and total fish (including both sport and commercial sources) for Michigan anglers. West *et al.* collected the data over a six-month period through a mail survey sent to a sample of licensed Michigan angler. The consumption rate recall period was seven days and the data were not adjusted for avidity bias. Although there were many methodological differences between the Michigan study and our study, we compared the results in Table 13.

The Michigan study showed higher consumption rates for both sport fish and total fish. This may be explained in part by the shorter recall period (seven days) used in the Michigan study compared to our study that used a four week recall. Both studies showed that anglers augment their intake of sport fish with fish from commercial sources.

Table 13. Comparison of Sport Fish and Total Fish Consumption Rates (g/d, unadjusted) Between San Francisco Bay Recent Consumers and Michigan Anglers

	SF Bay Seafood Consumption Study (unadjusted)		Michigan Anglers (Murray and Burmaster 1994)	
	Sport Fish[a] n=501	Total Fish[b] n=501	Sport Fish n=191	Total Fish[b] n=191
Arithmetic Mean (Standard Deviation)	33.0 (42.8)	46.5 (62.5)	45.0 (23.7)	55.1 (33.1)
Median	16.0	32.0	32.7	40.8
95th Percentile	112.0	324.0	98.0	114.3

[a] Sport fish includes fish from SF Bay and other areas (see Table K45a).
[b] Total Fish includes sport fish and commercial fish.

G. Health Advisory

We compared our findings on angler's awareness of health advisories to findings from other angler studies that included the Save the Bay and Santa Monica Bay studies (see Table 14). The comparison studies also included an angler survey at Berkeley Pier in SF Bay by the Office of Environmental Health Hazard Assessment (Russel *et al.* 1997) that focused on angler awareness of advisories on posted signs. Awareness to health advisories among the subset of anglers who consume Bay fish (consumers) could not be derived for the comparison studies so only awareness among all survey respondents is compared. Because some of these studies only included pier anglers, we also compared pier anglers from this study to the other studies. We found awareness to health advisories in this study to be very similar to the two other angler studies from SF Bay.

Table 14. Comparison of Awareness to Health Advisories among Respondents of the San Francisco Bay Seafood Consumption Study, Save the Bay Study and OEHHA Study

	SF Bay Seafood Consumption Study (unadjusted)	SF Bay Seafood Consumption Study (unadjusted)	Save the Bay (Wong *et al.* 1997)	OEHHA (Russell *et al.* 1995)	Santa Monica Bay (Allen *et al.* 1996, SCCWRP/MBC 1994)
Population	Shore-based and Private Boat Anglers	Pier Anglers	Pier Anglers	Anglers at Berkeley Pier	All Respondents (Shore-based Anglers and Party and Private Boat Anglers)
No. of Survey Respondents	n=1227[a]	N=695[a]	n=212[b]	n=520	n=1244
No. Aware of Health Advisory	722	392	124	278	942
%	59%	56%	58%	53%	76%

[a] missing, don't know, and declined to answer responses are not included in total
[b] responses for 16 anglers appear to be missing and are excluded from the total; inclusion of these anglers would lower the rate slightly

Awareness of health advisories among respondents in the Santa Monica Bay study was higher overall than among SF Bay anglers. This difference could be due to health advisory awareness actually being higher in the Los Angeles area. It could also be due in part to a higher proportion of boat anglers—57% compared to 35% in this study (excluding party boat anglers). Although not reported in the Santa Monica Bay study, this study found that boat anglers are more likely to be aware of health advisories than anglers at shore-based modes.

None of the comparison studies attempted to assess angler's knowledge or understanding of health advisories so comparisons with this study could not be made, although OEHHA assessed respondent's knowledge of posted signs.

We also compared findings on what anglers thought was the best way for them to get information on health advisories (see Table 15). The results from this study and the Save the Bay study were similar, with anglers reporting television and newspapers most often. In the OEHHA study, anglers reported the posting of signs more often than other methods. This may have been due to the recently posted signs at Berkeley Pier for the previously issued striped bass advisory when OEHHA administered their survey in 1995. In addition, because the main goal of the OEHHA study was to determine the effectiveness of signs, anglers were asked many questions specifically about signs, which may have influenced their responses relative to the other studies.

Table 15. Comparison of Sources of Health Advisories Information among Respondents of San Francisco Bay Seafood Consumption Study, Save the Bay Study, and OEHHA Study

	SF Bay Seafood Consumption Study (unadjusted)	SF Bay Seafood Consumption Study (unadjusted)	Save the Bay (Wong *et al.* 1997)	OEHHA (Russell *et al.* 1997)
Population	Shore-based and Private Boat Anglers	Pier Anglers	Pier Anglers	Anglers at Berkeley Pier
No. of Survey Respondents	n=1227	n=695	n=212[a]	n=520
Newspaper	35%	34%	30%	13%
Television	33%	35%	29%	17%
Sign	22%	25%	14%	27%
Family/Friend or word of mouth	20%	20%	20%	10%/3%[b]

[a] responses for 16 anglers appear to be missing

[b] 10% reported "friend" and 3% reported “family”

H. Highly Exposed Populations

A primary goal of this study was to identify populations that may be highly exposed to chemicals from eating Bay fish. We used several different criteria to identify highly exposed populations including consumption rates, the proportion consuming above health advisory levels, species consumed, and consumption methods. We also looked at whether an angler's higher level of exposure was related to lack of access to health advisory information.

Overall, differences among ethnic groups were more distinct than for other demographic locators. Among ethnic groups we found that Asians (particularly Filipinos) were consistently the most highly exposed group. Filipinos and African Americans had the highest overall consumption rates of SF Bay fish. (Pacific Islanders also had high rates but this was based on a small sample.) Vietnamese, Chinese, and Filipinos were more highly represented among anglers who consumed above advisory levels.

Of the three species of Bay fish of greatest health concern (white croaker, striped bass, leopard shark), most anglers in all ethnic groups ate striped bass. However, Asians more frequently ate white croaker compared to other groups and Vietnamese and Chinese more frequently ate leopard shark. In general, Asians were more likely to follow consumption methods (i.e., eating skin, cooking juices, etc.) that increased their exposure to chemicals.

One reason Filipinos may be highly exposed is because of their lack of access to health advisory information. Filipino consumers had the lowest overall awareness and lowest understanding of health advisories compared to other groups.

Some criteria showed shore-based anglers to be more highly exposed than boat anglers. For example, shore-based anglers more frequently consumed white croaker and were more likely to follow consumption methods that increased their exposure to chemicals. This may be due in part to the fact that Asians dominated shore-based fishing modes, although we did not find higher consumption rates among shore-based anglers.

We expected to find a correlation between high consumption of Bay fish and a low level of income and/or education, but we did not. In fact, at the highest levels of consumption (above the 95th percentile), it appeared that anglers with incomes greater than $45,000 are more highly represented than those with lower incomes. Anglers with low income/education levels are still an important concern, however, for several reasons. Firstly, low income and education are related to consumption of two highly contaminated species, white croaker and leopard shark. Secondly, low income and education were often correlated with consumption methods that increase exposure to chemicals, such as eating skin. Finally, low income and education are related to low awareness and understanding of health advisories.

The health advisory for SF Bay recommends stricter consumption limits for women who are pregnant, breastfeeding, planning to become pregnant, and for young children (under the age of six), because these populations are at greater risk than others. Although consumption rate information on household members was not obtained, anglers reported that these high-risk groups consume the fish the anglers catch from SF Bay.

I. Study Strengths and Limitations

To improve upon previously conducted studies, we included several unique elements in our sampling plan and data analyses procedures. Specifically, we determined a target sample size needed to estimate consumption rates with a defined level of precision. The study was designed to obtain a representative sample of the fishing population in SF Bay, thus the results could be extrapolated to the overall angler population. Moreover, efforts were taken to characterize the group of anglers who declined to participate. We describe consumption rates of SF Bay fish for consumers, recent consumers, and per angler. We also presented data on consumption of sport fish from sources other than SF Bay and commercial fish.

The study greatly benefited by having all phases of the study design, field implementation, data analyses, and report generation undergo rigorous review by members of the Seafood Consumption Task Force and selected outside reviewers (see Appendix C). The data and information contained in this report can reliably be used to estimate demographic characteristics and seafood consumption practices of anglers fishing in San Francisco Bay.

Although we designed and conducted this study to minimize sources of measurement error or other biases, it was not possible to eliminate all sources of bias. To help the reader understand the limitations of the data and to assist in the design of future studies, we have summarized some of these limitations below:

1) We experienced higher decline-to-participate rates among shore-based anglers. Since higher proportions of non-Caucasian ethnic groups were represented among shore-based anglers who declined, especially those of Asian ethnicity, our sample may have underrepresented these ethnic groups. We can never truly know consumption rates of anglers who declined to participate. However, we have extrapolated consumption rates for these anglers based on consumption rates derived for anglers who did participate and found no change in overall consumption rates.

2) In general, the sampling plan excluded low activity sites and focused on high activity sites for shore-based and private boat modes. (In some cases, low activity beach and bank sites, if adjacent to a high activity pier site, were included). An ideal sampling plan would have begun with a sampling frame that included all known sites. However, such plans would have resulted either in a much lower sample size (since interviewers would be spending time in lightly-used area) or much higher cost. Since the study costs were fixed, our only options were to have lower sample size (with a less precise consumption rate estimate) or a higher sample size with a less representative sample. We opted for a more precise consumption rate estimate.

3) Consistent with our sampling plan, interviewers at private boat sites attempted to interview all boat anglers using the site during the scheduled sampling period. Most of the time, the interview staff assigned to a site could attempt to interview all anglers using that site. The field coordinator also made an effort to ensure that sufficient interview staff was assigned to sample these sites. However, on a few sampling days, for example, when we had not anticipated a higher level of fishing activity, not all anglers in a group or an entire group of anglers could be interviewed. We did not attempt to quantify the number of anglers that were not interviewed. These anglers who were missed resulted in a slight under sampling of private boat anglers. Additionally, although interviewers attempted to find anglers who had been fishing on berthed boats, no berthed boat anglers could be found to be interviewed.

4) The sample of party boat anglers was about 50% lower than our target. This was due to the lack of cooperation by party boat captains. Furthermore, the sample we did obtain may not be representative of party boat anglers in SF Bay for a number of reasons. For example, the port of origin of the party boat and the sampling days were not randomly selected, and the actual sampling days were not allocated by activity over the 12-month sampling period. In addition, we did not attempt to stratify the party boat sample by day, thus most interviews occurred on weekend days. Also, during exit interviews that we initiated in May 1999, we could not interview all anglers who had been on a boat.

5) Party boat anglers were not asked any health advisory questions to avoid discouraging their participation in the survey. As a result, health advisory results only apply to other fishing modes.

6) As discussed in our sampling plan (see Appendix D), we over-sampled weekend days and under-sampled weekdays relative to the amount of fishing activity by day type (weekend or weekday) in SF Bay at shore-based modes. We over-sampled weekend days to obtain sufficient sample size. Anglers who fish on weekends may differ in their demographic characteristics and consumption patterns than those who fish on weekdays. Since we did not analyze our data for differences by day, the magnitude and direction of any possible bias due to day type differences are not known.

7) Interviewers used a model of an 8-ounce raw fish fillet to help estimate the amount of fish the respondents ate at one time. Most respondents said their portion size was equal to the model. The degree to which the 8-ounce model influenced anglers' responses to this question is not known.

8) Consumption rate estimates based on a 12-month recall may be unreliable. Survey questions that use long recall periods are difficult for respondents to answer accurately.

9) We made no adjustment for the length of the angler's fishing trip at shore-based sites, a type of bias called length-of-stay bias. This bias is similar to avidity bias in that the probability of being sampled may be greater for anglers whose fishing trip is longer than average, compared to those whose trip is shorter than average (Pollock 1994, Otis 1993, Thomson 1991). Length-of-stay bias will not affect anglers such as boat anglers who are interviewed after their fishing trip is completed. Anglers who tend to fish for longer periods of time may also catch and consume more fish than anglers who fish for shorter periods of time. Unless corrected, as with avidity bias, this bias may result in consumption rates that are biased upwards.

10) In our sampling design, interviewers asked anglers if they had been interviewed for this study before. If they had, they were not interviewed again (sampling without replacement). In adjusting our data for avidity bias, we assumed that the probability of being sampled is proportional to an angler's avidity. However, for anglers sampled without replacement, the probability of being sampled is less than proportional to an angler's avidity (USEPA 1997). This occurs because anglers who are not resampled tend to be more avid, on average, than anglers in the sample. The effect of sampling without replacement is that the magnitude of the avidity bias is lessened, thus our adjusted consumption rate results may be biased upward.

11) Interviewers' contact with anglers may have influenced anglers' responses to the health advisory questions. Interviewers read respondents a paragraph describing the health advisory and provided written information for those who requested it at the end of the interview. It is likely that information we provided over the 12-month data collection period was shared with other anglers.

VI. Recommendations

This study was undertaken to fill gaps in our understanding of anglers' exposures to Bay fish, to identify highly exposed populations, and to gather information needed for developing educational messages and outreach activities for these populations. Much of the information presented in this report describes parameters for characterizing anglers' exposures, including highly exposed groups. Findings from this study can also be used to help develop educational messages and activities aimed at reducing anglers' exposures to chemical contaminants. Our recommendations focus primarily on how educational messages should be developed, and how outreach and educational activities should be conducted. We also identify areas where additional research is needed.

A. Recommendations for Outreach and Education Activities

- Conduct outreach and education activities to reach highly exposed groups

  One of the central goals of the study was to identify highly exposed groups and gather information needed for developing educational messages for these groups. As discussed in Section V.H, we identified Asians, particularly Filipinos, as the group most consistently among the highly exposed. In addition, African Americans had high overall rates of Bay fish consumption. The highest priority should be given to developing messages specifically targeted to these groups.

- Develop educational messages that are culturally appropriate

  Given the ethnic diversity of SF Bay anglers, we recommend that culturally appropriate educational messages be developed. To be culturally appropriate, these messages need to be multilingual, sensitive to ethnic differences, and be at an appropriate literacy level.

- Develop educational messages that address the consumption practices of the target groups

  We found clear demographic differences among groups in the species that they eat, the parts of the fish they eat, and the ways in which they cook or prepare the fish. For example, Asians were much more likely to eat white croaker than other groups and, in general, Asians ate parts of the fish or prepared fish in ways that increased their exposure. We recommend that educational messages for target groups address these specific consumption practices. Thus, educational messages for Asians should focus on limiting white croaker consumption and emphasize safe consumption practices that would decrease their exposure.

- Develop educational messages that reflect the current advisory (see Appendix A)

  Until the current advisory is updated, we recommend that all educational messages convey the content of this advisory.

- Develop educational programs using a variety of approaches

  Because we found that none of the methods of delivering educational information to anglers received overwhelming support by all anglers, education activities will likely require a diversity of approaches. Both the survey results and the fish discussion groups indicated the need for educational material with a range of complexity and depth to meet the needs of the highly diverse SF angler population. We recommend that different methods, including newspaper, television, radio, and written materials, be explored.

- Post warning signs in all areas of SF Bay

  Although we found signage to be the third most popular method of communicating to anglers on fish contamination issues, signs seem to be the most direct way to reach anglers. We recommend comprehensive sign posting and maintenance in SF Bay at piers, beaches and banks, and at marinas to warn anglers about contaminants in Bay fish.

- Direct the Education and Outreach Task Force on Fish Consumption and Fish Contamination Issues to carry out the outreach and education activities recommended above

  The goals of the Task Force are consistent with the outreach and educational activities we recommended above. However, the Task Force has been constrained by lack of resources. We recommend that additional resources be obtained to enable the Task Force to implement the outreach and education activities recommended above.

- Direct the Task Force to take a leadership role

  A major barrier to conducting educational activities, particularly posting of warning signs, in the SF Bay area has been uncertainty over which organizations have jurisdiction to undertake these activities. For example, it is often unclear who has authority to post and maintain a warning sign at a pier. We recommend that the Task Force take a leadership role in developing and overseeing the implementation of an integrated strategy to communicate health advisories on fish in a more effective manner. This would include coordinating input from the different agencies and organizations when conducting educational activities.

B. Recommendations for Community Involvement

- Expand the membership of the Task Force to have broader community representation

  For outreach and educational activities to be successful, the Task Force membership must more closely reflect the interests of the highly diverse angler population. We recommend that the Task Force seek broader representation from community-based organizations that represent health care, environmental, fishing, and other pertinent interests in the SF Bay area and that commensurate resources be made available for this purpose.

- Conduct activities that enhance participation from community-based organizations

  In addition to seeking broader membership on the Task Force, we recommend that the Task Force specifically undertake activities that will enhance participation and support from community-based organizations. CDHS is piloting a community-based approach to outreach and education on fish issues in the Los Angeles area. We recommend using this approach as a model for SF Bay activities.

C. Recommendations for Further Study

- Investigate the influence of the portion-size model on consumption rates

  The use of a single physical model to estimate the amount of fish anglers eat influences the angler's response. In this study, the model produced a consumption rate distribution that was peaked around common multiples or fractions of the model, and introduced an unquantifiable degree of uncertainty in the consumption rate results. Further study should focus on ways to estimate consumption rates that minimize this effect. For example, models of different portion sizes could have elicited a broader range of responses and may have produced more accurate consumption rate responses.

- Gather additional data on shellfish consumers in SF Bay

  Due to resource constraints, the data we gathered in this study on shellfish consumers was limited. Although we asked anglers (i.e., people who fish) if they consumed shellfish, we did not conduct any interviews with persons who collected only shellfish but did not fish. We also know little about the quantity of shellfish people eat from the Bay, the types of shellfish eaten, and the parts of the shellfish that are consumed. Because Bay shellfish may pose health risks to people who consume it, we recommend that more information be gathered about shellfish consumers in the Bay.

- Gather additional data on party boat anglers in SF Bay

  The sample of party boat anglers we collected in this study fell short of our target, thus our findings may not accurately reflect this population. In addition, party boat anglers were not asked any questions about health advisories. We recommend that additional data be gathered on party boat anglers to better characterize their consumption rates and practices and their awareness to health advisories.

- Gather additional data on high risk groups

  We know that some groups, i.e., pregnant and breastfeeding women, women planning to become pregnant, and young children, are at higher risk because they may be more sensitive to the harmful effects of chemicals found is Bay fish. Although we interviewed only people who fish in this study, we did find that many anglers have women of child bearing age and young children in their

households who consume Bay fish. The limited data on female anglers of child bearing age in this study indicate that consumption rates are similar to male anglers. Thus, if these women are pregnant, nursing, or planning to become pregnant, they may be exceeding the more restrictive advisory for these groups. However, we know very little about exposures to these groups and how to develop educational message to reach them. We recommend that additional data be gathered on these groups.

- Test the effectiveness of educational messages and activities

  Data on the actual effectiveness of alternative messages and how these messages are communicated to target audiences are lacking. We recommend that further research examine how alternative messages are understood and how effective different activities are at reaching target audiences.

VII. References

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Appendix A

1994 Interim Health Advisory for the San Francisco Bay

San Francisco Bay Seafood Consumption Study

Health Advisory on Catching and Eating Fish
Interim Sport Fish Advisory for San Francisco Bay

The California Environmental Agency's Office of Environmental Health Hazard Assessment (OEHHA) has performed a preliminary review of the data from the 1994 San Francisco Bay pilot study, "Contaminant Levels in Fish Tissue from San Franciso Bay." The results of the study showed elevated levels of chemical contaminants in the fish tissues. Based on these results, OEHHA is issuing an interim consumption advisory covering certain fish species from the bay.

- Adults should limit their consumption of San Francisco Bay sport fish to, at most, two meals per month.*
- Adults should not eat any striped bass over 35 inches.
- Women who are pregnant or may become pregnant, or who are breast-feeding, and children under 6, should not eat more than one meal per month and, in addition, should not eat any meals of large shark (over 24 inches) or large striped bass (over 27 inches).
- This advisory does not apply to salmon, anchovies, herring, and smelt caught in the bay; other ocean caught sport fish; or commercial fish.
- This advisory supersedes the existing advisory on striped bass in the bay, but does not revoke the recent advisory issued for the Richmond Harbor Channel Area.

Individuals who follow these interim guidelines will protect themselves from potential adverse effects caused by the levels of the chemicals found in fish by the study. OEHHA scientists also have the following simple suggestions for catching and eating fish from San Francisco Bay: (1) fish in a variety of locations, (2) eat smaller amounts of several species of fish rather than large amounts of a single species that may have a higher level of contamination, (3) clean and gut fish, eat only the fillet portion, (4) skin and trim fat from fish, (5) bake, broil or steam fish on a rack, (6) discard the juices from cooked fish.

This interim consumption advice is being issued due to health concerns based on exposure to sport fish form the bay contaminated with methylmercury, polychlorinated bipheyls (PCBs), dioxins, and pesticides like DDT. The principal effects of concern (from long-term consumption of fish) are possible neurotoxicity to developing fetuses, infants, and small children (e.g., impaired mental and motor development), mainly associated with excessive methylmercury or PCBs exposure, and potential increased risks for cancer due to exposure to PCBs, dioxins, and the pesticides. There is some indication of greater sensitivity of the nervous system in fetuses, infants, and young children. Because of this sensitivity, more restrictive consumption advice is given for young children and pregnant or breast-feeding women who may pass the contamination on to their fetus or child.

Although this advisory is based only on a preliminary review of the data form the study, OEHHA felt it would be prudent to issue interim guidelines at this time. More specific advisories and recommendations will be issued when a thorough evaluation of the study data is completed by OEHHA in conjunction with other public agencies.

More information can be obtained by calling OEHHA at (916) 324-7572.

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* A fish meal for a 154-poound (70 kilogram) person is considerd to be an 8 oz. portion of fish prior to cooking. Meal size should be adjusted according to body weight, with roughly 1 ounce of fish per 20 pound body weight. for a 40-pound child, for example, a fish meal would be 2 ounces of fish.

Appendix B

Education and Outreach Task Force

San Francisco Bay Seafood Consumption Study

Education and Outreach Task Force
On Fish Consumption and Fish Contamination Issues

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	Save San Francisco Bay Association Formerly represented by: Johnston Carlyle
	Office of Environmental Health Hazard Assessment Formerly represented by: Hanafi Russell

Appendix C

San Francisco Bay Seafood Consumption Study
Advisory Task Force and Reviewers

San Francisco Bay Seafood Consumption Study

The following individuals served as Task Force Members:

Ray Arnold, Exxon Biomedical Sciences, representing Western States Petroleum Association (WSPA)
Marcia Brockbank, San Francisco Estuary Project
Carlyle Johnston, Save San Francisco Bay Association
Bridgette DeShield, Harding Lawson, representing WSPA (replacing Paul Krause)
Margy Gassel, Pesticide and Epidemiology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency
Martin Golden, National Marine Fisheries Service
Paul Gregory, California Dept. of Fish and Game
Kay Johnson, Tetra Tech
Paul Krause, Harding Lawson, representing WSPA (replacing Ray Arnold)
Carrie Pomeroy, Institute of Marine Sciences, University of California, Santa Cruz
Brian Sak, Bureau of Public Works, City and County of San Francisco
Karen Taberski, San Francisco Regional Water Quality Control Board, Region II
Carol Thornton, San Francisco Estuary Project

The following individuals served as special consultants and outside reviewers:

Jeff Bigler, USEPA, Office of Water
Robert Brodberg, PETS/OEHHA, CA EPA
Jordan Gold, Applied Marine Sciences
Tom Grieb, Tetra Tech
Barbara Knuth, Dept. of Natural Resources, Cornell University
John Ong, Office of Water, USEPA, Region IX
Cassandra Roberts, Moss Landing Marine Laboratories
Gail Roper, CA Dept. Fish and Game
Hanafi Russell, PETS/OEHHA, CA EPA
Bob Smith, EcoAnalysis

Task Force members and outside reviewers performed the following tasks:

A. Proposal Review and Contractor Selection

Ray Arnold
Jay Davis – SFEI
Margy Gassel,
Rainer Hoenicke (SFEI Project Manager)
Brian Sak
Karen Taberski

B. Phase I – Survey Design

Project Staff: Diana Lee, Alyce Ujihara, Dan Smith, Martha Harnly, Bob McLaughlin, Christine Arnesen, Ian Walker, Gloria Cardona – Environmental Health Investigations Branch (EHIB), California Dept. of Health Services
Jim Allen
Ray Arnold
Marcia Brockbank
Margy Gassel
Jordon Gold
Martin Golden
Rainer Hoenicke
Kay Johnson
Barbara Knuth
Carrie Pomeroy
Gail Roper
Hanafi Russell
Brian Sak
Karen Taberski
Patty Velez

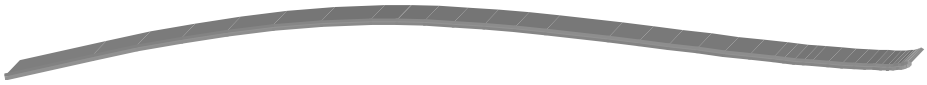
C. Phase II – Implementation of Field Survey
EHIB/DHS team
All task force members except Brian Sak, Carrie Pomeroy

D. Phase III – Data Analysis and Report Preparation and Review
All Phase II participants
Bridgette DeShields
Paul Krause
John Ong
Cassandra Roberts
Hanafi Russell

Appendix D

Sample Design, Site Selection, and Sampling Schedule

San Francisco Bay Seafood Consumption Study



Appendix D - Sampling Plan for the San Francisco (SF) Bay Seafood Consumption Study

In Section II.B, we provided an overview of the study's sampling plan. This appendix describes the sampling plan in further detail.

A. Survey Approaches

There are many different survey approaches that can be used to gather fish consumption information about anglers. These approaches include off-site methods such as mail and phone surveys as well as on-site methods such as personal interviews at fishing locations. We determined that the best way to gather fish consumption information from SF Bay anglers was to use personal interviews at fishing sites.

Off-site methods could not be used for this study because, in California, no comprehensive list of anglers, from fishing licenses or other sources, was available when this study was planned. A list of fishing license holders, even if available, may not be complete for SF Bay anglers because fishing licenses are not required at public piers in California (CDFG 2000). A significant amount of fishing activity occurs on these public piers in SF Bay and the proportion of pier anglers who hold licenses is not known. Additionally, on-site personal interviews conducted by bilingual interviewers would enhance participation of respondents who may have difficulty understanding written questionnaires due to cultural or language barriers, or low literacy. Finally, because of the importance of estimating consumption rates, we opted to use a physical model of a fish fillet to elicit information about the quantity of fish typically eaten by the angler. The use of the fillet model required us to use personal interviews.

B. Sampling Frame

The sampling frame is a complete list of the populations units that will be sampled (Pollock et al 1994). For example, the population units can be the individual members of a population, if all the members can be identified. With on-site surveys, the sampling frame is a complete list of all time-place combinations where anglers are present. In other words, it includes all possible fishing sites or access points in the study area and all possible sampling days and times during the study period.

The study area included the San Francisco Bay within the Golden Gate Bridge, including San Pablo Bay in the north (see Figure 1 in the report). To the east, the study area includes the Carquinez Straits and Suisun Bay to Chipps Island (near the city of Pittsburg). The list of fishing sites used in this study was drawn from the Marine Recreational Fisheries Statistics Survey (MRFSS) site list (Roper 1997). The site list from the MRFSS for SF Bay identified 47 sites with shore-based fishing[1], 24 with private boat access, and 8 with party boat access.

[1] Although the MRFSS identifies two shore-based modes, (1) man-made (e.g. piers) and (2) beach and bank, we combined these modes into a single "shore-based" mode.

To ensure that the MRFSS site list included all possible fishing locations in our study area, we consulted task force members, California Department of Fish and Game staff, and other sources. In addition, we identified sites in the Carquinez Straits and Suisun Bay areas of SF Bay where the MRFSS is not conducted. Some areas of SF Bay where we could not gain access, such as military bases, were not included in the study.

In addition to a comprehensive list of sites in the study area, the sampling frame includes all days and times when anglers are present at the sites. The possible sampling days included the one-year period, from July 1, 1998 to June 30, 1999.

C. Sample Size Estimate

1. Sample Size of Recent Consumers

We set a target sample size based on an estimate of the minimum number of interviews needed to meet the objectives of the study. Because of the emphasis placed on defining exposure assessment parameters such as consumption rate, the sample size was based on the minimum number of interviews needed to estimate a reasonably precise mean consumption rate. The consumption rate was derived from the subset of anglers who consumed fish caught from SF Bay in the four weeks prior to the interview, a group we refer to as recent consumers. In choosing the four week time period, we sought to maximize the time period over which a consumption rate estimate could be made while minimizing recall bias. In addition, the Santa Monica Bay Seafood Consumption Study (Allen 1996, SCCWRP/MBC 1994) has to date provided the best estimates of fish consumption rates from a California population. This study also used a four week recall to estimate consumption rate. By using a similar method to define consumption rate, we could compare rates derived from both studies.

We used consumption rate data from the Santa Monica Bay study to estimate the target sample size for this study. Using the mean and standard deviation from the Santa Monica Bay study, we calculated confidence limits around a geometric mean and upper percentiles (90th and 95th) for different sample sizes (Hahn and Meeker 1991). Figure 2 (in the report) shows that for a sample size of n=480, the 95% confidence limits are +/-10% around a geometric mean. At n=480, the 95% confidence limits around the 90th and 95th percentiles are slightly larger (+/-13-15%). As can be expected, the width of the confidence limits increases as the sample size decreases. Figure 2 also shows that as the sample size increases beyond n=480, little increase in precision of the consumption rate estimate is gained. We consider a 95% confidence limit of +/-10-15% to be reasonable and thus select n=480, or n~500, as our target sample size for the group of recent consumers.

2. Target Interview Attempts

The sample size estimate described above showed that we needed to conduct interviews of about 500 recent consumers in order to calculate a reasonably precise consumption rate. We then estimated the number of anglers we would need to approach to obtain

completed interviews of 500 recent consumers. The last row in Table D1 shows that in three past angler surveys, 23% to 32% of attempted interviews yielded a completed interview of a recent consumer.

Table D1. Comparison of Response Rates in Three Angler Surveys in California

Angler Survey	**Santa Monica Bay[a]**	**SF Bay Pier Anglers[b]**	**SF Bay Pier Anglers[c]**
Interviews attempted	1740	388	111
Refusal	496 (29%)	160 (41%)	28 (25%)
Persons interviewed	1244 (71%)	228 (59%)	83 (75%)
Respondents without recent consumption	689 (40%)	137 (35%)	54 (49%)
Respondents with recent consumption	555 (32%)	91 (23%)	29 (26%)

[a] Allen et al. (1996) and SCCWRP/MBC (1994).
[b] Wong et al. (1997).
[c] Ujihara (1997).

The highest percentage (32%) of respondents providing recent consumption information comes from the Santa Monica Bay Seafood Consumption Study. Although this study had a much larger sample size than the other studies, over half of the interviews were of private or party boat anglers, where the proportion of recent consumers was higher than shore-based fishing modes (Table D2).

Table D2. Proportion of Recent Consumers by Fishing Mode for Santa Monica Bay Seafood Consumption Study

Fishing Mode	Attempted Interviews	Recent Consumers
Pier/Beach Intertidal	806	216 (27%)
Private Boat	630	233 (37%)
Party Boat	304	106 (35%)

Source: SCCWRP/MBC (1994) and Allen et al. (1996).

Only shore-based anglers were interviewed in the SSFBA and EHIB studies. The proportion of total attempted interviews where anglers reported recent consumption from these two studies was only 23% and 26%. As discussed further in subsequent sections, SF Bay fishing activity is dominated by shore-based fishing, leading us to estimate that approximately 25% of our interview attempts of anglers will yield interviews of recent consumers. Thus, we concluded that 2000 (500/0.25) interviews must be attempted to reach our target of 500 recent consumers.

D. Sampling Plan Elements

In addition to meeting our sample size goals, there were a number of elements included in the sampling plan that guided our selection of sampling sites and determined how frequently we sampled at the selected sites. These elements include stratification of the sample by mode, season, and day type. In addition, we describe how our budgetary resources shaped the sampling plan.

1. Sample Stratification by Mode

Stratification of a sample into homogenous, non-overlapping groups called strata can improve the overall precision, facilitate administration, and reduce costs of the survey (Pollock et al. 1994, Scheaffer et al. 1996). To determine how much to sample in each strata, Pollock et al. (1994) recommends distributing sampling effort in proportion to fishing effort or the variable of interest such as catch. We stratified our sample by the three fishing modes based on the relative amount of fishing activity in each mode. We used fishing activity (the relative number of anglers using a site) rather than fishing effort (relative amount of time anglers spend at a site) because of our primary interest in angler characteristics (e.g., consumption rate, demographic factors) rather than factors that describe fishing effort (e.g., catch per effort, catch).

For estimates of fishing activity we relied on fishing pressure data developed for the MRFSS. Fishing pressure, as defined by MRFSS, is an estimate the average number of anglers that are present at a site over an eight-hour day. For boat modes, the fishing pressure is an estimate of the number of anglers using a launch ramp or departing from a marina. The number of anglers present at a site is provided as a range, i.e., a site can be assigned a fishing pressure of zero, 1-4 anglers, 5-8 anglers, 9-12 anglers, 13-19 anglers, or 20-29 anglers, etc. A separate fishing pressure estimate is made for weekend days and the weekdays for each of the 12 months of the year at each site.

In order to estimate the relative amount of fishing activity for each mode, we summed MRFSS fishing pressure estimates for 1997, using the mid-points of the ranges, for all sites in SF Bay. We then averaged this value over the 12 months in a year, and weighted the weekend and weekday estimates by the proportion of weekend days and weekdays in a year. The resulting value provided an estimate of the relative number of anglers fishing in each mode for an average eight hour day. These values are shown in column 2 of Table D3.

Table D3. Fishing Activity in SF Bay and Original Target Survey Attempts by Mode

1	2	3	4	5	6
Mode	Fishing Activity in SF Bay (uncorrected)*	Proportion Outside SF Bay	Fishing Activity in SF Bay (corrected)*	% of total	Target number of attempted surveys
Shore-based	263.0	0%	263.0	62.5%	$n_{shore\text{-}based} = 1250$
Private boat	131.9	11.8%	116.3	27.6%	$n_{private} = 553$
Party boat	93.4	55.6%	41.5	9.9%	$n_{party} = 197$
Total	488.3	---	420.7	100%	$n_{total} = 2000$

*The average number of anglers fishing on typical day by mode.

Some anglers on private and party boats depart from sites within SF Bay but they fish primarily outside the Bay. Because the focus of our study is fishing within SF Bay, we sought a correction to eliminate fishing activity originating in the Bay but occurring outside the Bay from our estimates of fishing activity by boat modes. Using data collected by MRFSS interviewers for 1994-1996, we found that a significant amount of the fishing activity, particularly among party boats, originated within SF Bay but was primarily conducted outside the Bay. Of fishing trips originating within the Bay, Table D4 shows the proportion of boat trips that were primarily conducted outside the Bay.

Table D4. Boat Anglers Fishing Outside and Inside SF Bay from MRFSS 1994-1996

	FISHING MODE			
	Private Boat		Party Boat	
	No.	%	No.	%
Outside SF Bay	471	12	421	56
Inside SF Bay	3512	88	336	44
Total	3983	100	757	100

Source: Van Buskirk (1997).

Table D4 shows that 12% of private boat anglers and 56% of party boat anglers originated their trip in the Bay but fished primarily outside the Bay. We then corrected our fishing activity estimates in Table D3 by reducing fishing activity for out of Bay trips among boat modes. Column 3 of Table D3 shows the proportion of fishing activity outside the Bay and column 4 shows the revised fishing activity estimate. We concluded in column 5 that about 62% of the total fishing activity in SF Bay is attributed to anglers fishing at shore-based sites (n_{shore}), 28% to anglers fishing within SF Bay on private boats ($n_{private}$), and 10% to anglers fishing within SF Bay on party boats (n_{party}).

Column 6 of Table D3 provides an initial target number of interviews we should attempt in each mode, derived by multiplying the percent of total activity for each mode by our targeted of 2000 interview attempts. For example, we estimated that 0.625 x 2000 = 1250 interview attempts for shore-based anglers.

2. Seasonal Variation

One of the study's objectives was to characterize seasonal variation in fish consumption patterns and angler characteristics. In order to observe seasonal variations that occurred over the one year study period, we planned to visit the same group of sites each month. Thus, observed differences could be attributed to changes over time rather than differences among the sites sampled. Visiting the same group of sites on a monthly basis also facilitated administration of the survey.

3. Day Type Differences

Overall, there is more fishing activity in SF Bay on a typical weekend day than on a typical weekday. However, in number, there are more weekdays than weekend days. (The ratio of weekdays to weekend days is 5:2). In Table 5 we calculated the relative amount of fishing activity for 1997 by shore-based and private boat modes, based on MRFSS fishing pressure data. For shore-based modes, there is more fishing activity on a typical weekend day, but this is offset by the greater number of weekdays. Thus, the amount of fishing activity by day type over a year is roughly equal. For private boat modes, fishing activity is far greater on a typical weekend day than a weekday. Even after adjusting for the greater number of weekdays, the ratio of fishing activity on weekends to weekdays at private boat sites is approximately two to one.

In making this estimate, we could not exclude fishing activity that originated in the Bay but was primarily conducted outside the Bay. For private boats, the proportion is relatively small (12%) and thus, we ignored it. Because this proportion is large for party boats (56%), we did not make an estimate of fishing activity by day type for this fishing mode.

Table D5. Fishing Activity by Day Type at Shore-based and Private Boat Sites in SF Bay

Fishing Mode	Day Type		
	Weekday	Weekend	Total
Shore-based	51%	49%	100%
Private Boat	38%	62%	100%

In an ideal sampling plan, we would allocate sampling effort by day type according to the percentages in Table D5. Because fishing activity is much lower on weekdays, it is more costly to sample weekdays and the higher the proportion of weekend days, the greater the expected sample size. To reach our sample size goals, we considered oversampling weekend days. But, in order to address concerns that the population fishing on weekdays could be significantly different from the population fishing on weekends, we sought to include some sampling on both day types.

4. Resources

Ultimately, our field data collection efforts were restricted by the resources available in our budget. After taking into account the resources needed for training the interviewers, we calculated that we had about 1700 person-hours available for field data collection activities. We allocated those person-hours by the relative amount of fishing activity in each of the 3 modes (Table D6).

Table D6. Person-Hour Allocation for Data Collection by Mode

Mode	Fishing Activity inside SF Bay	% of total	Person Hours Available for Data Collection
Shore-based	263	62.5%	1063
Private boat	116.3	27.6%	469
Party boat	41.5	9.9%	168
Total	420.7	100%	1700

5. Exclusion of Low Activity Sites

In an ideal study, the sampling frame would include all sites for shore-based and private boat anglers at all fishing locations where anglers fish and all points where anglers depart from. However, according to MRFSS data, many fishing sites in SF Bay have low activity and require more resources per interview to sample.[2] In selecting sites, we attempted to maximize the number of sites that could be included. But, in order to reach our sample size goal, most sites with low activity were excluded from the sampling plan. In general, low activity areas were included only if adjacent to a high activity site. For example, we included beach or bank areas next to a busy fishing pier.

We did consider the trade-off between the possible introduction of a bias by excluding low activity sites and the loss in precision from a reduced sample size if low activity sites were included. An outside consultant was hired to model these factors for shore-based sites (Smith 1998). This analysis found that any bias introduced by focusing on only high activity sites would be small in comparison to the loss in precision from a smaller sample size that would result by including low activity sites.

6. Geographic Distribution

Because the study addresses fishing throughout SF Bay, we considered the overall geographic distribution of sampling sties. We sought to include sites from all areas of the Bay.

[2] We defined low activity as sites where the MRFSS has assigned zero or the lowest fishing pressure estimate, a range of 1-4 anglers over an 8-hour day.

E. Sampling Plan for Shore-Based Sites

To derive an optimal sampling plan for shore-based sites we considered several sampling alternatives. For comparison, one alternative included sampling at all 46 MRFSS sites. The other alternatives included fewer numbers of sites but focused on the sites with the highest fishing pressure.

1. Fishing Activity Differences Among Sites

In order for the sampling plan to capture fishing activity differences between sites, the amount of time we conducted interviews at each site was not predetermined. Interviewers were instructed to interview all anglers present at a site. If no anglers were present, they remained for a minimum of one hour before going to the next site or ending the sampling day. By using this method, site differences in activity would be reflected in the relative number of anglers interviewed at a site.

2. Projecting Interview Attempts

For each sampling alternative, we projected the number of interviews we could expect to attempt during the study using MRFSS fishing pressure data. MRFSS data reflect the number of anglers at a site over an eight hour day, while we planned to interview all anglers present at a site and then leave. We did not expect to remain at a site for eight hours, even at the busiest locations. Thus we had to adjust the MRFSS fishing pressure estimates in order to project the number of interviews we could expect at a site. Based on a census of anglers during site visits we made in 1997, we estimated conservatively that we could expect to find 75% of the MRFSS fishing pressure estimate during our site visits where we remained at a site long enough to interview all anglers present. In other words, if MRFSS data estimate that 13-19 anglers will be present at a site over an 8-hour day, we took the midpoint of the range, 16, and multiply by 75%. Thus we estimated that we expected to find 16*.75=12 anglers on average during a site visit.

3. Projecting Person-Hours

In addition to projecting the number of interviews we could attempt for each sampling alternative, we also projected the number of person-hours needed to sample these alternatives. The person-hour estimates included the time needed to conduct the interview, including interviews in languages other than English, the time needed for conducting a census of anglers, travel between sites, and reviewing the completed surveys at the end of the day.

Because of the difficulty in keeping the study within our resources while still maintaining a reasonable a number of sampling sites, several changes were made to the sampling design to reduce costs. We grouped sites into pairs based on geographic proximity and site pairs were sampled together. Interview team size, originally set at three persons to cover all the target languages, was reduced to two persons.

4. Shore-based Sampling Plan Selected

As could be expected, we found that the greater the number of sites included in the sampling plan, the lower the expected sample size. To sample at all 46 sites and stay within our budget, we estimated that the number of interview attempts would be about 40% below our target of 1250.

The final site combination selected included 14 sites (7 site pairs). Two sites were specifically included in the selected sites to improve geographic coverage. One site (Martinez) was added in the Carquinez Straits area which is outside the area of the MRFSS. Also, one site (Dumbarton Bridge) was added to replace the San Mateo Bridge site. The San Mateo Bridge site is one of the most heavily used sites in the Bay but was closed during the duration of survey. The 14 selected sites are listed in Table D7 and shown in Figure D1.

Table D7. MRFSS Fishing Pressure at 14 Selected Shore-based Sites

			MRFSS Fishing Pressure	
Rank	County	Site Name	Weekday	Weekend
1	San Francisco	Fort Point Pier	13.9	19.4
2	Marin	Fort Baker Pier	12.9	20.5
3	Marin	McNear's Pier	9.2	16.7
4	San Francisco	Municipal Pier	8.2	12.8
5	Alameda	Berkeley Pier	5.5	16.5
6	Alameda	Alameda Rockwall	6.6	11.3
7	San Francisco	Candlestick Point	4.3	16.3
8	San Mateo	Oyster Point	4.8	9.5
9	Contra Costa	Point Pinole	2.8	12.0
10	San Mateo	Coyote Point	3.4	10.7
11	Alameda	Port View Park	2.0	13.0
12	Solano	Vallejo shoreline	4.8	9.2
13	Alameda	Dumbarton Pier	1.0	6.5
14	Contra Costa	Martinez Pier*	1.0	1.0
		Total	80.3	175.4

*Martinez Pier is outside the area of the MRFSS. We estimated the fishing pressure based on our own observations.

In Table D5, we estimated that shore-based fishing activity was 51% weekdays and 49% weekends. Thus, we allocated equal sampling days to weekends and weekdays by

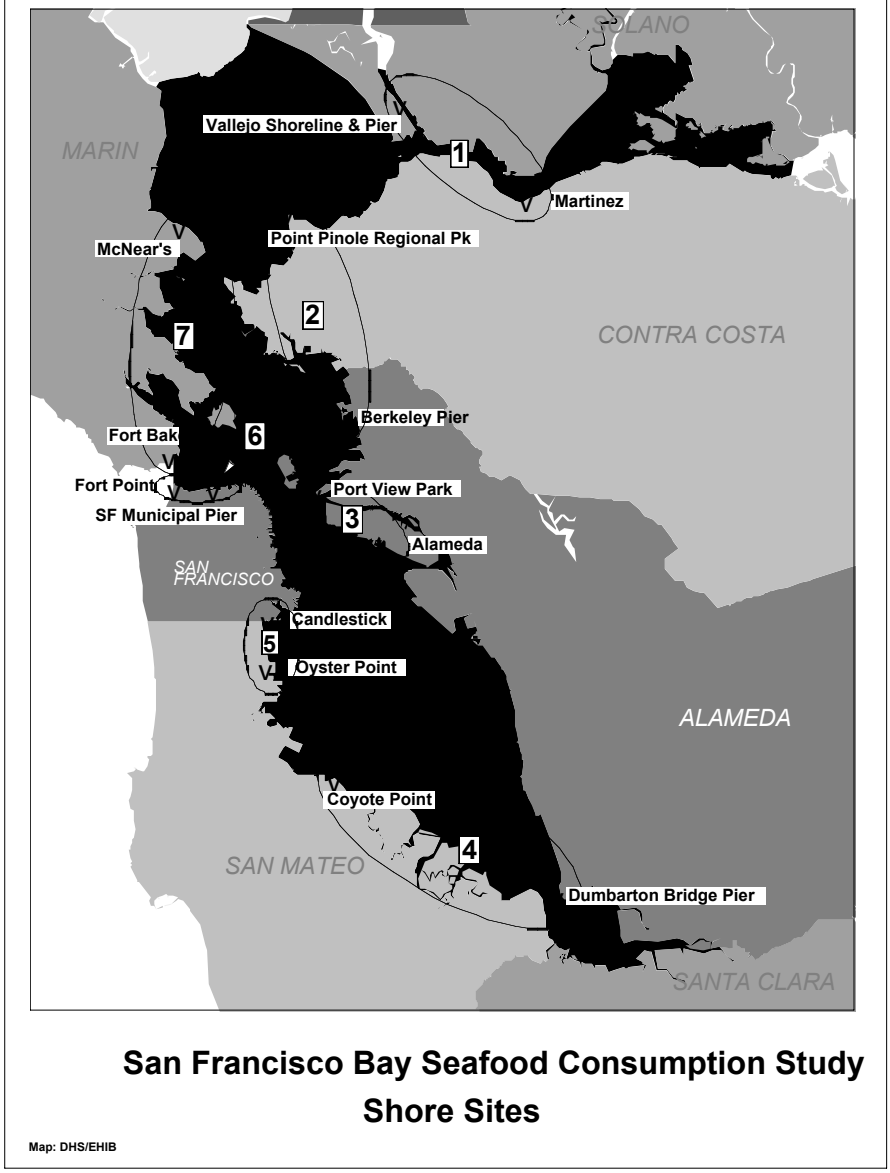


Figure D1. Shore-based Sites

alternating day types at a site each month. However, because activity at all sites was generally higher on weekends, our sampling effort was approximately 2/3 weekend and 1/3 weekday. This resulted in an oversampling of weekend days relative to our estimate of fishing activity but allowed us to maintain an adequate sample size.

Table D7 also shows the average fishing pressure at the 14 sites. We used these averages to estimate the projected number of interview attempts shown in Table D8. By visiting each site one time per month, half on weekdays and half on weekends, we estimated attempting 1150 interviews, below our original target of 1250 but within our resources (Table D9).

Table D8. Estimating Interview Attempts for 14 Shore-based Sites

	Weekday	Weekend	Total
MRFSS Fishing Pressure (average number angler per 8 hour day)	80.3	175.4	256
Estimated Interview Attempts per Visit (75% of fishing pressure)	60.2	131.6	192
Sum Over 12 months (6 weekday and 6 weekend visits per site)	361	789	1151

Table D9. Comparison of Original Target Sampling With Revised Target at Shore-Based Sites

	Interview Attempts	Person-Hours
Original Target	1250	1063
Revised Target Chosen Sampling Plan	1151	1042

F. Sampling Plan for Private Boat Sites

As with the shore-based sites, we considered several sampling alternatives for private boat sites. One alternative included all 24 identified private boat sites in SF Bay. Other alternatives included the top 5 and top 10 sites with the highest fishing pressure. Our primary goal for sampling private boat anglers was to interview anglers at access points as they left on a fishing trip or returned from a fishing trip. The primary access point was a boat launch, where anglers launch boats from trailers. We also screened anglers to ensure that their fishing trip that day was in SF Bay; we did not interview anglers fishing predominately outside SF Bay.

There were concerns that interviewers stationed at launch ramps would miss private boat anglers who used berthed boats. To include anglers using berthed boats, interviewers were instructed to visit marina areas adjacent to launch ramps sites and look for berthed boats about to depart or returning from a fishing trip and interview these anglers.

1. Fishing Activity Differences at Sites

Unlike the shore-based sampling plan, the length of time interviewers were stationed at a launch ramp was precisely determined based on fishing activity differences at the sites. Following Pollock, we assigned a shift length that was proportional to the relative amount of fishing activity at the site, using MRFSS fishing pressure data. Thus, these private boat sampling shifts varied by site, by month and day type (weekend or weekday). In other words, sites with the most activity were assigned longer shifts than sites with less activity. In general, shifts were longer during weekends and during warm weather months because these times generally had more activity.

2. Projecting Interview Attempts

In order to evaluate the sampling alternatives, we projected the number of interview attempt we could expect for each alternative using MRFSS estimates. For example, if MRFSS data estimated a range of 13-19 anglers at a site for an eight hour weekend day in July, we took the range midpoint (16) and estimated that we could encounter two anglers per hour (16 anglers/eight hour day =two angler/hour) at that site for a weekend day in July. The interview rate (interview attempts per hour) was multiplied by the assigned shift length (hours) to derive an estimate of the number of interview attempts for a sampling shift. We then summed the interview attempts for all sites, day types, and months to give an estimate of the total interview attempts for the one year study period.

3. Projecting Person-Hours

We also projected the total person-hours by summing all shift lengths for all sampling alternatives. The total was multiplied by two because we planned to assign two interviewers to all shifts. We also assigned additional person-hours to allow interviewers to review their completed surveys at the end of the day.

4. Private Boat Sampling Plan Selected

As with the shore-based sampling plan, the greater the overall number of sites, the lower the projected sample size. The sampling alternative selected included five sites. This was the minimum number of sites that gave reasonable geographic distribution of the Bay (Table D10 and Figure D2).

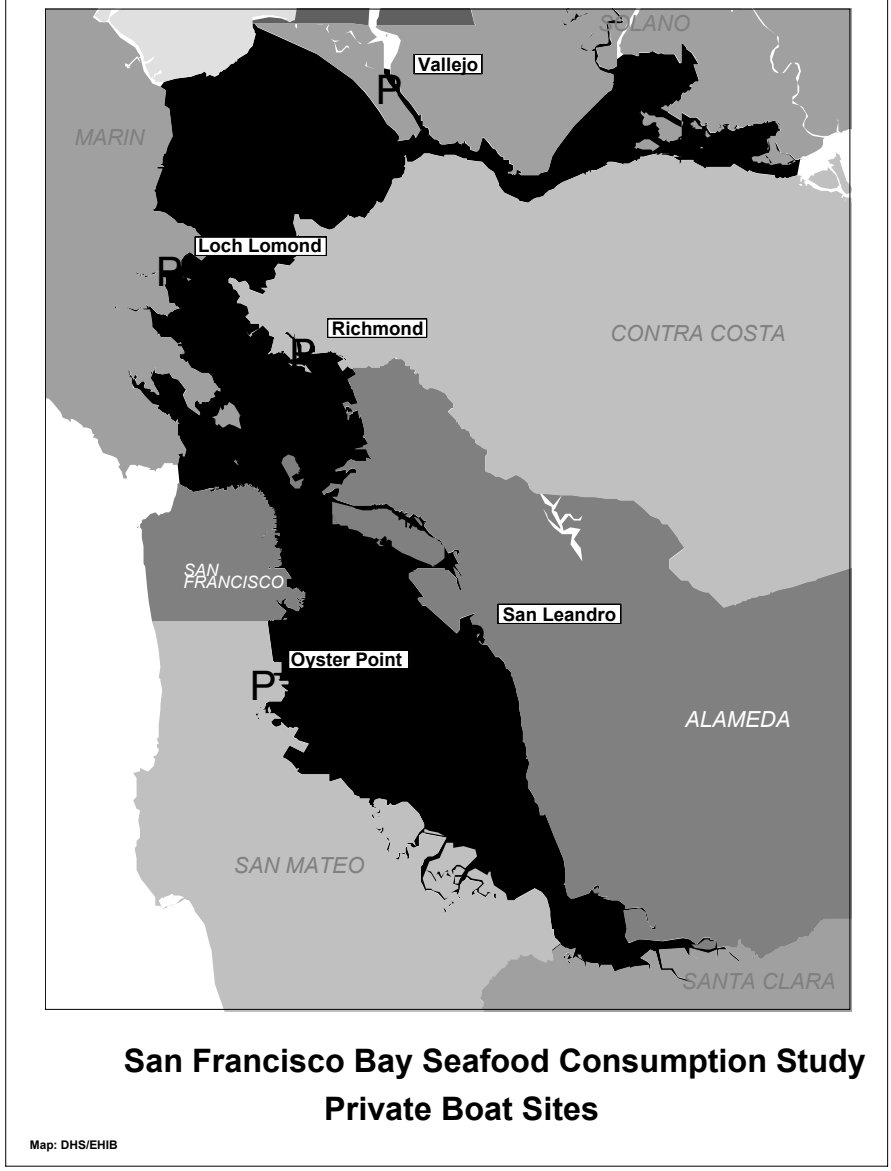


Figure D2. Private Boat Sites

Table D10. MRFSS Fishing Pressure at 5 Selected Private Boat Sites

			MRFSS Fishing Pressure	
Rank	County	Site Name	Weekday	Weekend
1	Contra Costa	Richmond	10.5	22.4
2	Solano	Vallejo	9.2	20.3
3	San Mateo	Oyster Point	8.2	19.5
4	Alameda	San Leandro	1.0	21
5	Marin	Loch Lomond	6.5	14.6
		TOTAL	35.4	97.8

The number of interview attempts we projected was 27% below our original target (Table D11). We opted to accept this lower sample size rather than make other modifications to the sampling plan. Based on the SMB study results (Table D2), we anticipated that we would have greater sampling success with private boat anglers than for shore-based fishing. Thus, we anticipated that the number of private boat anglers who were recent consumers would be adequate.

Table D11. Comparison of Original Target Sampling With Revised Target at Private Boat Sites

	Interview Attempts	Person-Hours
Original Target	553	469
Projection for Chosen Sampling Plan	406	510

In order to reduce the total number of person-hours needed to sample at the five selected sites, we chose not to sample at one of the sites, San Leandro, on weekdays. This site had very low weekday activity. We projected that we would interview only about one angler after six weekday visits. Our person-hour estimate still exceeded our target by about 10%.

G. Selection of Sampling Days and Times for Shore-based and Private Boat Sites

Selection of sampling days and times for shore-based and private boat sites was similar and is discussed in this section.

1. Sampling Days

We randomly selected the sampling days at shore-based and private boat sites. All days in a month were divided into two pools, one for weekdays and one for weekend days. Sampling days were then randomly selected from each pool. A few holidays were

excluded as possible sampling days[3] and some weekday holidays were counted as weekend days.[4]

Because of the difficulty in scheduling more than one interview team per day, sampling days for both shore-based sites and private boat sites were selected from the same pool, without replacement. Thus, only one site, either shore-based or private boat, could be sampled on a given day. The starting point for allocating sampling days was rotated among the sites each month, but the order in which days were assigned to sites followed the same order.

To ensure equal coverage of weekend and weekdays, day type was assigned, with half the sites designated as weekday sampling and the remaining sites designated as weekend sampling. For example, for shore-based sites, four site pairs were assigned as weekend days and the remaining three sites were assigned as weekdays for the first month. The weekday/weekend day designations alternated every month.

2. Sampling Times

To ensure coverage of the sampling day, shore-based sites were assigned morning or afternoon shifts. For example, site pair 1 (shore-based sites Vallejo and Martinez) followed the pattern in Table D12 for the first four months of sampling. For safety reasons, we assigned sampling times only during daylight hours for both shore-based and private boat sites. In order to maximize coverage of daylight hours, shifts at shore-based sites began earlier and ended later during the longer summer months.

Table D12. Sampling Schedule for Site Pair 1 for July 1998-October 1998

Month	Date	Day Type	Shift time during day
1	July 1998	Weekend	AM
2	August 1998	Weekday	PM
3	September 1998	Weekend	PM
4	October 1989	Weekday	AM

Private boat anglers generally leave in the morning and return in the afternoon. Because we anticipated that anglers may have more time for an interview when returning from a trip than when departing, all sampling shifts were conducted in the afternoon. However, interviewers attempted to interview all private boat anglers they encountered at a site regardless of whether they were beginning or ending a fishing trip.

For shore-based sites, the individual site of each site pair that was sampled first was also alternated each month.

[3] New Years Day, Thanksgiving, Christmas Eve and Christmas Day

[4] Martin Luther King, Jr. Day, Presidents Day, Memorial Day, July 3rd (a Friday), Labor Day, and the day after Thanksgiving

H. Sampling Plan for Party Boat Sites

Because the MRFSS fishing pressure data for party boat sites predominately reflect fishing trips outside of SF Bay, which was not the objective of this study, these data were not used to develop a sampling plan for party boats. In order to focus only on party boat fishing within SF Bay, we examined data collected by the California Department of Fish and Game (CDFG 1998) on party boat activities. CDFG requires all commercial passenger fishing vessels (also called party or charter boats) owners or operators to file detailed reports on their trips. Using data from the PMASTER database provided by CDFG for 1996 (CDFG 1998), we calculated the total number of party boat trips within SF Bay and determined how there trips were distributed by month. We also looked at the average number of anglers on these trips, and weekend and weekday differences

CDFG data showed that party boat activities within SF Bay were heaviest between May and August, and were lightest in January and December. These data also showed that the average number of anglers per trip was 13 and the amount of fishing activity by day type was about 50% weekends and 50% weekdays. We estimated conservatively that we could attempt 12 interviews per fishing trip and that a typical trip was nine hours. Based on our budget and our estimate of available person-hours, we estimated that we could meet our sampling target in 18 party boat sampling trips. We then allocated these 18 sampling trips by the relative amount of fishing activity for each month (Table D13).

Table D13. Party Boat Sampling Schedule

Month and Year	Number of Sampling Trips	Projected Interview Attempts	Projected Person-Hours
July 1998	2	24	18
August 1998	3	36	27
Sept. 1998	1	12	9
Oct. 1998	1	12	9
Nov. 1998	1	12	9
Dec. 1998/ Jan. 1999	1	12	9
Feb. 1999	1	12	9
March 1999	1	12	9
April 1999	1	12	9
May 1999	3	36	27
June 1999	3	36	27
TOTAL	18	216	162

Because our party boat sampling effort was relatively small and because few party boats usually remained within SF Bay, we did not attempt to stratify our sample by site. Furthermore, because we had to rely on the party boat captains to agree to allow us to send an interviewer, we did not attempt to randomly select sampling days. Finally, the

primary interviewer we selected to conduct party boat interviews was only available on weekdays, we did not attempt to stratify the sampling days by day type.

Appendix D References

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Appendix E

Questionnaire (English and Spanish)

San Francisco Bay Seafood Consumption Study

Date ☐☐ / ☐☐ / ☐☐ Site Code ☐☐ Mode ☐ Time Begin ☐☐☐☐ Interviewer: ☐☐

Person is: ☐ Fishing (has poles only) ☐ Both fishing and crabbing

Hello, my name is _____. I am doing a survey for the San Francisco Estuary Institute **(SHOW IDENTIFICATION)** We are gathering information about what types of fish or shellfish people catch and eat from the San Francisco Bay. I am not checking fishing licenses or checking your catch. Your answers will be kept confidential and you don't have to answer all the questions. You will also receive a small gift at the end of the survey **(CAN SHOW ITEM)**. May I talk to you for a few minutes?

Q1a. ☐ Yes (SKIP TO Q2a) ☐ No (END SURVEY, FILL OUT Q1b-Q1e)

Q1b. Reason

- ☐ No time
- ☐ Language problem
- ☐ Appeared threatening
- ☐ Other
- ☐ DK

Q1c. Observed Ethnicity

- ☐ Caucasian
- ☐ Native American
- ☐ African American
- ☐ Filipino
- ☐ Latino/Hispanic
- ☐ Chinese
- ☐ Asian (unknown)
- ☐ Vietnamese
- ☐ DK
- ☐ Other

Q1d. Language

- ☐ English
- ☐ Spanish
- ☐ Vietnamese
- ☐ Cantonese
- ☐ Mandarin
- ☐ Tagalog
- ☐ Other
- ☐ DK

Q1e. Gender

- ☐ Male
- ☐ Female

Q2a. Our study is called the San Francisco Bay Seafood Consumption Study. Have you been interviewed before for this study? (talked to someone with same vest/hat on?)

- ☐ Yes Q2b. When (m/y): ☐☐ / ☐☐ ☐ DK
- ☐ No (CONTINUE)
- ☐ DK (CONTINUE)
- ☐ Refuse

(STOP, END INTERVIEW)

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When I talk about the San Francisco Bay, I mean this area here: (SHOW MAP). I will mainly be referring to fish and shellfish from the Bay. When I say shellfish, I am referring to crab, mussels, or clams.

Q3a. Is this the first time you have ever fished in the SF Bay?

☐ Yes (SKIP TO Q5) ☐ DK ☐ Refuse

☐ No **Q3b.** When was the last time you fished in the Bay? (m/y) ☐☐ / ☐☐ ☐ DK

Q4. Not including today, **in** the **last 4 weeks,** what is the total number of times you have gone fishing in the San Francisco Bay? ☐☐☐ ☐ DK ☐ Refuse

Q5. What do you usually do (plan to do -**FOR FIRST TIME FISHERS**) with the fish or shellfish you catch from the SF Bay? (CHECK ALL THAT APPLY)

☐ Eat it ☐ Give it to family or friends ☐ Trade or sell it ☐ Use for bait ☐ Catch and release it ☐ DK ☐ Refuse

☐ Other (specify)

For the next few questions, I am asking about eating fish that you or someone you know has caught from San Francisco Bay. This can be fish that's fresh, or fish from the Bay that you have frozen, dried, canned, or smoked after being caught to eat at a later time.

Q6a. Do you eat fish that you or someone you know catches from the SF Bay?

☐ Yes ☐ DK ☐ Refuse

☐ Used to, but don't anymore **Q6b.** stopped when:m/y ☐☐ / ☐☐ ☐ DK

☐ No (SKIP TO Q10)

Q7. How many years have you been eating fish that you or someone you know has caught from the SF Bay?

☐ Less than 1 year ☐ 6-10 years ☐ 21-30 years ☐ DK

☐ 1-5 years ☐ 11-20 years ☐ more than 30 years ☐ Refuse

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Q8a. In the **last 4 weeks,** did you eat fish that you caught or someone you know caught from the SF Bay?

☐ Yes ☐ DK

☐ No (SKIP TO Q9) ☐ Refuse

Q8b. In the **last 4 weeks,** how many times did you eat fish that you or someone you know caught from the Bay?

times per day ☐☐ times per week ☐☐ total times in last 4 weeks ☐☐☐

☐ DK

☐ Refuse

Q9. Over the last 12 months (__/97-8 to _/98-9) how many times overall did you eat fish that you or someone you know caught from the SF Bay?

times per day ☐☐ times per week ☐☐ times per month ☐☐☐ times in last 12 mos. ☐☐☐

☐ DK

☐ Refuse

Q10a. This is a model of 8 ounces (half pound) of raw fish fillet. When you eat fish from anywhere (the Bay, other places, stores, restaurants), is the amount that you eat: **(SHOW PERSON FISH PORTION BUT DO NOT LET THEM HOLD IT.)**

☐ About this size (SKIP TO Q11) ☐ DK ☐ Refuse

☐ More ⇓ **Q10b.** About how much more? ⇓⇓ ☐ Half more ☐ Two time (double) more ☐ DK ☐ Refuse

☐ Other ☐

☐ Less ⇓ **Q10c**. About how much less? ⇓⇓ ☐ Half this amount ☐ One third this amount ☐ DK ☐ Refuse

☐ Other ☐

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Now I'm going to show you pictures of 3 specific fish that can be caught from the SF Bay and ask you whether you eat them or not. Again this can be fresh fish, or fish that is frozen, dried, canned or smoked after being caught.

11a. Do you eat this fish **(KINGFISH)** that you or someone you know catches from SF Bay? (POINT TO PIX)

☐ Yes
☐ No (SKIP TO Q12)
☐ DK ☐ Refuse

What do you call it?

11b. Have you eaten any **(kingfish)** from the Bay in the last 4 weeks? (fresh, frozen, dried, canned, smoked)

☐ Yes No. times ☐☐ DK ☐
☐ No
☐ DK
☐ Refuse

11c. When you eat **(kingfish)**, how often do you eat the _____?

11c1. Skin

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

11c2. Guts

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

11d. When you eat **(kingfish)**, how often do you ___?

11d1. eat cooking juices/drippings

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

11d2. eat it in soup

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

11d3. eat it raw

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

12a. Do you eat this fish **(LEOPARD SHARK)** that you or someone you know catches from SF Bay? (POINT TO PIX)

☐ Yes
☐ No (SKIP TO Q13)
☐ DK ☐ Refuse

What do you call it?

12b. Have you eaten any **(leopard shark)** from the Bay in the last 4 weeks? (fresh, frozen, dried, canned, smoked)

☐ Yes No. times ☐☐ DK ☐
☐ No
☐ DK
☐ Refuse

12c. When you eat **(leopard shark)**, how often do you eat the _____

12c1. Skin

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

12c2. Guts

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

12d. When you eat **(leopard shark)**, how often do you ___?

12d1. eat cooking juices/drippings

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

12d2. eat it in soup

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

12d3. eat it raw

☐ more than half the time
☐ less than half the time
☐ never
☐ DK ☐ Refuse

13a. Do you eat this fish **(STRIPED BASS)** that you or someone you know catches from SF Bay? (POINT TO PIX)

- ☐ Yes
- ☐ No (SKIP TO Q14)
- ☐ DK ☐ Refuse

What do you call it?

13b. Have you eaten any **(striped bass)** from the Bay in the last 4 weeks? (fresh, frozen, dried, canned, smoked)

- ☐ Yes No. times ☐☐ DK ☐
- ☐ No
- ☐ DK
- ☐ Refuse

13c. When you eat **(striped bass)**, how often do you eat the_____?

13c1. Skin

- ☐ more than half the time
- ☐ less than half the time
- ☐ never
- ☐ DK ☐ Refuse

13c2. Guts

- ☐ more than half the time
- ☐ less than half the time
- ☐ never
- ☐ DK ☐ Refuse

13d. When you eat **(striped bass)**, how often do you ___?

13d1. eat cooking juices/drippings

- ☐ more than half the time
- ☐ less than half the time
- ☐ never
- ☐ DK ☐ Refuse

13d2. eat it in soup

- ☐ more than half the time
- ☐ less than half the time
- ☐ never
- ☐ DK ☐ Refuse

13d3. eat it raw

- ☐ more than half the time
- ☐ less than half the time
- ☐ never
- ☐ DK ☐ Refuse

Q14a Now I have some pictures of other fish that can be caught from SF Bay. Looking at these pictures, please show me which fish you have eaten in the last 4 weeks. Again, these are the fish you ate in the last 4 weeks which you caught or someone you know caught from SF Bay. The fish could have been fresh, frozen, dried, canned or smoked.

Q14b. How many times have you eaten this fish in the last 4 weeks? **(ASK AS RESPONDENT POINTS TO PICTURE, RECORD RESPONSE IN COLUMN 14B.)**

Q14c. What do you call this? **(ASK AS RESPONDENT POINTS TO PICTURE, RECORD RESPONSE IN COLUMN 14c.)**

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(SHOW PICTURES AND HAVE RESPONDENT POINT OR TELL YOU WITH PROBING AS NEEDED: "ANY OTHER FISH YOU HAVE EATEN IN THE LAST 4 WEEKS THAT YOU CAUGHT OR SOMEONE YOU KNOW CAUGHT FROM SF BAY?")

	Q14a. Eaten in last 4 weeks?	**Q14b.** No.of times		**Q14c.** What do you call this?
Jacksmelt	☐ Yes	☐☐	☐ DK	
Halibut	☐ Yes	☐☐	☐ DK	
Brown Smoothhound Shark	☐ Yes	☐☐	☐ DK	
Brown Rockfish	☐ Yes	☐☐	☐ DK	
Pacific Sanddab	☐ Yes	☐☐	☐ DK	
Pacific Sardine	☐ Yes	☐☐	☐ DK	
Black Perch	☐ Yes	☐☐	☐ DK	
Shiner Surfperch	☐ Yes	☐☐	☐ DK	
Walleye Surfperch	☐ Yes	☐☐	☐ DK	
Sturgeon	☐ Yes	☐☐	☐ DK	
Crab	☐ Yes	☐☐	☐ DK	
Clams	☐ Yes	☐☐	☐ DK	
Mussels	☐ Yes	☐☐	☐ DK	

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Q14d. Are there any other fish from the Bay that you or someone you know catches that you ate in the last 4 weeks for which I don't have pictures? **(IF RESPONDENT NAMES ONE OF THE FOLLOWING LISTED FISH, CHECK THE BOX AND INDICATE NUMBER OF TIMES EATEN. IF RESPONDENT NAMES A FISH THAT IS NOT LISTED, SPECIFY TYPE OF FISH AND NUMBER OF TIMES EATEN IN LAST 4 WEEKS IN THE BLANK BOXES BELOW.)**

Perch	☐ Yes	☐☐	☐ DK	Pacific Tomcod	☐ Yes ☐☐ ☐ DK
Anchovy	☐ Yes	☐☐	☐ DK	Goby	☐ Yes ☐☐ ☐ DK
Starry Flounder	☐ Yes	☐☐	☐ DK	Bat Ray	☐ Yes ☐☐ ☐ DK
Shark (OTHER THAN Brown Smoothhound or Leopard shark)	☐ Yes	☐☐	☐ DK		

	☐☐ ☐ DK		☐☐ ☐ DK
	☐☐ ☐ DK		☐☐ ☐ DK

Q15. Who in your household eats the fish that you or someone you know catches from the SF Bay? **(CHECK ALL THAT APPLY)**

☐ Yourself ☐ Women between ages 18-45 years ☐ Women who are currently pregnant or breastfeeding

☐ Children under age of 6 ☐ Children between 6 and 17 years ☐ People 65 or older ☐ DK ☐ Refuse

Q16. How many people altogether, including yourself, are in your household? ☐☐ ☐ DK ☐ Refuse

Q17. Who usually cooks or prepares the fish you catch and eat from the Bay? **(CHECK ALL RESPONDENT INDICATES)**

☐ Self ☐ Family member (specify)

☐ Friend ☐ Other (specify)

☐ DK

☐ Refuse

Now I want to ask you some questions about fish from OTHER places, rather than fish from the SF Bay. Again we ask you to think about fresh fish as well as fish that has been, frozen, dried, canned, or smoked after being caught.

Q18. In the last 4 weeks, did you eat fish that you caught or someone you know caught from places other than the SF Bay (like a lake or river)? **SHOW MAP AS NEEDED TO REMIND RESPONDENT ABOUT AREA COVERED BY SF BAY)**

☐ Yes ☐ No (SKIP TO Q21) ☐ DK ☐ Refuse

Q19. From what places, other than the San Francisco Bay, did you or someone you know catch fish that **you** ate in the **last 4 weeks**? (check all that Respondent indicates)

☐ Lake/Reservoir

☐ River ☐ DK ☐ Other (specify)

☐ Delta ☐ Refuse

☐ Ocean (outside SF Bay/other Bays)

Q20. In the last 4 weeks, how many times did you eat fish that you or someone you know caught from places other than SF Bay?

times per day ☐☐ times per week ☐☐ total times in last 4 weeks ☐☐☐

☐ DK

☐ Refuse

Q21. In the last 4 weeks, have you eaten any fish from a store or restaurant? This includes any fish fillet burgers or canned tuna also.

☐ Yes ☐ No (SKIP TO Q23) ☐ DK ☐ Refuse

Q22. How many times **in the last 4 weeks** did you eat fish from a store or restaurant, including any fish fillet burgers or canned tuna ?

times per day ☐☐ times per week ☐☐ total times in last 4 weeks ☐☐☐

☐ DK

☐ Refuse

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Now I am going to ask you a few questions about information you may have heard about eating fish from the Bay.

Q23. Have you heard or seen any information or health advisories about eating fish from the Bay?

☐ Yes ☐ No (SKIP TO Q25) ☐ DK ☐ Refuse

Q24. What did the information say about fish from the Bay? ☐ DK ☐ Refuse

Q24a. Has the information you have heard or seen about eating fish from the Bay caused you to change your fish eating habits?

☐ Yes ☐ No ☐ DK ☐ Refuse

Q24b. If yes, how have you changed your fish eating habits? If no, why not?

Q25. What is the best way for you to get information about catching and eating fish from the Bay? (CHECK ALL THAT RESPONDENT INDICATES)

☐ Friend/Family ☐ Sign ☐ Fishing regs ☐ Newspaper ☐ Radio ☐ TV ☐ Other (specify) ☐ DK ☐ Refuse

These next few questions will help us describe the people who fish from the SF Bay. We find this information helpful when we are developing information and materials for people who fish. Please remember the information is kept confidential and you don't have to answer if you don't want to.

Q26. How would you describe your racial or ethnic background?

- ☐ Black/African American
- ☐ Latino/Hispanic
- ☐ Caucasian
- ☐ Native American
- ☐ Chinese
- ☐ Filipino
- ☐ Vietnamese
- ☐ DK
- ☐ Refuse
- ☐ Pacific Islander (specify) _____
- ☐ Other Asian (specify) _____
- ☐ Other (specify) _____

Q27. What category best describes your age?

- ☐ Under 18
- ☐ 18-45
- ☐ 46-65
- ☐ 65+
- ☐ DK
- ☐ Refuse

Q28. What is the highest grade in school you have completed?

- ☐ Less than 12th grade
- ☐ Completed HS or GED
- ☐ Some college or trade school
- ☐ Completed at least 4 years college
- ☐ DK
- ☐ Refuse

Q29a. Is your total yearly household income greater than $20,000 per year?

- ☐ Yes (ASK Q29b)
- ☐ No (DO NOT ASK Q29b)
- ☐ DK
- ☐ Refuse

Q29b. greater than $45,000?

- ☐ Yes
- ☐ No
- ☐ DK
- ☐ Refuse

Q30. Gender of Respondent:

- ☐ Male
- ☐ Female

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That's about all the questions I have. In order to thank you for your participation, we would like to give you a small gift. (OFFER GIFT). We'd also like to enter your name into a monthly drawing. You will be eligible to win a $20 gift certificate to either Sportmart or Target. If you would like your name entered, we will take down your name, address, and phone number. We can also send you information about the results of this survey when they become available. My supervisor may also contact you to check my work or for some further follow-up.

Q31. Would you like to have your name entered into the drawing? ☐ Yes (FILL OUT NAME,ETC. BELOW) ☐ No

Q32. Would you like us to send you information about the results of our survey when they become available?

☐ Yes (FILL OUT NAME,ETC. BELOW) ☐ No

Q33. May my supervisor contact you ? ☐ Yes (FILL OUT NAME,ETC. BELOW) ☐ No

Name

Address

City State Zip

Phone - -

I'd also like to give you some information about the current advisory for the SF Bay **(OFFER COPY OF ADVISORY; READ TO RESPONDENT):** The current health advisory for fish caught from the San Francisco Bay recommends that adults limit their consumption of most types of fish caught from the San Francisco Bay to no more than 2 eight ounce meals/month (one pound total per month). Women who are pregnant, planning to become pregnant, or breastfeeding, and children under 6 years of age should not eat more than one meal per month. There is more detailed information in the handout. If you'd like more information about the advisory or about the survey, you can contact the agencies listed here.

Thanks again. You've really helped us out a lot!

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Time completed interview:

Interviewer'sinitials ☐☐

Interviewer's impression of quality of consumption info: ☐ Reliable ☐ Not very reliable

Other observations or notes:

Language in which interview was conducted:

- ☐ English
- ☐ Spanish
- ☐ Vietnamese
- ☐ Cantonese
- ☐ Mandarin
- ☐ Other (specify)

If Respondent refused to answer **Q26**, note observed ethnicity of Respondent:

- ☐ Black/African American
- ☐ Caucasian
- ☐ Chinese
- ☐ Vietnamese
- ☐ Pacific Islander (specify)
- ☐ Other Asian (specify)
- ☐ Latino/Hispanic
- ☐ Native American
- ☐ Filipino
- ☐ DK
- ☐ Other (specify)

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Fecha / / Codigo de Lugar Modo Hora de Inicio Encuestador
Persona esta: Pescando (cana de pesca unicamente) Pescando y sacando cangrejos

---

Hola, me llamo_____. Estoy haciendo una encuesta para el Instituto Estuario de San Francisco. **(MOSTRAR IDENTIFICACION)** Estamos recabando informacion sobre los tipos de peces y mariscos que la gente pesca y come en la Bahia de San Francosco. No estoy revisando las licencias de pesca ni lo que pesca. Sus respuestas se mantendran en secreto (confidencialidad) y ademas Ud. no tiene que contestar todas las preguntas si asi lo desea. Estamose dando (incentivo) a los paricipantes. Me permite entonces hablar uno minutos con Ud?

Q1a Si (AVANCE A Q2a) No (FIN DE ENCUESTA, LLENE Q1b-Q1e)

Q1b. Razon	**Q1c. Etnicidad Observada**	**Q1d. Idioma**	**Q1e. Genero**
Falta de Tiempo	Caucaseo	Ingles	Masculino
Problema con el Idioma	Afro-americano	Espanol	Femenino
Apariecia amenazante	Latino/Hispano	Cantones	
Otro	Chino	Mandarin	
	Filipino	Tagalo	
	Vietnamita	Vietnamita	
	Nativo-americano	Otro	
NS	Asiatico (desconoce)	NS	
	Otro		
	NS		

Q2a. Nuestro proyecto se llama Estudio de Consumo de Pescados y Mariscos do la Bahia de San Francisco. Ha sido entrevistado anteriomento para este estudio? (ha hablado con alguien usando este chaleco/gorra?

SI Q2b. Cuando (m/a): / N/S (ALTO, FIN DE LA ENCUESTA)
No (CONTINUE)
NS (CONTINUE)
Rehusa

Cuando hablo de la Bahia de San Francisco, me refiero a esta area (MUESTRE EL MAPA). Me refiero principalmente a los peces y mariscos de la Bahia. Cuando digo mariscos, me refiero al cangrejo (jaiva), mejillones o almejas.

Q3a. Es esta la primera vez que pesca en la Bahia de San Francisco?

Si (AVANCE A Q5) ns Rehusa
No

Q4. Sin incluir hoy dia, en las ultimas 4 semanas, en total, cuantas veces ha pescado en la Bahia de San Francisco?
NS Rehusa

Q5. Usualmente que hace (planea hacer-PESCADORES PRIMERIZOS) con el pescado o marisco que pesca en la Bahia de San Francisco? (marque todos los que correspondan)

Lo como Lo doy a familia/amigos Lo intercamio/vendo Uso como carnada NS Rehuso
Otro (especifique)

Las siguientes preguntas se referiran a pescado que Ud o alguien que UD conoce ha pescado en la Bahia de San Francisco. Puede tratarse de pescado fresco, o congelado, secado, enlatado, o ahumado para comerlo posteriormente.

Q6. Come pescado que Ud o alguien que Ud conoce pesca en la Bahia de San Francisco?
Si NS Rehusa
Antes si, pero ya no

Q6b. Detuve cuando: m/a / NS
No (AVANCE A Q10)

Q7. Cuantos anos lleva comiendo pescado que Ud o alguien que conoce haya pescado en la Bahia de San Francisco?

Menos de 1 ano	6-10 anos	21-30 anos	NS
1-5 anos	11-20 anos	mas de 30 anos	Rehusa

Q8. En las ultimas 4 semanas, ha comido pescado que Ud o alguien que conoce haya pescado en la Bahia de San Francisco?
Si NS No Rehusa

Q8b. En las ultimas 4 semanas, cuantas veces ha comido pescado que Ud o alguien que Ud conoce haya pescado de la Bahia?

Veces por dia veces por semana total de veces en las ultimas 4 semanas

Otro

NS

Rehusa

Q9. En los ultimos 12 meses (__/97-8 a __/98-9) cuantas veces en total ha comido pescado que Ud o alguien que Ud conoce haya pescado en la Bahia de San Francisco?

veces por dia veces por semana veces por mes veces en ultimos 12 meses

Otro

NS

Rehusa

Q10. Este es un modelo de 8 onzas (media libra) de un filete de pescado crudo. Cuando Ud come pescado de cualquier lugar (la Bahia otros lugares, tiendas, restaurantes), es la cantidad que Ud come:
(MUESTRE LA PORCION DE PESCADO PERO NO DEJE QUE LA PERSONA LO AGARRE)

De este tamano(AVANCE A Q11) NS Rehusa

Mas Q10b. Cuanto mas? Mitad mas Doble NS Rehusa Otro

Menos Q10c. Cuanto menos? La mitad de esta cantidad Un tercio NS Rehusa Otro

Ahora voy a mostrarle fotos de 3 clases de peces que se pueden pescar en la Bahia de San Francisco y quisiera saber si Ud los come o no. Recuerde que puede ser fresco o congelado, seco, enlatado o ahumado, despues de haber sido pescado.

11a. Ha comido este pescado (PEZ REY) que Ud o alguien que UD conoce lo haya pescado en la Bahia de San Francisco? (SENALE)

Si
No (AVANCE A Q12)
NS Rehusa

Como lo llama?

11b. Ha comido Pez Rey de la Bahia en las ultimas 4 semanas? (fresco, congelado, seco, enlatado, ahumado)

Si No. de veces NS
No
NS
Rehusa

11d. Cuando come Pez Rey que tan seguido come…

11d.1. jugos cocidos o destilados

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

11c. Cuando come el Pez Rey, que tan seguido come…

11c.1. El pellejo

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

11d.2. lo come en sopa/caldo

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

11c.2 Visceras (organos)

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

11d.3. lo come crudo o en ceviche?

mas de mitad de tiempo
menos de mitad de tiempo
nunca
NS Rehusa

12a. Ha comido este pescado (TIBURON LEOPARDO) que Ud o alguien que UD conoce lo haya pescado en la Bahia de San Francisco? (SENALE)

Si
No (AVANCE A Q13)
NS Rehusa

Como lo llama?

12b. Ha comido Tiburon Leopardo en las ultimas 4 semanas? (fresco, congelado, seco, enlatado ahumado)

Si No. de veces NS
No
NS
Rehusa

12d. Cuando come Tiburon Leopardo, que tan seguid come…

12d.1 jugos cocidos o destilados?

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

12c. Cuando come Tiburon Leopardo, que tan seguido come…

12c.1 El pellejo

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

12d.2 lo come en sopa/caldo

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

12c.2. Visceras (organos)

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

12d.3 lo come crudo o en ceviche?

mas de mitad de tiempo
menos de mitad de tiempo
nunca
NS Rehusa

13a. Ha comido este pescado (Robalo) que Ud o alguien que UD conoce lo haya pescado en la Bahia de San Francisco?

Si
No (AVANCE A Q14
NS Rehusa

13b. Ha comido Robalo de la Bahia en las ultimas 4 semanas? (fresco, congelado, seco, enlatado, ahumado)

Si No. de veces NS
No
NS
Rehusa

Como lo llama?

13c. Cuando come Robalo, que tan seguido come…

13c.1. El pellejo

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

13c.2. Visceras (organos)

mas de mitad de veces
menos mitad de veces
nunca
NS Rehusa

13d. Cuando come Robalo, qu tan seguido come

13d.1 jugos cocidos/destilados

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

13d.2 en sopa o en caldo

mas de mitad de tiempo
menos mitad de tiempo
nunca
NS Rehusa

13d.3 lo come crudo o en ceviche?

mas de mitad de tiempo
menos de mitad de tiempo
nunca
NS Rehusa

Q14a. Ahora le motrare fotos de otros peces que se pueden pescar en la Bahia de San Francisco. Por favor, muestreme aquellos que Ud. haya comido en las ultimas 4 semanas. Puede ser pescado que UD o alguien que Ud conoce haya pescado en la Bahia de San Francisco, que pudo haber sido congelado, secado, enlatado o ahumado.

Q14b. Cuantas veces ha comido este pescado en las ultimas 4 semanas?
(PREGUNTE MIENTRAS EL ENCUESTADO SENALA LA FOTO Y REGISTRE LA RESPUESTA EN LA COLUMNA 14c)

MUESTR LAS FOTOS Y DEJE QUE EL ENCUESTADO SENALE, LE DIGA O INDAGUE SI FUESE NECESARIO: “ALGUN OTRO PESCADO QUE UD HAY COMIDO EN LAS ULTIMAS 4 SEMANAS QUE UD O ALGUIEN QUE UD CONOCE HAYA PESCADO EN LA BAHIA DE SAN FRANCISCO?”

	Q14a. Ha comido en las ultimas 4 semanas?		Q14b. No. Veces	Q14c. Como le llama?
Perca Negra	Si	No	NS	
Pez Rocoso Marron	Si	No	NS	
Mero	Si	No	NS	
Esperleno	Si	No	NS	
Pez Arenero	Si	No	NS	
Sardina	Si	No	NS	
Perca Brillante	Si	No	NS	
Esturion	Si	No	NS	
Perca “Walleye”	Si	No	NS	
Cangrejo	Si	No	NS	
Almejas	Si	No	NS	
Mejillones	Si	No	NS	

Q14d. Algun otro pescado que Ud o alguien que Ud conoce lo haya pescado en la Bahia y que lo haya comido en las ultimas 4 semana pero que no estaba entre las fotos que le he mostrado (SI EL ENCUESTADO HA COMIDO LOS PECES DE LA LISTA SIGUIENTE, MARQUELO E INDIQUE EL NUMERO DE VECES QUE LOS HAYA COMIDO; SI EL ENCUESTADO MENCIONA ALGUN PEZ QUE NO ESTA EN LA LISTA, ESPECIFIQUELO EN EL ESPACIO DEL MEDIO, ASI COMO EL NUMERO DE VECES QUE LO HAYA COMIDO EN LAS ULTIMAS 4 SEMANAS)

Perca	Si	NS	Bacalao	Si	NS
Anchoveta Nortena	Si	NS	Gobio	Si	NS
Platija	Si	NS	Bataraya	Si	NS
Tiburon Café de Caza	Si	NS	Tiburon de Siete Agallas	Si	NS

Q15. En su casa, quien come el pescado que UD o alguien que UD conoce pesca de la Bahia de San Francisco?
(MARQUE TODOS LOS QUE CORRESPONDAN)
Ud. mismo Mujeres de 18-45 anos Mujeres embarazadas o lactando
Ninos menores de 6 anos Ninos entre 6-17 anos Personas de 65 anos o mas
NS Rehusa

Q16. En total, cuanta gente vive en su csa, incluyendolo a Ud? NS Rehusa

Q17. Usualmente, quien prepara o cocina el pescado que pesca y come de la Bahia?
(MARQUE TODAS LAS RESPUESTAS)
Yo mismo Pariente (especifique)_____
Amigo(a) Otro (especifique)_____
NS Rehusa

Ahora le voy a preguntar sobre peces de otros lugares, que no sean de la Bahia de San Francisco. Como le dije antes, puede ser pescado fresco, congelado seco, enlatado o ahumado.

Q18. En las ultimas 4 semanas, ha comido pescado que Ud o alguien que UD conoce haya pescado en otros lugares fruera de la Bahia de San Francisco (como de un lago or rio)?
DE SER NECESARIO, MUESTRE EL MAPA PARA RECORDAR EL AREA DE LA BAHIA DE SAN FRANCISCO.
Si No(AVANCE A Q21) NS Rehusa

Q19. En las ultimas 4 semanas, en que lugares fuera de la Bahia de San Francisco ha comido lo que ha pescado?
(MARQUE TODAS LAS CORRESPONDIENTES)
Lago/reservorio
Rio NS Otro (especifique)
Delta Rehusa
Oceano (fuera de SF/Otras Bahias)

Q20. En las ultimas 4 semanas, cuantas veces ha comido pescado que ha pescado en lugares fuera de la Bahia de San Francisco?
Veces por dia veces por semana total de veces en ultimas 4 semanas
Otro
NS
Rehusa

Q21. En las ultimas 4 semanas, ha comido pescado de una tienda o restaurante? Incluyendo hamburguesas de filete de pescado o atun.
Si No (AVANCE A Q23) NS Rehusa

Q22. En las ultimas 4 semanas, cuantas veces ha comido pescado de una tienda o restaurante?
Veces por dia veces por semana total de veces en ultimas 4 semanas
Otro
NS
Rehusa

Ahora le voy a preguntar sobre alguna informacion que Ud haya escuchado acerca del consumo del consumno de pescado de la Bahia.

Q23. Ha escuchado o visto alguna informacion or recomendaciones de salud sobre el consumo de pescado de la Bahia?
Si No(AVANCE A Q25) NS Rehusa

Q24. Que decia la informacion sobre el pescdo de la Bahia? NS Rehusa

Q24a. La informacion que Ud. ha escuchado o visto sobre el consumo de pescado de la Bahia, ha hecho que Ud. cambie sus habitc de consumo de pescado?
Si No NS Rehusa

Q24b. Si contesto que si, como ha cambiado sus habitos de consumo de pescado? Si es no, porque no?

Q25. Segun Ud. cual es la mejor manera de obtener informacion sobre la pesca y consumo en la Bahia?
(MARQUE TODOS LOS QUE CORRESPONDAN)

Amistades/Familiar Letrero Regulaciones de pesca Periodico Radio TV
NS Rehusa
Otro (especifique)

La proximas preguntas nos ayudaran a describir a las persona que pescan o sacan mariscos de la Bahia de San Francisco. Esta informacion es muy util para desarrollar materiales de informacion para estas personas. Por favor, recuerde que esta informacion es confidencial y si Ud desea no tiene que contestar.

Q26. Como describiria su ascendencia racial o etnica?

Afro-americano	Latino/Hispano	
Caucaseo	Nativo-americano	
Chino	Filipino	
Vietnamita	NS	Rehusa

Otro, Asia SE (especifique)

Isleno del Pacifico (especifique)

Otro, Asia (especifique)

Otro, (especifique)

Q27. Cual categoria describe mejor su edad?

Menor de 18	18-45
46-65	65+
NS	Rehusa

Q29a. Es su ingreso anual mayor de $20,000

Si (Pregunte Q29b)

No (No Pregunte Q29b)

Rehusa

Q29b. Mayor de $45,000?

Si

No

Rehusa

NS

Q30. Genero

Masculino

Femenino

Bueno, esto es todo. Para agradecerle por su participacion, me gustaria darle (incentivo). Tambien nos gustaria inscribirle en un sorteo mensual. Ud. podria ganar un cupon de $20 de las tiendas Target o Sportmart. Si esta de acuerdo, necesitare anotar su nombre, direccion y numero de telefono. Tambien le enviaremos informacion sobre los resultados de esta encuesta, tan pronto esten disponibles Ademas, quizas mi Supervisor le contacte para revisar el trabajo que estoy haciendo.

Q31. Le gustaria inscribirse en el sorteo mensual? Si (LLENE DATOS ABAJO) No

Q32. Le gustaria que le enviasemos informacion sobre los resultados de la encuesta?
Si (LLENE DATOS ABAJO) No

Q33.Puede mi Supervisor contactarle? Si (LLENE DATOS ABAJO) No

Nombre

Direccion

Ciudad Estado Codigo

Telefono

Me gustaria darle alguna informacion sobre las actuales recomendaciones de la Bahia de San Francisco. (OFREZCA UNA COPIA DE LAS RECOMENDACIONES; LEASELA): Las recomendaciones de salud para la pesca en la Bahia de San Francisco, indica que los adultos deben limitar el consumo de la mayoria de pescados de la Bahia, a no mas de dos comidas de 8 onzas por mes (en total, una libra por mes), Las mujeres embarazadas, que planean quedar embarazadas o que esten lactando, asi como los ninos menores de 6 anos, no deben comer mas de una comida por mes. En los folletos encontrara mas informacion. Si desea mas informacion sobre las recomendaciones o sobre los resultados, puede llamar a las agencia que estan en el folleto.

Muchisimas gracias. Realmente su ayuda ha sido muy valiosa!

Hora de Termino de Entrevista:

Iniciales de Entrevistador:

Otras observaciones:

Impresion del entrevistador sobre la calidad de informacion registrada

- Muy confiable
- Confiable
- No muy confiable
- Desconfiable

Idioma en que se condujo la entrevisa:

Ingles

Espanol

Vietnamita

Contones

Mandarin

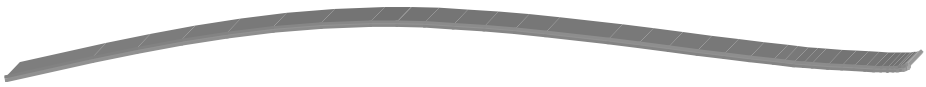
Si el encuestante rehusa la pregunta Q26 anote la etnicidad observada:

Negro/Afro-americano	Latino/Hispano
Caucaseo	Nativo-americano
Chino	Filipino
Vietnamita	Otro
Otro, Asiatico SE (especifique)	NS
Isleno del Pacifico (especifique)	
Otro, Asiatico (especifique)	

Appendix F

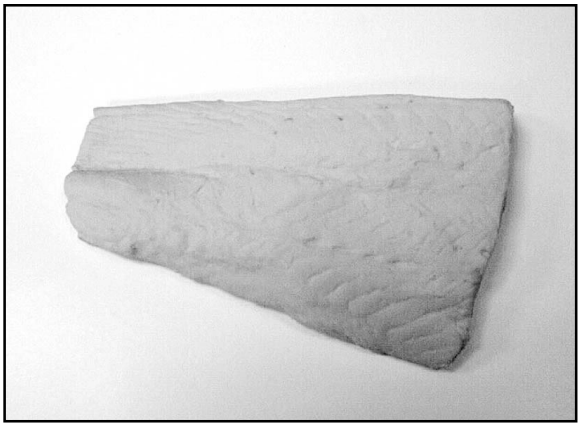
Survey Tools

San Francisco Bay Seafood Consumption Study



Some of the Survey Tools Used by Field Interviewers

Key Chain with Tape Measure, Hat, and Vest with Survey Logo



Plastic Model of an 8-ounce Portion of Raw Fish Fillet

Binder with Map of SF Bay and Color Photographs of 13 species of Fish, 3 Species of Shellfish

Appendix F. Survey Tools

Table F1 . SF Bay Fish Species for Which Pictures Were Available

Fish Name Shown on Pictures (Common name, if available)	Scientific Names
White Croaker (King fish)	Genyonemus lineatus
Leopard Shark	Triakis semifasiata
Striped Bass (Striper)	Morone saxatilis
Jacksmelt (Smelt)	Atherinopsis californiensis
California Halibut	Paralichthys californicus
Brown Smoothhound Shark	Mustelus henlei
Brown Rockfish	Sebastes auriculatus
Pacific Sanddab	Citharichthys sordidus
Pacific Sardine	Sardinops sagax
Black Perch	Embiotoca jacksoni
Shiner Surfperch (Shiner Perch)	Cymatogaster aggregata
Walleye Surfperch	Hyperprosopon argenteum
White Sturgeon	Acipenser transmontanus

Table F2. SF Bay Shellfish for Which Pictures Were Available

Shellfish Names Shown on Pictures	Most Common Bay Species	Scientific Names
Crab	Red Rock Crab	Cancer productus
Clams	Japanese Littleneck Clam	Tapes japonica
Mussels	Bay Mussel	Mytilus edulis

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9/9/98

Census of Shore Sites

Date	Site Name	Site Code	Mode Code	No. of Persons <18 years	No. of Persons 18 years & older	Interviewer

Shore Site Codes

1A. Vallejo Shoeline
1B. Martinez Shoreline Park
2A. Point Pinole Shoreline Park
2B. Berkeley Pier
3A. Port View Park
3B. Alameda Rockwall
4A. Dumbarton Bridge Pier
4B. Coyote Point
5A. Oyster Point
5B. Candlestick Pt. Rec Area
6A. SF Municipal Pier
6B. Fort Point
7A. Fort Baker Pier
7B. McNears Park/China Camp

Boat Site Codes

11. Vallejo Marina
12. Richmond Marina
13. San Leandro Marina
14. Oyster Point Marina
15. Loch Lomond Marina

Mode Codes for Shore Sites

1. "Free" piers. These areas, primarily municipal piers, where a fishing license is NOT required to fish. Free piers include areas that are not technically piers: the Vallejo Waterfront, Alameda Rockwall, and the jetty at Coyote Point. These areas are highlighted in red on the site maps.

2. All other shore based areas that are not free piers. These areas are primarily rip-rap banks. These areas may include man-made structures such as the small pier adjacent to the Vallejo Launch Ramp and the rock jetty at Fort Baker. These areas are highlighted in green on the site maps.

9/9/98

Summary of Shore and Boat Sites

Date	Site Code	Site Start Time	Site End Time	No. of Interview Attempts	Interviewer

Shore Site Codes

1A. Vallejo Shoeline
1B. Martinez Shoreline Park
2A. Point Pinole Shoreline Park
2B. Berkeley Pier
3A. Port View Park
3B. Alameda Rockwall
4A. Dumbarton Bridge Pier
4B. Coyote Point
5A. Oyster Point
5B. Candlestick Pt. Rec Area
6A. SF Municipal Pier
6B. Fort Point
7A. Fort Baker Pier
7B. McNears Park/China Camp

Boat Site Codes

11. Vallejo Marina
12. Richmond Marina
13. San Leandro Marina
14. Oyster Point Marina
15. Loch Lomond Marina

Party Boat Survey Form

San Francisco Bay Seafood Consumption Study

8/6/98

Interviewer_____ Date_____

Port_____ Boat Name_____

Fishing Trip Start Time_____ End Time_____

Target Species 1*_____

Target Species 2_____

Target Species 3_____

Target Species 4_____

Target Species 5_____

Target Species 6_____

*in SF Bay (exclude species targeted in areas outside SF Bay)

Area Fished Outside SF Bay_____

Fishing Activity Outside SF Bay _____

Number of Interview Attempts _____

NOTES (describe your attempt to board a boat even if the boat was full and no interviews were completed):

Site Codes

21. Point San Pablo (Contra Costa Co.)
22. Emeryville
23. Fisherman's Wharf, San Francisco
24. Loch Lomond, San Rafael

25. _____ 26._____

27. _____ 28._____

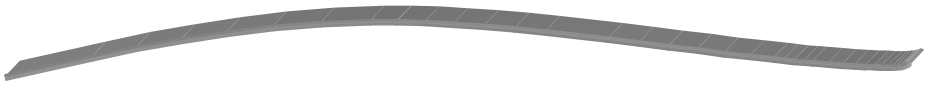
Mode Code

Party boat interviews should be assigned mode 9.

Appendix G

Field Interviewer Training Manual

San Francisco Bay Seafood Consumption Study



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1. INTRODUCTION

Welcome to the San Francisco Bay Seafood Consumption Study! This manual contains some tips and pointers to help make your job easier, and to ensure that the data you will collect are of the highest quality possible. This manual contains materials for the following topics:

- an overview of the study and its goals and objectives
- the importance of accurate data collection
- your desired state of mind for conducting good interviews
- approach and greeting guidelines, methods of dealing with refusals
- data collection tools and props
- angler census methods, and detailed coding instructions for each question
- weekly debrief and administrative duties
- health and safety issues
- travel to and access to sites

1.1. Study Overview, Goals and Objectives

Levels of certain chemical contaminants in fish commonly caught from the San Francisco Bay have raised public concern regarding health risks related to consuming fish and shellfish from the Bay. In response to this concern, the San Francisco Estuary Institute has contracted with the Environmental Health Investigations Branch of the California Department of Health Services and Impact Assessment, Inc. to conduct a comprehensive seafood consumption study of people who catch and consume fish and shellfish from the Bay. Information gathered through the study will be used to develop recommendations and methods for improving outreach and education efforts to different segments of the fishing population and to refine assessments of health risks to people who consume fish caught from the San Francisco Bay.

The goals of the study are as follows:

- To gather quantitative data that can be used to characterize exposures of the general fishing population of San Francisco Bay to chemical contaminants from consumption of Bay-caught fish and shellfish.

- To identify highly exposed fish and shellfish consuming sub-populations

- To gather information needed to develop educational messages for targeted sub-populations

Specific objectives of the study include the following:

1. Develop estimates of exposure assessment parameters (fish and shellfish consumption frequency, duration of exposure, and portion size) for San Francisco fishers. Characterize distributions for these parameters.

2. Characterize pier, boat, and shoreline fishing populations by age, sex, income, ethnic composition, education, mode of fishing, and consumption rates.

3. Characterize consumption of fish tissues other than muscle, such as skin and organs, and preparation/cooking methods.

4. Determine which species are consumed most commonly. Assess the frequency of consumption of white croaker, striped bass, and leopard shark.

5. Characterize what people do with the fish and shellfish they catch or harvest (i.e., release it, eat it themselves, share it with family or friends).

6. Characterize seasonal variation in consumption and demographics.

7. Characterize the frequency of consumption of fish and shellfish obtained from stores and markets, and of fish and shellfish obtained from fishing outside the SF Bay, including freshwater and marine locations.

8. Assess awareness of current health advisories and changes in behavior as a result of awareness (e.g., decreased consumption).

9. Identify how people are informed about advisories and preferred mechanisms for getting information.

10. Identify fishers' reasons for catching and consuming fish and shellfish.

11. Determine whether fishers think the term "sportfish" refers to fish they catch from SF Bay.

1.2. Importance of accurate data collection

As stated above, a crucial task for this study is to estimate consumption of seafood for various subgroups that compose the study population, and the population as a whole. Having the ability to do this relies heavily on an assumption that people have accurately and truthfully reported their seafood consumption. Your role in this task is to facilitate accurate and complete responses, to the extent possible. There is a subtle difference between helping study participants enhance their recall, as opposed to the interviewers providing the answers for them. We DO NOT want the latter situation to develop. You will have to monitor each person who participates in the survey and determine if he or she understands each question asked. You may rephrase the question if a participant is having difficulty giving a response, but DO NOT try to answer the question for them. If it appears that the respondent can't answer the question, give her or him a few minutes to ponder it. In this situation, it is much better to record a 'don't know' response, instead of having the participants guess at their true response.

There will most likely be tremendous variation as to how study participants respond to the survey. Some study participants will have questions about the study, others will not. Participants will vary in how long it takes them to complete the survey, how much they mull over a particular question, how often they change their minds, how many questions they ask you the interviewer, and how often they will digress or otherwise get "off track." The bottom line is

some interviews will be easy to administer, others will not. As a result, some days the surveys you administer will be done easily and you will have a very high completion rate. Other days, things may go very slow. This is to be expected! Do not try to rush things. If you are uncertain of participants' response, don't be reluctant to ask them the same question twice. You will be asking people to recall behaviors that may have occurred a year ago. Do you remember what you had for dinner two weeks ago? Put yourself in the position of the study participant for a few minutes, and you will gain some appreciation of the mental effort they may need to go through in order to accurately answer the questions. Be patient when administering interviews, and remember it is much more important to conduct a few high quality interviews each day, instead of conducting many interviews in a sloppy, incomplete manner. Having high quality data is crucial to the success of this study.

1.3. Adopting the right frame of mind

Your frame of mind will have a great influence on the quality of the data collected. Ideally, you should be in a good mood when you arrive on-site to begin your assignment. If you are not, you should take a few minutes to clear your head of whatever negative things may be occupying your thoughts. This may sound silly, but having the right frame of mind really does influence your ability to conduct a good interview. You should be thinking about what a great study this is, a great day to be outdoors, and what a great opportunity this is for the study participants to provide you information about seafood consumption behaviors that could impact their health. You need to believe in the value of this study, and the potential public benefits associated with it. Finally, you need to believe that you are doing the potential study participants a favor. This, too, may sound funny, but I'm being serious. You are asking potential participants for their invaluable opinions, you are offering an incentive, and if they agree to give their name and address, you will be offering them a chance to win something big. This is a good deal for study participants!

When first approached, anglers may not want to talk to you. They may try to avoid eye contact with you or in some other nonverbal way, ignore you. Don't be deterred! The best way to deal with this is to start the conversation off with an 'icebreaker', such as "How is the fishing today?" It is important to be patient at this point, and simply initiate a conversation. If you get a cold response to the initial question, try asking another non-threatening type question. However, if you are still having problems establishing a connection at this point, you still need to begin the interview protocol.

Dealing with refusals

The respondent may initially refuse to participate but may change his or her mind, as you read through the introduction. Sometimes if you can overcome a potential participant's objections by answering Frequently Asked Questions (study and know your FAQ and their answers! see Section 9) you may get his or her cooperation. However, in the event that you don't, record the nature of the refusal and the other observational type variables (i.e., gender, ethnic group) and move on to the next participant. Don't be discouraged by refusals! It is just part of the screening process that some people will not participate regardless of what you tell them, and regardless of how good you are at establishing rapport. Another possibility is that participants will discontinue the interview before you have completed asking all the questions. This will occur with some participants. In this situation, do not try forcing the respondent to continue. But after the interview has ended, make a note that the respondent did not complete all the questions.

Dealing with belligerent anglers

Some people that you approach won't want to talk to you. That's okay. However, some people won't want to talk to you and they will want to make sure that you know this. They may become hostile. Please bear in mind this is an extremely small minority of the people you will encounter. Everyone has a different tolerance point regarding verbal abuse, and you do not need to tolerate abuse from a potential study participant. During my first job as a field interviewer, I discontinued an interview because I felt the respondent was paranoid and abusive. I interviewed about 300 people for that particular project, and the above mentioned person was the only belligerent one I encountered.

Language barriers

It is likely that most of your interviews will be conducted in English. But an important component of this study is to conduct surveys in: Spanish, Cantonese, Mandarin, and Vietnamese, as needed. Ideally, your interview team will have capability in two languages in order to minimize language barriers for most respondents you will encounter. If you are able to switch to the potential participant's language, this may help put him or her at ease, and increase interview participation rates. If you encounter someone who is speaking a foreign language that you don't speak but your partner does, you should make a note of this, and let your partner know. Some people will pretend they don't speak English in order to avoid participating in the study. If the potential participant does not appear hostile, try asking him or her 2-3 questions in English to see if you can "get the ball rolling."

Frequently Asked Questions

Some individuals will ask questions of you during the interview. Having an answer for them is important. The types of questions you may be asked probably will pertain to:
1) credibility and qualifications of the organization sponsoring this study, 2) who is paying for the study, 3) the ecological health of the SF Bay, and 4) the personal health risks to the study participant from eating SF Bay caught fish.

To enable you to deal with questions in a brief and consistent manner, we have prepared a list of the most Frequently Asked Questions and their answers. We will amend this list after pretesting the survey.

Dealing with Multiple Participants

Sometimes two respondents will try and give you answers to the same survey. To conduct statistical analyses of these survey data, every respondent must complete their own survey independent of the opinions and behaviors of other members of their fishing party. In other words, we want one completed interview for each respondent. If two people try answering the questionnaire at the same time, tactfully tell them that you can only interview one of them at a time. If they don't get the idea that we only want one person to complete an interview at a time, just continue and complete the interview with them and record separate answers for each individual in the margins. At the end of the sampling session, fill out two separate surveys, one for each person.

2. DATA COLLECTION INSTRUMENTS AND OTHER IMPORTANT ITEMS

There are a number of items you will need with you for each interviewing day. The basic items that you will have with you for each interview day include:

- Interviewer identification, including a name badge, and vest and hat with a study logo
- Logo for car
- Clipboard
- Sharpie pens
- Census forms
- Survey forms
- Binder with SF Bay map, fish and shellfish pictures, and staff phone list
- Health advisories (in six languages)
- Referral info sheet
- Answers to frequently asked questions
- Fish fillet model
- Site Map book
- Gifts (tape measures with logo)
- Cellular phone (One per interviewer team)
- Watch or other timepiece

For your personal comfort and convenience:

- Dress in layers and be prepared for windy, cool weather
- Sunscreen
- Food and beverages for yourself
- Backpack or other carryall to hold your items
- Sunglasses

Please be careful with the survey forms! They need to be maintained in good shape to allow for optimal scanning.

3. DATA RECORDING

All data recording should be done with your Sharpie pens. This will allow for optimal scanning of all data collection forms.

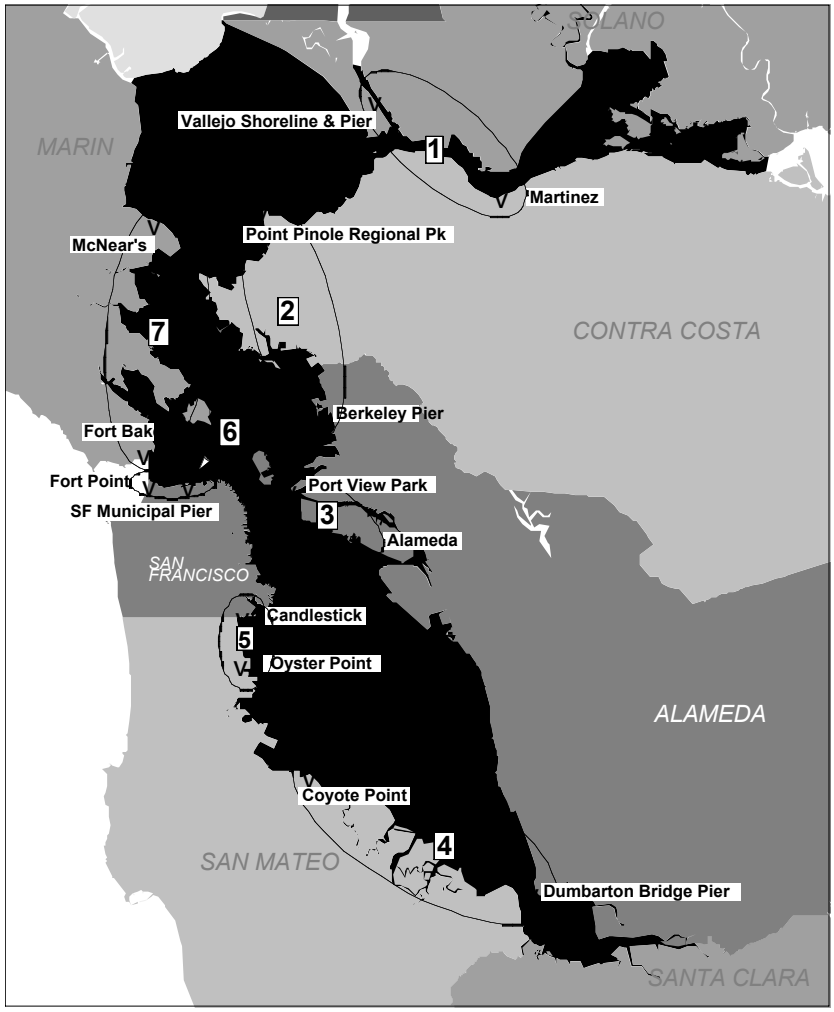
3.1 Shore Sites

3.1.1 Recording Site and Mode

The 14 shore sites are grouped into 7 pairs. Each site has been assigned a site code. The site codes, the site name and the county of the site are listed below. A map showing the sites can be found in Diagram 1. Detailed maps of the sites, including directions to the sites can be found in the Site Map Book.

Shore Sites

Site Code	Site Name	County
1A	Vallejo Shoreline	Solano
1B	Martinez Regional Shoreline Park	Contra Costa
2A	Point Pinole Regional Shoreline Park	Contra Costa
2B	Berkeley Pier	Alameda
3A	Port View Park	Alameda
3B	Alameda Rockwall	Alameda
4A	Dumbarton Bridge Pier	Alameda
4B	Coyote Point	San Mateo
5A	Oyster Point	San Mateo
5B	Candlestick Point State Recreation Area	San Francisco
6A	San Francisco Municipal Pier	San Francisco
6B	Fort Point	San Francisco
7A	Fort Baker Pier	Marin
7B	McNears County Park/China Camp	Marin



San Francisco Bay Seafood Consumption Study
Shore Sites

Map: DHS/EHIB

All the shore sites (except 4A. Dumbarton Bridge Pier) can be further divided into 2 or more areas. These areas are classified into fishing modes. The modes for the shore sites are:

Shore Site Modes

Mode Code	Description
1	"Free" piers. These are areas, primarily municipal piers, where a fishing license is NOT require to fish. Free piers include areas that are not technically piers: the Vallejo Waterfront, Alameda Rockwall, and the jetty at Coyote Point.
2	All other shore based areas that are not free piers. These areas are primarily rip-rap banks. These areas may include man-made structures such as the small pier adjacent to the Vallejo Launch Ramp and the rock jetty at Fort Baker.

3.1.2. Conducting the Census

Upon arrival at all shore sites, a census, or count of all anglers present, will need to be conducted. The purpose of the census is to estimate the number of persons fishing at a site at a single point in time. Because interviewing at a site may be conducted over one or more hours (depending on the number present), the number of anglers recorded from the census is likely to differ from the number of interviews completed at the site. Only one person should conduct the census. The other interviewer may begin interviewing.

As indicated on the census form (see next page) record the site code, mode code, date, start time and your initials. We recommend that you break the site up by mode and only census the part of the site you are planning to conduct interviews at next. In other words, census and interview at the pier first then census and interview at the shoreline/bank areas second (see example). The census is taken by walking the site and counting all persons who are fishing, i.e., have poles. It may be easiest to focus on one side of a pier first and then count the other side on the return trip. Only count those anglers who are "in front of you." This means that if you have already initiated the count and a new anglers arrives but you have already passed the point where he or she is standing, do not include him or her in the census.

You will also need to determine the number of anglers who are adults (18 years of age or older) and the number of anglers who are 17 years and younger. At times, it may be difficult to determine who is actually fishing and who is not, and who is an adult. Some anglers may not be stationed near their poles. Use your best judgement to determine who is fishing and the anglers' ages without actually stopping to talk with the anglers. Remember the census is only an estimate and should take no longer than the time to walk the site.

Also included on the Census Form is a Site Summary Chart. For each site you and your partner visit on an assigned shift, note the time you and your partner started your shift at the site, the time you left the site, and the total number of interviews attempted at the site. This number should equal the number of interview forms filled out by both you and your partner.

9/9/98

Census of Shore Sites

Date	Site Name	Site Code	Mode Code	No. of Persons <18 years	No. of Persons 18 years & older	Interviewer

Shore Site Codes

1A. Vallejo Shoeline
1B. Martinez Shoreline Park
2A. Point Pinole Shoreline Park
2B. Berkeley Pier
3A. Port View Park
3B. Alameda Rockwall
4A. Dumbarton Bridge Pier
4B. Coyote Point
5A. Oyster Point
5B. Candlestick Pt. Rec Area
6A. SF Municipal Pier
6B. Fort Point
7A. Fort Baker Pier
7B. McNears Park/China Camp

Boat Site Codes

11. Vallejo Marina
12. Richmond Marina
13. San Leandro Marina
14. Oyster Point Marina
15. Loch Lomond Marina

Mode Codes for Shore Sites

1. "Free" piers. These areas, primarily municipal piers, where a fishing license is NOT required to fish. Free piers include areas that are not technically piers: the Vallejo Waterfront, Alameda Rockwall, and the jetty at Coyote Point. These areas are highlighted in red on the site maps.

2. All other shore based areas that are not free piers. These areas are primarily rip-rap banks. These areas may include man-made structures such as the small pier adjacent to the Vallejo Launch Ramp and the rock jetty at Fort Baker. These areas are highlighted in green on the site maps.

9/9/98

Summary of Shore and Boat Sites

Date	Site Code	Site Start Time	Site End Time	No. of Interview Attempts	Interviewer

Shore Site Codes

1A. Vallejo Shoeline
1B. Martinez Shoreline Park
2A. Point Pinole Shoreline Park
2B. Berkeley Pier
3A. Port View Park
3B. Alameda Rockwall
4A. Dumbarton Bridge Pier
4B. Coyote Point
5A. Oyster Point
5B. Candlestick Pt. Rec Area
6A. SF Municipal Pier
6B. Fort Point
7A. Fort Baker Pier
7B. McNears Park/China Camp

Boat Site Codes

11. Vallejo Marina
12. Richmond Marina
13. San Leandro Marina
14. Oyster Point Marina
15. Loch Lomond Marina

3.1.3. What To Do If There are No Anglers

Sometimes, particularly on weekdays and during the winter months, there may not be any anglers present at a site. You must remain at the site for a minimum of one hour. You may conduct the census at this time and record a zero for the number of anglers. You will also have recorded the start time on the census form and will know when an hour is up. You do not need to revise the census if anglers appear later. If anglers appear, you must attempt to interview them. If you finish interviewing all anglers and one hour has not passed, please make sure you stay the entire 60 minutes. This is important so that we adhere to a consistent approach to counting and interviewing anglers. You should repeat this same procedure at the next site if there are not any anglers there when you arrive. If you have already conducted interviews that day, this would be a good time to review your surveys for completeness. This will save time at the end of your interview day.

3.1.4. How to Cover the Site

Our goal at shore sites is to interview all anglers present at a site. The order in which anglers are interviewed at a site should be similar to the way the census is conducted. We recommend that you break up the site by mode, and census and interview at one area before moving on the next area. This makes sense because some areas within a site are far apart. For example, you may want to start with the pier area first and then move to the shoreline/bank areas next. We also recommend that you interview anglers in a sequential fashion, for example, going up one side of a pier and doing the second side on the return trip.

Because you may be at a site for several hours, there may be many anglers coming and going during the time you are interviewing. We would like to interview new anglers who have arrived after you have begun interviews at an area if possible, <u>but only if you can keep track of the new arrivals.</u> This will require some judgement on your part. If you can't keep track of new anglers, it is best to stick to only those anglers "in front of you." We believe it will be possible to keep track of new arrivals in relatively contained areas (e.g., the pier at Portview Park) or when the number of anglers present is small. With long piers (such as Dumbarton and Berkeley Pier) it will be impossible to keep track of new anglers arriving.

We want to avoid the situation where certain types of anglers always get selected to be interviewed and certain other types of anglers always get overlooked. Keeping track of new arrivals is much harder to do than it sounds. At a site with 20, 30 or more anglers, the anglers really do begin to look alike. We have found that in these situations you may be able to remember <u>not</u> interviewing some anglers, but for many you will not be sure. Again, unless you can keep track of all new anglers arriving at a site you should stick to interviewing only the anglers "in front of you" and not attempt to interview new anglers that have arrived to a point past where you have already interviewed.

3.1.5. Before You Begin the Interview

Before beginning to interview, you can code some information in advance. These include:

- Date
- Site (use the appropriate site codes)
- Mode (use the appropriate mode codes)
- Time (use military time, such that 1300 refers to 1:00 p.m., etc.)
- Your initials
- Whether the angler is fishing only, or is fishing and crabbing

Before beginning an interview you need to make sure each potential study participant meets several screening criteria.

- The person must be fishing, i.e., has one or more poles (doing both crabbing and fishing is ok!)
- The person should not be a child (we want interviews from people 18 years or older) If you are uncertain if a person is at least 18 years old, ask them before beginning the interview
- The person should not have been interviewed previously for ***this seafood consumption study***

3.1.6. Reviewing Your Work

After you have completed interviewing at the sites, it is important to review all of your surveys for completeness. This should not take long, but you must flip through all pages to ensure all areas have been filled out properly. For example, there may be areas where you could not fill in a box but wrote in the margins instead. Now is the time to fill in the box. If you made a mistake filling in a box and had to correct the answer, be sure to mark or record the correct answer and circle the correct answer so that we can manually correct it when the form is being scanned. Make notes in the margins if necessary. Also, there may be clarifications that need to be made in the "Other observations or notes" section. We prefer that the review be done before you leave the last site but if it is getting dark, you may review them at home. Be sure the review is done on the same day the interviews were conducted. You may also have time to review some of your surveys while waiting for the other interviewer to finish an interview.

3.1.7. If You Are Unable to Complete Your Assigned Sites

We would like to keep the maximum number of hours worked in a day to no more than 8 hours (excluding a minimum of 30 minutes for a lunch or dinner break if you work 6 or more hours in a day). In some cases, you may not be able to complete the sites assigned to you for the day. This may happen because there are many more anglers than anticipated. We will try to anticipate the number of anglers at a site and add a third interviewer if the expected number is high. However, in some cases a sampling day may take longer than anticipated, and you simply will not be able to finish before dark or before an 8 hour work day has passed. You should also allow time within your shift for reviewing your completed surveys. In these cases it is important to notify the field coordinator as soon as possible (she may be able to find additional interviewers who are available before the day is over). You must notify the field coordinator even if it is near the end of the day when you realize you will not finish your assigned sites. Try to find a clear

ending point, for example, finish the pier or shoreline/bank area if you can. When sites are incomplete they will be finished the next day or as soon as possible.

3.2 Private Boat Sites

3.2.1 Recording Site and Mode

The 5 private boat sites are marinas where boats on trailers are launched at a launch ramp. These marinas also have privately-owned boats that are kept berthed. The site codes, site names, and county are listed below. A map showing the sites can be found in Diagram 2. Detailed maps of the sites, including directions to the sites can be found in the Site Map Book.

Private Boat Sites

Site Code	Site Name	County
11	Vallejo Marina	Solano
12	Richmond Marina	Contra Costa
13	San Leandro Marina	Alameda
14	Oyster Point Marina	San Mateo
15	Loch Lomond Marina	Marin

Anglers interviewed at private boat sites can be classified into two fishing modes. These modes are:

Private Boat Site Modes

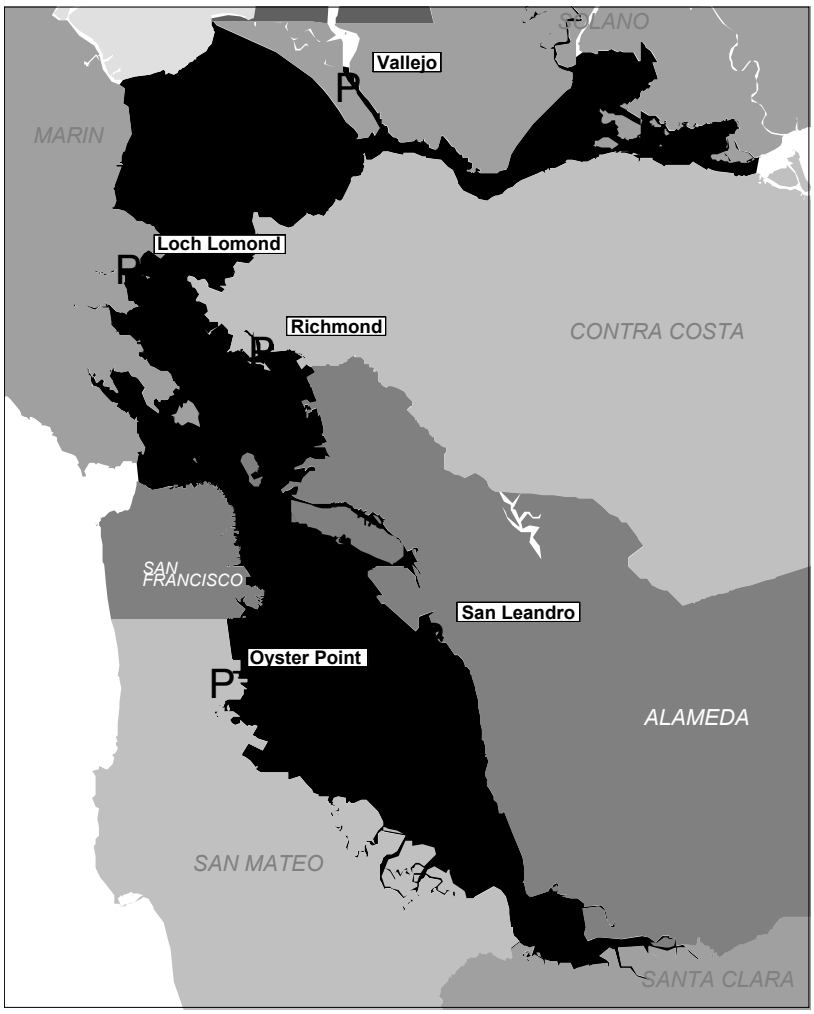
Mode Code	Description
3	Private boat anglers intercepted when using a boat launch facility
4	Private boat anglers from berthed boats

3.2.2 Shift Length

Unlike the shore sites, the number of hours you will attempt to conduct interviews at private boat sites has been preset. The private boat site shifts range from 2 to 5 hours. The length of the shift was set based on the amount of fishing activity at the site. The number of hours in a shift varies by site, season, and whether interviewing is on a weekend day or a weekday. If both interviewers cannot remain at the site for the entire shift, you must notify the field coordinator as soon possible.

3.2.3 Determining Whom to Interview

Our primary goal at the private boat sites is to interview all anglers who: (1) are beginning or ending a fishing trip and (2) are using a private boat launched at the launch ramp, and (3) plan to do (or have just completed) the majority of their fishing ithin San Francisco Bay. You should station yourself near the boat launching area and look for boats both coming in and going out.



San Francisco Bay Seafood Consumption Study
Private Boat Sites

Map: DHS/EHIB

The interview shifts for private boat sites are all in the afternoon so that you are more likely to encounter anglers returning from a fishing trip. Not all persons using the launch ramp are angler and not all persons on a fishing trip are anglers. When you encounter a boat, you must first determine whether any of the persons on the boat plan to fish that day (for outgoing boats) or have just finished fishing (for incoming boats). We want to talk to people before or after their fishing trip; we **do not want** to interview persons who do fish at times but are **not** going out on or coming back from a fishing trip.

You must also determine where they plan to fish (for outgoing boats), or where they went fishing (for incoming boats). **We want to include only people who are fishing within San Francisco Bay**. Some boat anglers leave from one of the 5 sites in the Bay but then travel to the open ocean (past the Golden Gate Bridge),or up the Delta (past Antioch/Pittsburg) to fish. Persons fishing exclusively in areas outside the Bay are to be excluded from the survey. Some anglers may fish in both the Bay and areas outside the Bay. If they do, try to determine whether half or more of their fishing activity was in the San Francisco Bay (regardless of how many fish they caught). If half or more of their fishing activity was in the Bay, you must interview them. In some cases, in outgoing boats, the anglers may not have decided where they are going to fish; where they fish may depend on where the fish are biting that day. In these situations, try to get the anglers' best guess as to where they will be fishing that day. If half or more of their anticipated fishing activity is going to be in the Bay, include them.

Our secondary goal at the private boat sites is to interview anglers on berthed boats who are: (1) beginning or ending a fishing trip and (2) plan to do (or have just completed) the majority of their fishing within San Francisco Bay. Although you should focus on the boats using the launch ramp, we expect there will be times when there is little or no activity at the launch ramp. When this happens, one of the interviewer should walk over to the marina area where berthed boats are docked and look for anglers who may be coming in from or about to depart on a fishing trip. You may also want to check the area where boaters can fuel their boats. As with anglers at the launch area, you want to interview persons who plan to fish that day on a private boat or have just returned from a fishing trip on a private boat. **Do not include** persons who have just fished on a party boat.

Once you encounter a launched or berthed boat with anglers, both interviewers should attempt to interview all anglers on that boat before moving on to a new boat. Sometimes it will not be possible to interview all anglers on a boat because the anglers are anxious to begin their trip or go home. Do the best you can to finish interviewing anglers on that boat. The reason we want to focus on one boat at a time is that we want to avoid selecting only one or two persons who are most vocal from each boat. These selected people as a group may not be representative of all private boat anglers.

As with the interviews conducted at shore sites, you can code some information in advance of beginning your interview. These include:

- Date
- Site (use the appropriate site codes)
- Mode (use the appropriate mode codes)

- Time (use military time, such that 1300 refers to 1:00 pm, etc.)
- Your initials

Before beginning an interview, you need to make sure that each potential study participant meets several screening criteria:

- The person must be planning to fish that day or have just finished fishing
- The person must have been fishing on a private boat, not a party boat
- The person must have conducted (or plans to conduct) the majority of his/her fishing activity in SF Bay
- The person should not be a child (we want to interview only people 18 years or older). If you are uncertain if a person is at least 18 years old, ask them before beginning the interview
- The person should not have been interviewed previously for ***this seafood consumption study***

3.2.4 Before you Begin the Interview

As with the interviews conducted at shore sites, you can code some information in advance of beginning your interview. These include:

- Date
- Site (use the appropriate site codes)
- Mode (use the appropriate mode codes)
- Time (use military time, such that 1300 refers to 1:00 p.m., etc.)
- Your initials

Before beginning an interview you need to make sure each potential study participant meets several screening criteria.

- The person must be planning to fish that day or have just finished fishing
- The person must have been fishing on a private boat, not a party boat
- The person should not be a child (we want interviews from people 18 years or older) If you are uncertain if a person is at least 18 years old, ask them before beginning the interview
- The person should not have been interviewed previously for ***this seafood consumption study***

Additional suggestions for approaching boat anglers include:

1. Read the survey introduction.

2. Determine whether anyone has been fishing (incoming boats) or plans to fish (outgoing boats). You can ask, for example, “Have you been fishing today?” or “Do you plan to fish today?”

3. Determine whether they are planning to fish or whether they have completed their fishing. For an incoming boat, ask the person “Can you tell me where you fished today?” If they are on an outgoing boat, you can ask “Can you tell me where you plan to fish today?” If they

want to know why you are asking them, tell them they must have fished in SF Bay to be interviewed for this survey. Show them your map of the SF Bay if necessary.

4. If they fished exclusively in the Bay, include them. If they fished exclusively outside the Bay, thank them for their time and go on to the next boat.

5. If they fished in both the Bay and other areas, try to determine whether at least half of their fishing activity was in the Bay. You can ask them: "Did you spend at least half your time fishing in the Bay?" If so, include them. For outgoing boats, if they plan to fish in both the Bay and other areas, ask them: "Do you plan to spend at least half your time fishing in the Bay?" If so, include them.

3.2.5 Reviewing Your Work

As with the shore interviews, it is important to review all of your surveys for completeness. This review can be done while you are waiting for boat anglers to arrive. We prefer that the review be done before you leave the site. At the latest, the review should be done before the day is over.

3.3 General Interviewing Guidelines

Once you have completed the screening questions, and have started the interview, be focused and brief. External factors, such as bad weather, another member of the group wanting to leave, or the study participant suddenly getting a fish on the line can break the tempo of the interview. The longer the interview takes, the greater the likelihood that external factors will prevent you from completing it. This perhaps sounds contradictory to the "be patient" advice discussed earlier, but there is a fine line between being patient and taking too long to complete an interview. After completing a few interviews you'll get the idea. One of the best things you can do to facilitate a good interview is to practice, and we will provide several practice opportunities during the training sessions. Feel free to practice on family and/or friends too!

Below are some guidelines you should be aware of when making the initial contact and conducting the interview.

- **Speak clearly.** You may also need to speak loudly due to weather conditions.

- **Don't say more than necessary.** Keep the initial contact and the interview as uncomplicated as possible. The more you talk about matters you are not asking questions about, the more reasons some people can think of not to be interviewed.

- **Please read the questions clearly and as written in order for the survey tool to be consistently administered to all respondents.** If a respondent does not understand the question, you may repeat it, but do not alter the wording. I know this can become tedious, but you must adhere to a consistent way of reading the questions. During the practice and field test sessions, if questions appear awkwardly worded, please make note of what suggested changes are needed.

- **You should be familiar enough with the questions that you can read them naturally and know what is coming next.** This is why we have scheduled several practice sessions. By the time actual data collection begins, you should sound coherent and relaxed.

- **Throughout the interview form, instructions to interviews are written in capital letters.** Do not read these aloud. Also, become familiar with the different skip patterns in the survey.

- **Be aware of the possible responses for each question, and how to the code them.** The attached coding instructions (Section 8) are intended as reference material, but you should read through them at least once before you begin practicing administering the interview.

4. WEEKLY DATA TRANSFER AND DEBRIEFING

Every week that you conduct interviewing you will be required to:
- Turn in completed survey forms to the research coordinator
- Fill out a timesheet
- Fill out a mileage reimbursement form
- Pick up additional survey forms as needed
- Briefly meet with the Field Coordinator to discuss the week's events

If your week of data collection has been uneventful this will be a very short meeting, probably 10 or 15 minutes. If there were problems such as high refusal rates, low numbers of anglers to interview, or health and safety issues, our meetings will take more time. Ideally, the Field Coordinator will review your completed interview forms within 1-2 days after receiving them, so any problems with data quality can be resolved in a timely manner. Your availability for work the upcoming week will also be reviewed.

5. HEALTH AND SAFETY

Your health and safety are more important than the data we are collecting. Please be aware of several potential safety hazards that may be present en route to or at some of the sites that you are visiting.

Bad weather can make docks, piers, rocks, and boat ramps slippery. It can also make you wet, cold, and miserable. Please wear shoes with good traction, and always bring warm clothing with you. Even during the Summer months standing immobile next to the Bay for several hours can make you feel pretty uncomfortable.

Do NOT board private boats. When you are trying to interview people in this fishing mode, do not board any private boats, even if someone invites you on board. For those of you who will be interviewing people on party boats, please do not board or disembark from the boat until the captain or the deck hand has given you an okay.

Beware of bad traffic situations. You all know how bad the Bay Area traffic can be. Some days you may encounter serious delays in getting to your assignment. Do not start driving carelessly or recklessly if you find yourself late for work.

Avoid heavy lifting. There isn't anything you need to lift for this job that weighs more than 10-15 pounds. Please do not try moving heavy furniture or boxes during your visits to the office. We have other staff that do that type of work; it is not worth injuring your back doing a job you are NOT paid to do. For those of you who are interviewing on party boats, do not volunteer your services for heavy lifting.

Beware of people conducting illegal activities. Some of the people that use these sites may be doing illegal activities. We are trying to avoid times when illegal activities occur by only conducting interviews during daylight hours. Please do not remain at these sites after dark. If you observe illegal activities taking place, do not get involved in these situations! Also, beware of people that may threaten your own safety. If you have any doubts about whether a site is unsafe, leave immediately.

6. TRAVEL AND ACCESS TO THE SITES

There are 14 shore sites, 5 sites for sampling individuals on private boats, and 4 sites where some of you will be boarding and riding party boats. Please plan accordingly to try and be on time to your interviewing assignments. Some of the sites may require more than 45 minutes travel one way to reach them, assuming no traffic problems. As part of our training session, we will be visiting each site so you can familiarize yourself with them. Also provided in the Site Map Book are maps and directions to help you locate the sites, and a local point of contact.

Two of the sites, Pt. Pinole, and Dumbarton Bridge require traveling at least 1.5 miles from the parking lots to the piers. At Pt. Pinole, a shuttle bus departs every 30 minutes except on Tuesdays and Wednesdays. At Dumbarton Bridge, vehicular access is restricted for five months, from April through August. Access to this pier is 3 miles from the parking lot on a flat road. If you must interview at Dumbarton during this limited access time, you must go to the ranger station and obtain a key to unlock the gate to allow you to drive to the pier. Many of the sites require public users to pay an entrance fee. YOU SHOULD NOT HAVE TO PAY A FEE for access to any of these sites. We have made arrangements to have entrance fees waived for all of our interviewers. During your first visit to a site requiring a fee, please take a few minutes to introduce yourself to rangers/managers that are present and show your identification. However, if you are required to pay a fee, you will be reimbursed by claiming it on your travel reimbursement.

7. COMPENSATION

In order to be compensated for your time and reimbursed for project related expenses, there are two forms you must complete. Every week that you work you need to turn in a timesheet and a reimbursable expense record. Impact Assessment, Inc. issues paychecks twice a month. At a minimum you will be paid 4 hours per shift, even if there are no anglers to interview. The other form you must complete pertains to reimbursable expenses. For the most part these expenses will be limited to tolls, parking, and private vehicle mileage. For mileage you will be reimbursed

at the State of California rate of $0.24/mile for travel between sites and for travel from your home to the site and from the site back to your home. For expenses less than $6.00 each, you do NOT need to turn in receipts, but for expenses more than this amount, receipts are required. If you are using your own cellular phone to make emergency telephone calls, you will be reimbursed for the number of minutes the call(s) take. A copy of your phone bill itemizing the calls made must be submitted with your reimbursement claim. In general, guidelines for reimbursement for travel related expenses follow those established for state employees.

You are allowed to take one 15 minute break for every 4 hours worked. You will be paid for the break. If you work at least 6 hours, you must take a break of at least 30 minutes (up to one hour) for lunch or dinner. You will not be paid for this lunch/dinner break. We want to limit your workday to no more than 8 hours; for most days you will only work 4 to 6 hours. If it looks like you will not finish your assigned sites within 8 hours, you must notify the Field Coordinator as soon as possible.

8. DETAILED CODING INSTRUCTIONS

- **Use Sharpie pens**
- **Avoid making stray marks on the survey forms, especially in marked boxes.**
- **If you must make notes as the Respondent is trying to answer a question, write in the margins or where there are no boxes.**
- **Write clearly and mark boxes within the boundaries of the box.**
- **When you print letters and numbers, use block letters. Print only one character per box, keeping the character's lines completely inside the box. Do not cross zeros, sevens, or the letter "Z".**
- **If you must correct an answer, circle the corrected answer.**
- **Fill in text in the "other" boxes; please write legibly and neatly.**
- **Mark all appropriate boxes!**
- **In asking the questions, you will read the response categories, unless otherwise noted for specific questions. For all questions, DO NOT READ DK (don't know) or Refuse. The latter two responses are available to be recorded if needed, but do not need to be read.**
- **For people who initially respond DK, try some gentle probing first to see if their memory can be "enhanced" (a true art!)**
- **If there are confusing marks or answers on the survey form, or you used a "translated" form to ask the questions, transcribe the responses to another form and make note of doing so on the original form. Clip both forms together and turn both forms in, indicating to the Field Coordinator that both forms reflect the responses from one Respondent.**

Introducing yourself and the survey: Before reciting the formal introduction, ask a casual question, such as "How's the fishing?", or "What are you catching?", or "Been out here awhile?", etc. Take a minute to engage the person in conversation if they will talk to you, then start the formal introduction. Try to adopt a conversational tone and approach. The end of the interview must include the question asking for permission to interview.

Q1a. Permission to conduct interview: You must obtain the person's consent before beginning the interview. Check one of the boxes 'yes', or 'no'.

Q1b, Q1c, Q1d, and Q1e. Fill out only for individuals refusing to participate. Do not fill these out if Respondent agrees to participate (yes to Q1a). If you have recorded a 'no' to **Q1a**, then you must record only one response for **Q1b** ("reason for refusal"). It may take you a few minutes to gauge the reason for refusal; the person may tell you why he or she will not participate in the study, or you may have to use your judgment and record a reason. DON'T PROBE THE PERSON FOR REASONS! IF THE POTENTIAL RESPONDENT (R) DOES NOT APPEAR HOSTILE THANK HIM OR HER FOR THEIR TIME, AND THEN MOVE ON TO THE NEXT POTENTIAL RESPONDENT.

Q1c, Q1e. Check observed ethnic group and gender. (your best guess).

Q1d. Language (if Non-English Speaking): You have several response categories here. Again, choose and mark only one choice. DO NOT GUESS! If the person is speaking a language that you do not understand, simply record 'undetermined.'

Q2. Has the person already been interviewed for our seafood consumption study? A response to this question may be given during a refusal following the interview introduction. A person may tell you that she or he has already been interviewed. You should be aware of the other fishery/creel survey type studies that are occurring in the SF Bay area. If a person tells you that she or he has been previously interviewed, try to determine whether it was for this study or some other one. For instance, ask if they have talked to someone wearing the same hat and vest as you have on, with the SF Bay Seafood Consumption Study logo. If the person was interviewed for our study, then check the 'yes' box, and ask if she or he remembers the month and year they were interviewed (Q2b). Mark the noted month and year in the designated boxes. If the person does not remember when, mark the DK box next to the date box. {Note there are two DK boxes, mark the appropriate one!) Thank and end the interview with all individuals who answered YES to Q2, indicating that you can only interview individuals once for this study.

When you have received permission to conduct the survey, and have determined the person has NOT been previously interviewed you are ready to move on to the next portion of the survey instrument.

Show the Respondent (**R**) the map of San Francisco Bay, and identify the boundaries of the area with which we are concerned. You may want to point out a few landmarks (e.g., Antioch, Dumbarton Bridge, etc.) You can also say that you may be referring to the San Francisco Bay as "the Bay". You will need to clarify what you mean by fish and shellfish.

Q3a. "Is this the first time you have ever fished in the San Francisco Bay?" There are four response categories, check one only. If R says No, ask **Q3b**. when was the last time, noting month (if known) and year. If R indicates not remembering or not knowing the last time he or she fished in the Bay, mark the DK box next to the date field and continue to Q4.

For "first time anglers", or those responding yes, skip to Q5.

Q4. **Not including today, i**n **the last 4 weeks, what is the total number of times you have gone fishing?**

People will probably need a little time to think about their answer. They may give you a total number or they might say something like 3 to 4 times each week. You would then have to say to them: "so like 12 to 16 times total for the last four weeks? Is it closer to 12 or 16 or some number inbetween?" Try to get a specific number and record that number in the noted box.

Q5. "What do you usually do (plan to do for FIRST TIME FISHERS) with the fish or shellfish you catch from the SF Bay?" THIS IS A MULTIPLE RESPONSE QUESTION, SO YOU MAY CHECK AS MANY CATEGORIES THAT APPLY.

TRANSITION: YOU WILL NOW BE ASKING A DIFFERENT SET OF QUESTIONS. TO GET THE RESPONDENT IN THE PROPER FRAME OF MIND, YOU NEED TO READ THE TRANSITION PARAGRAPH TO HIM/HER. TRY TO MAKE SURE HE/SHE UNDERSTANDS WHAT YOU ARE SAYING!

Q6a. "Do you eat fish that you or someone you know catches from the SF Bay?" Read off Yes; Used to, but don't anymore; or No. If R answered Used to, ask Q6b. and mark month/yr in the noted box. If R indicates he/she doesn't know when they stopped eating fish from the Bay, mark the DK box next to the date box. If R indicates a 'no', then skip to Q10. If R indicates DK to the overall question (not the date as to when he/she stopped eating fish from the Bay), or doesn't wish to answer the question, mark the appropriate box.

Q7. "How many years have you been eating fish that you or someone you know caught from the Bay?" You have eight possible response categories, record only one response. **You do not need to read** the categories to R, but make sure his/her answer fits one of the eight categories. NOTE: This may be the first question where you encounter a 'don't know' response, since some people may not be able to accurately recall how long they have been fishing. If someone is vague in the time frame they give you, or gives a couple of conflicting answers, record a 'don't know' response.

Q8a. "In the last four weeks, did you eat fish that you caught, or someone you know caught from the Bay?" Make sure R understands you are asking for about the last 4 weeks. For this question there are four response categories, record only one response.

Q8b. In the last four weeks, how many times did you eat fish that you caught or someone you know caught from the Bay? Again, make sure the time frame is understood. Let the Respondent think a bit. Answer can be stated in times per day, times per week, or total times in last 4 weeks. **Record only one response**.
You can prompt: "how many times per day or times per week did you eat fish from the Bay in the last 4 weeks?" or "how many times all together?" The Respondent may give you a total number of times, or give you different frequencies such as "ate it every day a week ago, but not so much last week." You would have to probe more specifically, such as "So you only ate fish from the Bay every day for a week over the last 4 weeks? You didn't eat fish the first two

weeks? So you ate fish seven times over the last 4 weeks?, etc. **Make notes and tally later if needed**. Record the number of times corresponding to the specified time period.
If Respondent gives a range, such as 2-3 times/week, ask "was it more likely 2 times or 3 times?

Q9. **"In the last 12 months (specify time period, using the current date and then asking for the previous 12 months) how many times overall, did you eat fish that you caught or someone caught from the SF Bay**. Make sure the R knows you are talking about the last 12 months! Answer can be stated in times per day, times per week, times per month, or total times in last 12 months. You can prompt: "About how many times per day or times per week?" (especially for frequent consumers). You may have to prompt about seasons or months they fish and eat more often, etc. **You may have to make notes and count up the total times separately.**
Someone who doesn't eat it a lot may be able to tell you easily the total number of times in the last 12 months.
Record only one response. Record the number of times corresponding to the specified time period.

Q10a. This is a model of 8 ounces (half pound) of raw fish fillet. When you eat fish from anywhere (the Bay, other places, stores, restaurant), is the amount that you eat about this size, more or less? " SHOW PARTICIPANT THE FISH MODEL BUT DO NOT LET THEM HOLD IT; ALLOW THEM TO LOOK AT IT FOR SEVERAL MINUTES. NOTE: YOU SHOULD KEEP THE 3D MODEL IN YOUR VEST UNTIL YOU REACH THIS QUESTION. ALSO, THIS QUESTION REFERS TO FISH CAUGHT/EATEN FROM ANYWHERE, INCLUDING RESTAURANTS, STORES, AND NOT RESTRICTED TO THE SF BAY. Make sure the participant is aware of this distinction, because in the previous questions we have been talking about Bay caught fish.

If the person responds "about this size", then skip to **Q11**.
If the person indicates the amount of fish eaten is more than that shown in the 3D model, then ask **Q10b**.
If the person indicates the amount of fish eaten is less than that shown in the 3D model, then skip to question **Q10c**.

Be aware that cooking generally reduces the size by about 25% (one fourth); in other words, 8 ounces of raw fish will generally result in 6 ounces cooked fish.

It is likely that some respondents will not relate to the model, and will not be able to confidently determine their consumption. DON'T TRY TO FORCE AN ANSWER but probe gently. For instance, repeat that this is a model of 8 oz. (half a pound). Do you think you eat half more, a fourth more, etc. Try showing what half or one fourth would like, using either paper or your hands to cover up part of the fillet model. If the respondent really seems unsure, check the 'don't know' category.

TRANSITION TO THE NEXT SECTION BY READING THE STATEMENT "Now I'm going to show you pictures of 3 specific fish that can be caught from the SF Bay and ask you whether you eat them or not. YOU WILL NEED TO FOCUS THE RESPONDENT'S ATTENTION TO

THE THREE SPECIES MENTIONED IN Q11-14. TO DO THIS, READ THE ENTIRE PARAGRAPH BEFORE BEGINNING QUESTIONS 11-14.

Q11a. "Do you eat this fish that you or someone you know catches from San Francisco Bay?" (POINT TO Kingfisher/Croaker picture)

Starting with Kingfish, you will record a 'yes', 'no', or 'don't know'. Ask them what he/she calls it and write the response in the noted space. For those responding affirmatively you will continue asking questions Q11b-Q11d3. For those responding with a 'no' or 'don't know', you will then ask the same question for the next species (Leopard shark). You will repeat this procedure for all three fish species.

Q11b. "Have you eaten any _____ from the Bay in the last 4 weeks?" (use the name given by the R) For each species the R reports eating, you will ask if he/she has eaten any in the last 4 weeks. It is important to emphasize the last four weeks AND the fish may be freshly caught or frozen, dried, canned or smoked after being caught. If the respondent answers 'yes', you will need to record the number of times that he or she has eaten the specific fish. If the R can't recall the no. of times eaten in the last 4 weeks, mark the DK box next to the No. of times box.

Q11c1 – skin and 11c2- guts. **When you eat kingfish (or whatever the respondent indicates calling the pictured fish), how often do you eat the skin of the fish?** …., (how often do you eat the guts or organs of the kingfish?) Read: "more than half the time, less than half the time or never?" Mark the appropriate box.

Q11d1, d2, d3. When you eat kingfish, how often do you eat the cooking juices or drippings (make soup with it?; eat it raw?) Read: "more than half the time, less than half the time, or never?" Mark the appropriate box.

Q12a to Q12d3 – ask similar questions for **leopard shark**.

Q13a to Q13d3 – ask similar questions for **striped bass**.

Q14a. **Now I have some picture of other fish that can be caught from SF Bay. Looking at these pictures, please show me which fish you have eaten in the last 4 weeks**. **Again these are the fish you ate in the last 4 weeks which you caught or someone you know caught fromSF Bay. The fish could have been fresh, frozen, dried, canned, or smoked.**
SHOW PICTURES AND HAVE RESPONDENTS POINT OR TELL YOU WHICH ONES THEY HAVE EATEN IN THE LAST 4 WEEKS. Some probing may be necessary and you may have to show the pictures more than once. Mark the Yes box only for those the R indicates.

Q14b. As Respondent identifies fish he/she has eaten in the last 4 weeks, ask **"How many times have you eaten this fish in the last 4 weeks?"**

Q14c. "What do you call this?". (ASK RESPONDENT AS HE OR SHE POINTS TO THE PICTURES, AND THEN RECORD THE RESPONSE IN COLUMN 14C.) NOTE: For those interviews conducted in Spanish, please record the exact word given by the Respondent; ask them to spell it for you if you are unsure. For interviews conducted in Chinese, Mandarin, or Vietnamese, write the characters or the equivalent.

Q14d. Are there any other fish from the Bay that you eat most often for which I don't have pictures? If R names one of the listed fish, check box and indicate number of times eaten. If R names a fish that is not listed, specify the type of fish and the number of times eaten in the last 4 weeks in the blank box(es).

Q15. "Who in your household eats the fish that you catch from the SF Bay?"
Please read the 6 main response categories and check all that apply.

Q16. "How many total people, including yourself, are in your household?" You have three choices for this question, record only one response: the number of total people, a don't know, or a refuse to answer response.

Q17. "Who usually cooks or prepares the fish you catch and eat from the Bay?" This a multiple response type question, so you may check more than one response. Please record the noted family member or other individuals in the appropriate boxes.

TRANSITION: THE NEXT SET OF QUESTIONS DEALS WITH FISH FROM PLACES OTHER THAN THE SF BAY. YOU WILL NEED TO READ THIS PARAGRAPH TO RESPONDENTS BEFORE ASKING THE NEXT FEW QUESTIONS.

Q18a. "In the last four weeks, did you eat fish that you or someone you know caught from places other than the SF Bay (like a lake or river) in the last four weeks?" (SHOW MAP AS NEEDED TO REMIND RESPONDENT ABOUT THE AREA COVERED BY THE SF BAY)
Mark the given response in the appropriate box. If no, DK, or refuse skip to Q21a. If yes, continue to Q19.

Q19. "From what places, other than the San Francisco Bay, did you or someone you know catch the fish that you ate in the last four weeks?" This is a multiple response type question, so you may check all responses that apply. Fill in text box if Other is marked.

Q20. "In the last four weeks, how many times did you eat fish that you or someone you know caught from places other than SF Bay?" Answer can be stated in times per day, times per week or total times in last 4 weeks. **Record only one response**. If other is marked, please record in the indicated box what the Respondent indicates.

Q21. In the last 4 weeks, have you eaten any fish that you got from a store or restaurant, including any fish fillet burgers or canned tuna?" Check only one response. If the respondent gives a yes response go to Q22. If the respondent gives a 'no', 'don't know', or 'refuse' response, go to Q23.

Q22. "How many times in the last four weeks did you eat fish that comes from a store or a restaurant, including any fish fillet burgers or canned tuna?" Answer can be stated in times per day, times per week or total times in last 4 weeks. **Record only one response**.

TRANSITION: READ OR SAY: "Now I am going to ask you a few questions about information you may have heard about eating fish from the Bay."

Q23. "Have you heard or seen any information or health advisories about eating fish from the Bay?" Record only one response. If the respondent answers 'yes', go to **Q24**. For all other responses, go to **Q25**.

Q24. "What did the information say about fish from the Bay? This is an open-ended question. Listen to what the Respondent says and then repeat back in a summary form to make sure you have heard him/her correctly and then record the noted response.

Q24a. Has the information you have heard or seen about eating fish from the Bay caused you to change your fish eating habits? Record only one response.

Q24b. If yes, how have you changed your fish eating habits? If no, why not? Listen to what the Respondent says and then repeat back in a summary form to make sure you have heard him/her correctly and then record the noted response.

Q25. "What is the best way for you to get information about catching and eating fish from the Bay?" This is a multiple response type question; check all that apply. If the other box is checked, record the Respondent's answer in the text box.

TRANSITION: (The last series of questions deals with personal information, and respondents may be uncomfortable answering these questions.) Read the transition paragraph: **These next few questions will help us describe people fishing or collecting shellfish from the SF Bay. We find this information helpful when we are developing information and materials for people who fish or collect fish. Please remember the information is kept confidential and you don't have to answer if you don't want to.**

Q26. "How would you describe your racial or ethnic background?" You do not need to read the response categories. Code the response as the Respondent answers, checking only one box. Note that several of the the response categories require you to record a specific description in the text box. Pacific Islander groups include Samoan, Tongan, Guamanians. Other Asian can include Koreans, Japanese, Cambodians, Thailanders, Laotians, etc. If Respondent indicates a mixture of ethnic backgrounds or some group not listed, check Other and note the response in the text box.

Q27. "What category best describes your age?" Read "under 18, 18-45, 45-65, over 65?" You have six response categories, check only one.

Q28. "What is the highest grade in school you have completed?" Read "less than 12^{th} grade,

etc." (not DK or Refuse!) You have six response categories, check only one.

Q29a. "Is your total yearly household income greater than $20,000?" You have four response categories, check only one. If the respondent answers 'yes', then ask Q-29b.

Q29b. "Greater than $45,000?" you have four response categories, check only one.

Q30. Gender DON'T ASK THIS- JUST RECORD THE APPROPRIATE CATEGORY based on your observation.

TRANSITION: You are getting ready to end the interview. Offer R the tape measure key chain as our gift for participating. Read the noted paragraph and ask the following questions.

Q31. "Would you like to have your name entered into the drawing?" Mark the noted box. If yes, fill out name, address, etc. in designated boxes.

Q32. "Would you like us to send you information about the results of our survey when they become available?" Mark the noted box. If yes, fill out name, address, etc. in designated boxes.

Q33. "May my supervisor contact you?" Mark the noted box. If yes, fill out name, address, etc. in designated boxes.

Read paragraph regarding the advisory and offer copy of advisory in the appropriate language. You can point out more specific recommendations as given in the handout. If the R wants more information, refer them the agencies listed on the sheet.

Be sure to thank the Respondent for participating!

Enter time the interview was completed in the noted boxes. Use military time.

The **final page** of the interview form is for you to note your impressions of the quality of the interview, additional observations you may want to note, and language in which the interview was conducted. Also if the Respondent refused to answer Q26 (ethnicity), note your observation of the Respondent's ethnicity.

9.0 FREQUENTLY ASKED QUESTIONS

1. Who is paying for this study?
The San Francisco Estuary Institute (SFEI), located in Richmond, is paying for this study. SFEI is a nonprofit research organization that conducts studies to assess and monitor the ecological health of the San Francisco Bay.

2. Who do you work for?
I work for a private company, Impact Assessment Inc. Impact Assessment Inc. is under contract with SFEI and is working in close collaboration with the California Department of Health Services to carry out this study.

3. How much are you paid to do this job?
You can answer this question honestly if you wish although you can also politely tell the respondent that this isn't something you want to share with him or her.

4. How much did SFEI get to do this study?
I am not sure. My supervisor, Gloria Cardona, can provide you with an answer to this question. Her number is (510) 450-3818 (or give them a copy of the referral sheet).

5. Who is in charge of this study?
Gloria Cardona is my immediate supervisor and there are two other people at the Department of Health Services who work with Gloria, Diana Lee and Alyce Ujihara. The phone number for Gloria, Diana, and Alyce is (510) 450-3818 (of give them a copy of the referral sheet).

6. Can I get a copy of the study results?
Yes. We will send you a copy of the final study results when we have completed this project in June 2000. Record "yes" on question 32 in the survey. If he or she is not a survey participant, take down his or her name and address and give to Gloria.

7. Is San Francisco Bay badly polluted?
Nearly all water bodies near urbanized areas show some degree of contamination in the sediments, water, and/or biota. Chemical contaminants measured by SFEI's Regional Monitoring Program show that most contaminants are considerably higher inside the Bay than outside the Golden Gate. However, overtime, the level of contamination is slowly decreasing.

8. Which SF Bay fish are safe to eat?
Most species of Bay fish are included in the health advisory for San Francisco Bay. There are some species that are not included in the health advisory. These are salmon, anchovies, herring and smelt. Although these species have not been tested, they are expected to have lower contamination levels because they spend most of their lives in the sea or because their diets differ from the species included in the health advisory.

9. What about Striped Bass and Sturgeon Caught in the Delta?

Striped bass and sturgeon live in both the Bay and Delta thus the Health Advisory applies to these species in both areas.

10. I have never become sick eating fish from the Bay, why should I worry about the amount of fish I consume? What will happen if I eat contaminated fish?

At the levels found in Bay fish, the chemicals should not make you sick from eating just occasional meals or from eating a large amount of fish at one time. Even regularly eating large amounts of contaminated fish is not certain to cause health effects. But the link between eating contaminated fish and potential health effects is not well understood. Some health effects like cancer may develop only after many years of regularly eating large amounts of fish. To be safe, we recommend that you follow the limits in the health advisory. These limits should protect you from any adverse health effects.

11. Should my children and breastfeeding wife eat Bay fish?

Children under 6 and women who are pregnant, may be come pregnant, or who are breastfeeding should not eat more than one meal per month of most Bay fish. In addition, they should not eat any meals of large shark (greater than 24 inches) or large striped bass (over 27 inches). A fish meal for a 120 pound female is about 6 ounces. For a 40 pound child a fish meal is about 2 ounces.

12. Don't contaminated fish look sick? Should I just avoid fish that look sick?

Fish that contain chemicals do not look sick and they do not look any different from fish that do not contain chemicals. You should follow the health advisory for all fish caught in SF Bay.

13. Are there better places to fish?

Chemicals at levels of health concern were found in fish throughout the Bay so the health advisory applies to all areas of the San Francisco Bay west of the Pittsburg/Antioch area. For striped bass and sturgeon, the health advisory should be followed in the Delta as well. There are not any health advisories for fish in the ocean (outside the Golden Gate Bridge) except for Southern California. There are also many freshwater rivers, lakes and reservoirs in the area. Be sure to consult the Department of Fish and Game Sport Fishing Regulations for a listing of other health advisories in freshwater areas.

14. Are store bought fish any better?

The fish you buy in a store or restaurant may also contain chemicals but in most cases they are probably safe. The federal Food and Drug Administration (FDA) monitors levels of chemicals in fish from commercial sources and has set limits on the amount of chemicals these fish can contain. However, because of the many different sources and species, not all fish and shellfish are tested. The FDA has issued advice for consumers of shark and swordfish because these species have higher levels of mercury than other kinds of fish. FDA recommends that pregnant women and women who may become pregnant limit their consumption of shark and swordfish to no more than once a month. For all other persons, shark and swordfish consumption should be limited to no more than once per week. A typical adult serving is about 7 ounces.

15. Would you eat fish from the Bay?

We can't answer this question for you. But, you should expect to be asked this question in the field and have thought of a response before you begin interviewing in the field. In thinking about a response, it is helpful to be familiar with the materials on the health advisory.

Appendix H

Field Activities Summary

San Francisco Bay Seafood Consumption Study

FISCAL YEAR 1998-1999 FIELD SUMMARY

Site and Site #		Shift Length (hr:min)	Site Actual Shift Length	Site Pair Actual Shift Length*	Census	Site Total Attempts	Site Pair Total Attempts
Vallejo	1A	54:30	20:25	40:22	97	118	179
Martinez	1B		13:57		69	61	
Pt. Pinole	2A	70:30	19:25	56:00	107	74	290
Berkeley	2B		28:40		347	216	
Portview	3A	58:00	14:33	34:08	43	39	80
Alameda	3B		15:05		29	41	
Dumbarton	4A	56:00	20:30	42:00	90	83	125
Coyote Point	4B		15:15		38	42	
Oyster Pt.	5A	57:30	16:17	36:10	59	79	129
Candlestick	5B		14:45		42	50	
Muni Pier	6A	60:00	16:10	36:10	111	99	178
Ft. Point	6B		15:00		74	79	
Ft. Baker	7A	60:00	19:15	43:45	109	96	207
McNears	7B		22:00		144	111	
TOTAL		416:30	251:17	288:35	1,359	1,188	1,188
Private Boats							
Vallejo	11	0:00	19:35		0	150	
Vallejo	11	1:30	2:00		0	28	
Richmond	12	10:00	22:35		0	143	
Richmond	12	2:00	6:00		0	5	
San Leandro	13	0:00	0:00		0	85	
Oyster Point	14	23:00	21:40		0	65	
Loch Lomond	15	10:00	10:00		0	81	
TOTAL		214:30	201:50		0	557	
Party Boats							
San Pablo	21	0:00	9:00		0	13	
Emeryville	22	0:00	10:15		0	24	
Emeryville	22	0:00	12:30		0	26	
Emeryville	22	0:00	8:25		0	10	
Fshrmn's Whrf	23	11:00	11:30		20	25	
Fshrmn's Whrf	23	0:00	8:00		23	25	
TOTAL		11:00	59:40		43	123	
GRAND TOTAL		**642:00**	**512:47**	**288:35**	**1,402**	**1,868**	**1,188**

*Actual shift length includes travel time between site pairs

Field Summary July 1998

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census<18 yrs. Old	Attempts	Total Attempts per site pair	Interviewers	Actual Interviewers	On-site
Candlestick	6/13/99[1]	Sun	5B	7:00 AM	1:00 PM	6:00	9:00 AM	11:15 AM		8	2	9		Javier, Yoko	Javier	
Oyster Pt.	7/11/99[2]	Sun	5A				11:35 AM	12:45 PM	3:45:00			8	17	Javier, Yoko	Yoko, Sheila	
Coyote Point	6/30/99	Wed	4B	2:00 PM	7:00 PM	5:00	2:15 PM	3:15 PM		1	12	3		Sheila	Sheila	
Dumbarton			4A				3:35 PM	4:00 PM	1:45:00	0	3	2	5	Gloria	Javier	Gloria
McNears	6/6/99	Sun	7B	1:00 PM	7:00 PM	6:00	1:00 PM	3:00 PM		20	4	5		Javier,Jeff	Javier, Jeff	
Ft. Baker			7A				4:00 PM	7:00 PM	6:00:00	13	5	17	22	Yoko	Yoko	
Berkeley	6/9/99	Wed	2B	7:30 AM	1:30 PM	6:00	7:25 AM	8:35 AM		3	0	5		Jeff	Jeff	Gloria
Pt. Pinole			2A				9:00 AM	10:00 AM	2:35:00	0	0	0	5	Adrienne	Gloria	
Alameda	6/25/99	Fri	3B	1:30 PM	7:30 PM	6:00	1:30 PM	2:45 PM				3		Melissa	Melissa	
Portview			3A				3:00 PM	4:00 PM	2:30:00			5	8	Adrienne	Sheila	
Ft. Point	6/20/99	Sun	6B	7:00 AM	1:00 PM	6:00	8:00 AM	9:00 AM		5	0	4		Javier	Javier, Jeff	
Muni Pier			6A				9:10 AM	10:10 AM	2:10:00	3	2	2	6	Jeff		
Martinez	6/8/99	Tues	1B	8:00 AM	1:00 PM	5:00	8:00 AM	9:00 AM		2	0	2		Jeff	Jeff	
Vallejo			1A				9:30 AM	10:20 AM	2:20:00	7	0	7	9	Sheila	Sheila	
TOTAL						**40:00:00**			**21:05:00**	**62**	**28**	**72**	**72**			
PRIVATE BOATS																
Oyster Point	6/20/99[3]	Sun	14	4:00 PM	7:00 PM	3:00	4:00 PM	7:00 PM	3:00			13	13	Cong,Quy		
San Leandro	6/19/99	Sat	13	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00			11	11	Quy, Jeff	Quy, Jeff, Cong	
Vallejo	6/15/99	Tues	11	2:00 PM	7:00 PM	5:00	2:00 AM	7:00 AM	5:00			24	24	Jeff, Sheila	Jeff, Sheila	
Loch Lomond	6/26/99	Sat	15	2:00 PM	4:00 PM	2:00	2:00 PM	4:00 PM	2:00			7	7	Cong, Melissa	Cong, Melissa	Gloria
Richmond	6/23/99	Wed	12	2:00 PM	7:00 PM	5:00	12:00 PM	3:00 PM				9		Sheila, Jeff		
	7/8/99[2]	Thurs	12				5:00 PM	7:00 PM				3	12			
TOTAL						**18:00:00**			**#REF!**			**67**	**67**			
PARTY BOATS																
Fisherman's Wharf	6/19/99	Sat	23									0	0	Courtney		
Fisherman's Wharf	6/20/99	Sun	23									10	10	Courtney	Gloria, Courtney	Gloria
Fisherman's Wharf	7/11/99	Sun	23									0	0	Courtney	Courtney, Sheila	
TOTAL									**0**	**0**		**10**	**10**			
GRAND TOTAL						**58:00:00**			**#REF!**			**149**	**149**			

*actual shift length includes travel time between site pairs

1 Conflict with MRFSSS Survey

2 Reschedule to finish site

3 Reschedule to accommodate interviewers schedule

Field Summary August 1998

SITE	Date	Day of Wk	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs.	Census <18 yrs. old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Ft. Point	8/8/98		6B	1:00 PM	8:00 PM	7:00	2:10 PM	3:30 PM		40	7	15		Jeff, Quy	Jeff, Quy	
Muni Pier		Sat	6A				5:00 PM	6:50 PM	4:40:00	14	2	17	32			
Berkeley	8/13/98		2B	1:00 PM	7:00 PM	6:00	12:00 PM	2:00 PM	2:00	18	3	12		Angle, Ellen	Angel, Ellen,	Gloria
Pt. Pinole		Thur	2A				2:40 PM	4:05 PM	4:05:00	5	0	5	17			
McNears	8/15/98		7B	7:00 AM	1:00 PM	6:00:00	7:00 AM	12:00 PM		8	0	9		Jeff, Javier	Jeff, Javier, Yoko	
Ft. Baker		Sat	7A				10:30 AM	12:30 PM	5:30:00	20	3	24	33			
Candlestick	8/16/98		5B	1:30 PM	7:30 PM	6:00:00	1:40 PM	3:30 PM		11	3	15		Jeff, Javier	Jeff, Javier, Yoko	
Oyster Pt.		Sun	5A				4:10 PM	6:30 PM	4:50:00	10	7	19	34			
Coyote Point	8/19/98		4B	9:00 AM	1:00 PM	4:00:00	9:00 AM	10:30 AM		5	0	5		Jeene, Angel	Jeene, Angel, Yoko	
Dumbarton		Wed	4A				11:15 AM	12:15 PM	3:15:00	1	0	1	6			
Martinez	8/21/98		1B	1:30 PM	6:30 PM	5:00:00	1:35 PM	2:55 PM		3	7	6		Angel, Quy	Angel, Quy	
Vallejo		Fri	1A				3:40 PM	5:30 PM	3:55:00	10	5	10	16			
Alameda	8/24/98		3B	8:00 AM	1:00 PM	5:00:00	8:45 AM	9:45 AM		4	0	3		Javier, Jeene	Javier, Jeene	
Portview		Mon	3A				10:25 AM	10:58 AM	2:13:00	0	0	1	4			
TOTAL						**39:00:00**			**30:28:00**	**149**	**37**	**142**	**142**			
PRIVATE BOATS																
Oyster Point	8/2/98	Sun	14	1:00 PM	5:00 PM	4:00	11:20 AM	2:35 PM	3:15:00			17	17	Javier, Jeff	Jeff, Sheila	Alyce
Richmond	8/12/98	Wed	12	10:30 AM	3:30 PM	5:00	10:30 AM	3:30 PM	5:00			16	16	Jeene, Angel	Ellen, Jeff	
Vallejo	8/14/98	Fri	11	1:30 PM	4:30 PM	3:00	1:30 PM	4:30 PM	3:00			15	15	Javier, Cesar	Javier, Cesar	Gloria
San Leandro	8/23/98	Sun	13	11:00 AM	4:00 PM	5:00	11:00 AM	4:00 PM	5:00			23	23	Javier, Cong	Javier, Cong	
Loch Lomond	8/30/98	Sun	15	3:00 PM	6:00 PM	3:00	3:00 PM	6:00 PM	3:00			15	15	Quy, Javier	Quy, Javier	
TOTAL						**20:00:00**			**19:15:00**			**86**	**86**			
PARTY BOATS																
Emeryville	8/11/98	Tue	22									3	3	Angel	Angel	
Emeryville	8/21/98	Fri	22				5:00 AM	3:30 PM	10:30:00			21	21	Yoko	Yoko	
Emeryville	8/23/98	Sun	22				5:35 AM	2:00 PM	8:25:02			10	10	Courtney	Courtney	
TOTAL									**18:55:02**	**0**		**34**	**34**			
GRAND TOTAL						**59:00:00**			**68:38:02**			**262**	**262**			

*actual shift length includes travel time between site pairs

Field Summary September 1998

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Oyster Pt.	9/10/98	Thurs.	5A	2:00 PM	7:00 PM	5:00	2:00 PM	3:45 PM		5	2	6		Jeff, Sheila	Jeff	Gloria
Candlestick	9/10/98		5B				4:00 PM	4:45 PM	2:45:00	5	1	3	9			
Pt. Pinole	9/12/98	Sat.	2A	12:30 PM	7:30 PM	7:00	12:30 PM	3:00 PM		15	5	11		Cong, Yoko, Quy	Cong, Yoko	
Berkeley	9/12/98		2B				4:00 PM	7:30 PM	7:00:00	38	18	21	32			
Vallejo	9/13/98	Sun.	1A	1:00 PM	6:00 PM	5:00	1:00 PM	3:00 PM		14	1	16		Yoko, Javier	Yoko, Javier	
Martinez	9/13/98		1B				4:00 PM	6:00 PM	5:00:00	13	1	13	29			
Ft. Baker	9/14/98	Mon.	7A	9:00 AM	2:00 PM	5:00	9:05 AM	10:20 AM		4	0	4		Sheila, Cesar	Sheila	Gloria
McNears	9/14/98		7B				11:00 AM	12:00 PM	2:55:00	6	0	4	8			
Portview	9/20/98	Sun.	3A	8:00 AM	1:00 PM	5:00	8:00 AM	8:55 AM		0	0	0		Javier, Jeene	Javier, Jeene	
Alameda	9/20/98		3B			0:00	9:00 AM	11:35 AM	3:35:00	5	0	10	10			
Dumbarton	9/27/98	Sun.	4A	8:00 AM	1:00 PM	5:00	8:00 AM	10:30 AM		9	0	17		Angel, Cong	Angel, Cong	
Coyote Point	9/27/98		4B			0:00	11:30 AM	1:30 PM	5:30:00	10	2	10	27			
Muni Pier	9/29/98	Tues.	6A	1:30 PM	6:30 PM	5:00	1:40 PM	2:40 PM		2	0	3		Jeff, Sheila	Jeff, Sheila	
Ft. Point	9/29/98		6B			0:00	3:00 PM	4:00 PM	2:20:00	3	0	3	6			
TOTAL						**37:00:00**			**29:05:00**	**129**	**30**	**121**	**121**			
PRIVATE BOATS																
Vallejo	9/7/98	Mon(H)	11	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00:00			12	12	Javier, Cesar	Javier, Cesar	Gloria
Oyster Point	9/15/98	Tues.	14	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00:00			2	2	Jeff. Sheila	Jeff, Sheila	Alyce
Richmond	9/19/98	Sat.	12	1:00 PM	6:00 PM	5:00	1:00 PM	6:00 PM	5:00:00			32	32	Ellen, Jeff	Ellen, Jeff	
Loch Lomond	9/25/98	Fri.	15	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00:00			10	10	Ellen, Quy	Ellen, Quy	
TOTAL						**14:00:00**			**14:00:00**			**56**	**56**			
PARTY BOATS																
Fishermen's Wharf	10/4/98	Sun.	22	5:30 AM	4:30 PM	11:00:00	5:30 AM	4:30 PM	11:00:00	20		20	20	Courtney	Courtney	
TOTAL						**11:00**			**11:00:00**	**20**		**20**	**20**			
GRAND TOTAL						**62:00:00**			**54:05:00**			**197**	**197**			

*actual shift length includes travel time between site pairs

Field Summary October 1998

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census > 18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Candlestick	10/4/98[1]	Sat	5B	8:00 AM	1:00 PM	5:00	8:30 AM	9:30 AM		1	0	1		Ellen, Jeff	Ellen, Jeff	
Oyster Pt.			5A				9:50 AM	11:45 AM	3:15:00	8	0	9	10			
Coyote Poir	10/5/98	Mon	4B	11:00 AM	4:00 PM	5:00	11:00 AM	12:10 PM		3	0	4		Cesar, Sheila	Cesar, Sheila,	Gloria
Dumbarton			4A				12:55 PM	2:15 PM	3:15:00	16	3	10	14			
McNears	10/10/98	Sat	7B	12:30 PM	6:30 PM	6:00	1:00 PM	4:00 PM		29	3	24		Ellen,	Jeff, Javier	
Ft. Baker			7A				2:20 PM	6:00 PM	5:00:00	17	3	10	34			
Berkeley	10/14/98	Wed	2B	9:00 AM	2:00 PM	5:00	9:00 AM	10:00 AM		1	1	1		Sheila,	Sheila,	
Pt. Pinole			2A				11:00 AM	12:00 PM	3:00:00	6	6	6	7			
Alameda	10/23/98	Fri	3B	1:00 PM	6:00 PM	5:00	2:15 PM	2:40 PM		4	0	4		Quy, Angel	Angel, Quy, Sheila	
Portview			3A				3:30 PM	4:45 PM	2:30:00	0	0	0	4			
Ft. Point	10/25/98	Sun	6B	7:00 AM	12:00 PM	5:00	6:30 AM	7:45 AM		4	2	3		Javier, Jeff	Sheila, Jeff	
Muni Pier			6A				8:00 AM	9:30 AM	3:00:00	7	0	9	12			
Martinez	10/27/98	Tues	1B	8:00 AM	12:00 PM	4:00	8:45 AM	9:30 AM		4	0	5		Sheila,	Sheila,	Diana
Vallejo			1A				10:00 AM	12:00 PM	3:15:00	15	0	11	16			
TOTAL						**35:00:00**			**23:15:00**	**115**	**18**	**97**	**97**			
PRIVATE BOATS																
Oyster Poin	10/4/98	Sun	14	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			3	3	Javier,	Sheila	
Vallejo	10/28/98[1]	Wed	11	11:00 AM	4:00 PM	5:00	1:30 PM	4:30 PM	3:00			9	9	Cesar,	Cesar,	Alyce
Richmond	10/29/98	Thurs	12	11:30 AM	4:30 PM	5:00	11:30 AM	4:30 PM	5:00			15	15	Jeene, Jeff	Jeene, Jeff	
San Leandr	10/31/98	Sat	13	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00			13	13	Angel, Cong	Angel, Cong, Quy	
Loch Lomo	11/8/98[2]	Sun	15	2:30 PM	4:30 PM	2:00	2:30 PM	4:30 PM	2:00			5	5	Jeff, Sheila	Jeff, Sheila	
TOTAL						**16:00:00**			**14:00:00**			**45**	**45**			
PARTY BOATS																
	10/10/98[3]	Sat	22				5:00 AM	6:00 AM	1:00:00	0		0	0	Courtney	Courtney	
	10/24/98[3]	Sat	22				5:00 AM	7:00 AM	2:00:00	0		0	0	Courtney	Courtney	
TOTAL										**0**		**0**	**0**			
GRAND TOTAL						**51:00:00**			**39:15:00**			**142**	**142**			

*actual shift length includes travel time between site pairs
1Conflict with MRFSS Survey
2 Reschedule due to weather
3Attempts. Not able to get on boat due to denial and/or boat full.

Field Summary November 1998

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Candlestick	11/9/98	Mon	5B	8:00 AM	12:00 PM	4:00	8:00 AM	9:15 AM		0	3	0	0	Sheila, Angel	Sheila, Adrienne	
Oyster Pt.			5A				9:45 AM	10:45 AM	2:45:00	5	3	5	5			
McNears	11/11/98	Wed. (H)	7B	12:00 PM	4:00 PM	4:00	11:45 AM	2:15 PM		20	3	23		Sheila,Cesar	Sheila, Cong, Gloria	Gloria
Ft. Baker			7A				3:00 PM	4:00 PM	4:15:00	17	3	3	26			
Ft. Point	11/13/98	Fri.	6B	7:00 AM	12:00 PM	5:00	7:30 AM	9:40 AM		5	0	2		Cesar, Sheila,	Cesar, Gloria	Gloria
Muni Pier			6A				10:00 AM	12:45 PM	5:15:00	8	0	13	15			
Berkeley	11/21/98[1]		2B	7:00 AM	12:00 PM	5:00	7:00 AM	9:30 AM		9	0	9		Javier, Cong	Cong, Quy	
Pt. Pinole		Sat.	2A				10:30 AM	12:45 PM	5:45:00	15	2	12	21			
Coyote Point	11/27/98	Fri.(H)	4B	12:00 PM	5:00 PM	5:00	12:00 PM	1:00 PM		2	0	0		Ellen, Javier	Quy, Sheila	
Dumbarton			4A				1:45 PM	3:45 PM	3:45:00	17	0	6	6			
Martinez	11/28/98	Sat.	1B	7:30 AM	12:00 PM	4:30	7:30 AM	9:30 AM		4	0	10		Jeff, Cesar	Cesar, Jeff	
Vallejo			1A				10:00 AM	12:00 PM	4:30:00	8	1	15	25			
Alameda	12/4/98[2]	Fri	3B	12:00 PM	5:00 PM	5:00	11:45 AM	12:15 PM		0	0	0		Jeene, Javier	Sheila, Gloria	Gloria
Portview			3A				12:45 PM	1:45 PM	2:00:00	2	1	1	1			
TOTAL						**32:30:00**			**28:15:00**	**112**	**16**	**99**	**99**			
PRIVATE BOATS																
Vallejo	11/14/98[1]	Sat.	11	11:00 AM	4:00 PM	5:00	11:00 AM	4:00 PM	5:00			23	23	Jeff, Cpong	Jeff, Cong	
Oyster Point	11/10/98	Tues.	14	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			0	0	Jeff, Ellen	Jeff, Ellen	
Loch Lomond	11/12/98	Thur.	15	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			7	7	Sheila, Jeff	Sheila, Jeff	
Richmond	11/22/98	Sun.	12	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			11	11	Javier, Ellen, Cesar	Javier, Ellen	
TOTAL						**9:00:00**			**9:00:00**			**41**	**41**			
PARTY BOATS																
	11/20/98[3]	Fri	23				7:30 AM	8:00 AM	0:30:00			0	0	Courtney	Courtney	
	11/22/98	Sun	23				8:00 AM	2:00 PM	6:00:00	13		11	11	Courtney	Courtney	
TOTAL									**6:00:00**			**11**	**11**			
GRAND TOTAL						**41:30:00**			**43:15:00**			**151**	**151**			

*actual shift length includes travel time between site pairs
1Conflict with MRFSS Survey
2 Reschedule due to weather
3Attempts. Not able to get on boat due to denial and/or boat full.

Field Summary December 1998

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length	Actual Shift Length*	Census >18 yrs.	Census<18 yrs.	Attempts	Total Attempts per site pair	Actual Interviewers	On-site
Oyster Pt.			5A	12:00 PM	4:30 PM	4:30	12:00 PM	1:10 PM			1	1	4			
Candlestick	12/27/98[1]	Sun	5B				1:30 PM	2:30 PM		2:30:00	0	0	0	4	Sheila, Melissa	
Pt. Pinole	12/7/98	Mon.	2A	11:30 AM	4:30 PM	5:00	12:30 PM	1:45 PM			9	0	6		Quy, Melissa	Gloria
Berkeley			2B				2:20 PM	3:00 PM		2:30:00	6	0	9	15		
Vallejo	12/30/98	Wed	1A	12:00 PM	4:00 PM	4:00	12:30 PM	2:15 PM			15	2	14		Melissa, Quy, Gloria	
Martinez			1B				2:30 PM	3:45 PM		3:15:00	3	0	5	19		
Ft. Baker	12/12/98	Sat	7A	7:00 AM	12:00 PM	5:00	9:00 AM	10:00 AM			9	0	7		Jeff, Ellen	
McNears			7B				10:30 AM	12:30 PM		3:30:00	17	0	10	17		
Portview	12/21/08	Mon.	3A	8:00 AM	12:00 PM	4:00	8:00 AM	9:00 AM			0	0	0		Sheila, Melissa	
Alameda			3B				9:15 AM	9:45 AM		1:45:00	0	0	0	0		
Dumbarton	12/17/98	Thurs	4A	8:00 AM	12:00 PM	4:00	9:15 AM	10:50 AM	1:35:00		13	0	11		Yoko, Melissa	
Coyote Point	12/28/98[3]	Mon.	4B				12:30 PM	1:30 PM	1:00:00	2:35:00	1	0	1	12	Jeff, Sheila	
Muni Pier	12/6/98	Sun	6A	12:00 PM	5:00 PM	5:00	12:35 PM	1:45 PM			8	3	7		Sheila, Melissa, Ellen	Gloria
Ft. Point			6B				2:10 PM	3:35 PM		3:00:00	14	4	6	13		
TOTAL						**31:30:00**				**19:05:00**	**96**	**10**	**80**	**80**		
PRIVATE BOATS																
Vallejo	12/9/98	Wed	11	1:00 PM	4:00 PM	3:00	1:40 PM	4:00 PM		2:20:00			5	5	Melissa	Diana
San Leandro	12/13/98	Sun	13	11:00 AM	4:00 PM	5:00	11:00 AM	4:00 PM		5:00			11	11	Cong, Ellen	
Oyster Point	1/3/99[2]	Sun	14	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM		3:00			4	4	Jeff, Sheila	
Richmond	12/18/98	Fri.	12	11:00 AM	4:00 PM	5:00	11:00 AM	2:00 PM		3:00:00			12	12	Yoko, Melissa, Alyce	Alyce
Loch Lomond	12/26/98[2]	Sat	15	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM		3:00			14	14	Cong, Melissa	
TOTAL						**19:00:00**				**16:20:00**			**46**	**46**		
PARTY BOATS																
San Pablo	12/19/98	Sat	21			0:00:00	7:00 AM	4:00 PM		9:00			13	13	Courtney	
TOTAL						**0:00**				**9:00:00**			**13**	**13**		
GRAND TOTAL						**50:30:00**				**44:25:00**			**139**	**139**		

*actual shift length includes travel time between site pairs
1Conflict with MRFSS Survey
2Reschedule due to weather
3Reschedule to finish site

Field Summary January 1999: Revised

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Candlestick	1/12/99	Tues	5B	12:00 PM	4:00 PM	4:00	2:00 PM	3:00 PM		0	0	1		Sheila,	100	
Oyster Pt.			5A				3:20 PM	4:20 PM	2:20:00	4	0	1	2	Jeff	100	
Coyote Point	1/18/99	Mon(H)	4B	8:00 AM	12:00 PM	4:00	8:00 AM	9:00 AM		0	0	0		Jeff,	Jeff,	
Dumbarton			4A				10:00 AM	11:45 AM	3:45:00	0	0	1	1	Cesar	Cesar	
McNears	1/6/98	Wed	7B	8:00 AM	12:00 PM	4:00	8:00 AM	9:00 AM		0	0	0		Sheila,	Sheila,	Gloria
Ft. Baker			7A				9:15 AM	10:15 AM	2:15:00	4	0	2	2	Melissa	Melissa	
Berkeley	1/23/98	Sat	2B	11:30 AM	4:30 PM	5:00	11:30 AM	1:00 PM		9	0	8		Angel,	Yoko	
Pt. Pinole			2A				2:00 PM	3:30 PM	4:00:00	14	0	10	18	Cesar	Cesar	
Alameda	1/10/99	Sun	3B	8:00 AM	12:00 PM	4:00	9:15 AM	10:15 AM		0	3	1		Melissa,	Melissa,	
Portview			3A				10:30 AM	11:45 AM	2:30:00	4	0	7	8	Jeff	Jeff	
Ft. Point	1/28/99	Thurs	6B	12:00 PM	4:00 PM	4:00	12:00 PM	1:00 PM		8	0	4		Angel,	Angel,	Gloria
Muni Pier			6A				1:20 PM	2:20 PM	2:20:00	6	0	5	9	Sheila	Sheila	
Martinez	1/17/98	Sun	1B	12:00 PM	4:00 PM	4:00	12:00 PM	1:00 PM		2	2	1		Melissa,	Melissa	
Vallejo			1A				1:20 PM	2:20 PM	2:20:00	0	0	2	3	Javier		
TOTAL						**29:00:00**			**19:30:00**	**51**	**5**	**43**	**43**			
PRIVATE BOATS																
Oyster Point	1/5/99	Tues	14	11:00 AM	4:00 PM	5:00	11:00 AM	4:00 PM	5:00			4	4	Jeff, Sheila		
Vallejo	1/9/99[1] and	Sat	11	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			4		Jeff, Cong	Jeff, Cong	
	1/16/99	Sat	11	2:30 PM	4:00 PM	1:30	2:30 PM					10	14	Jeff, Sheila	Jeff, Sheila	
Richmond	1/2/99[1] and	Sat	12	11:00 AM	4:00 PM	5:00	11:00 AM	2:00 PM				9		Jeff, Cesar	Jeff	
	1/8/99	Fri		2:00 PM	4:00 PM	2:00	2:00 PM	4:00 PM				0	9	Jeff, Melissa	Jeff, Melissa	
Loch Lomond	1/25/99	Mon	15	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			3	3	Angel, Quy		Gloria
TOTAL						**16:30:00**			**8:00:00**			**30**	**30**			
PARTY BOATS																
	1/23/99[2]	Sat								0		0	0			
	1/24/99[2]	Sun								0		0	0			
	1/30/99[2]	Sat								0		0	0			
	1/31/99[2]	Sun								0		0	0			
TOTAL									**0**	**0**		**0**	**0**			
GRAND TOTAL						**45:30:00**			**27:30:00**			**73**	**73**			

*actual shift length includes travel time between site pairs
1Reschedule due to weather
2 Attempts. Not able to get on boat due to denial and/or boat full.

Field Summary February 1999: Revised

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Vallejo	2/2/99	Tues	1A	8:00 AM	12:00 PM	4:00	8:00 AM	9:20 AM		2	0	2		Melissa	Melissa	
Martinez			1B				10:00 AM	11:00 AM	3:00:00	4	0	4	6	Angel	Angel	
Pt. Pinole	2/4/99	Thur	2A	7:30 AM	12:00 PM	4:30	9:00 AM	10:30 AM		2	3	2		Yoko	Ellen	
Berkeley			2B				11:00 AM	12:30 PM	3:30:00	7	3	9	11	Sheila	Sheila	
Muni Pier	2/15/99[1]	Mon (H)	6A	8:00 AM	12:00 PM	4:00	9:00 AM	10:00 AM			1	4		Javier	Javier	Gloria
Ft. Point			6B				10:30 AM	12:00 PM	3:00:00		7	19	23	Jeff	Jeff	
Dumbarton	2/17/98[2]	Tues	4A	12:00 PM	4:00 PM	4:00	1:00 PM	3:00 PM		13	1	11		Angel	Angel	
Coyote Point			4B				3:40 PM	4:15 PM	3:15:00	0	0	0	11	Jeff	Jeff	
Oyster Pt.	2/28/99[2]	Sun	5A	8:00 AM	12:00 PM	4:00	9:10 AM	10:10 AM		3	0	3		Cong	Angel	Gloria
Candlestick			5B				10:20 AM	11:50 AM	2:40:00	2	0	9	12	Quy	Jeff	
Portview	2/24/99	Wed	3A	12:00 PM	4:00 PM	4:00	12:40 PM	1:45 PM		4	0	4		Melissa	Melissa	
Alameda			3B				2:00 PM	3:00 PM	2:20:00	2	0	2	6	Yoko, Sheila	Yoko, Sheila	
Ft. Baker	2/27/99	Sat	7A	11:30 AM	4:30 PM	5:00	11:30 AM	1:00 PM		15	5	11		Melissa	Sheila	
McNears			7B				1:30 PM	2:30 PM	3:00:00	9	1	11	22	Cong	Cong	
TOTAL						**24:30:00**			**17:45:00**	**63**	**21**	**91**	**91**			
PRIVATE BOATS																
Loch Lomond	2/7/99	Sun	15	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			2	2	Javier, Ellen	Javier, Yoko	
Oyster Point	2/13/99	Sat	14	11:30 AM	4:30 PM	5:00	11:30 AM	4:30 PM	5:00			14	14	Jeff, Ellen	Jeff, Ellen	
San Leandro	2/15/99	Mon(H)	13	11:30 AM	4:30 PM	5:00	11:30 AM	4:30 PM	5:00			26	26	Yoko, Sheila	Yoko, Sheila	
Vallejo	2/22/99	Mon	11	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			9	9	Angel, Sheila	Angel, Jeff	Gloria
Richmond	2/23/99	Tues	12	11:30 AM	4:30 PM	5:00	11:30 AM	4:30 PM	5:00:00			3	3	Angel, Sheila	Angel, Sheila	
TOTAL						**13:00:00**			**13:00:00**			**54**	**54**			
PARTY BOATS																
	2/20/99[3]	Sat								0		0	0			
	2/21/99[3]	Sun								0		0	0			
	2/27/99[3]	Sat								0		0	0			
	2/28/99[3]	Sun								0		0	0			
TOTAL						**0:00**			**0:00:00**	**0**		**0**	**0**			
GRAND TOTAL						**37:30:00**			**30:45:00**			**145**	**145**			

*actual shift length includes travel time between site pairs
1Conflict with MRFSS Survey
2Reschedule due to weather
3Attempts. Not able to get on boat due to denial and/or boat full.

Field Summary March 1999

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census > 18 yrs. Old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Interviewers	On-site
Oyster Pt.	3/2/99	Tues	5A	8:00 AM	12:00 PM	4:00	8:10 AM	9:37 AM		3	0	3		Melissa	Melissa,	
Candlestick			5B				9:45 AM	10:45 AM	2:35:00	1	0	1	4	Sheila	Sheila	
Muni Pier	3/5/99	Fri	6A	8:00 AM	12:00 PM	4:00	8:00 AM	9:00 AM		2	0	3		Sheila	Angel	
Ft. Point			6B				9:10 AM	10:00 AM	2:00:00	4	3	4	7	Jeff	Adrienne	
Pt. Pinole	3/7/99	Sun	2A	7:30 AM	12:30 PM	5:00	7:30 AM	9:00 AM		1	0	1		Melissa	Melissa	
Berkeley			2B				10:00 AM	12:00 PM	4:30:00	17	5	15	16	Javier	Javier	
Vallejo	3/13/99	Sat	1A	8:00 AM	12:00 PM	4:00	9:00 AM	12:10 PM		13	1	17		Yoko	Yoko	
Martinez			1B				12:30 PM	1:00 PM	4:00:00	6	3	2	19	Angel	Angel	
Portview	3/27/99[1]	Sat	3A	12:00 PM	4:00 PM	4:00	12:00 PM	2:00 PM		13	9	7		Yoko	Yoko	
Alameda			3B				2:30 PM	4:15 PM	4:15:00	1	5	5	12	Jeff	Sheila	
Dumbarton	3/27/99	Sat	4A	12:00 PM	5:00 PM	5:00	12:00 PM	4:00 PM		4	4	8		Quy	Quy	
Coyote Point			4B				2:45 PM	3:00 PM	3:00:00	6	6	2	10	Cong	Cong	
Ft. Baker	3/30/99	Tues	7A	12:00 PM	4:00 PM	4:00	12:00 PM	1:45 PM		7	0	5		Sheila	Sheila	
McNears			7B				2:00 PM	3:00 PM	3:00:00	7	0	6	11	Ellen	Ellen	Gloria
TOTAL						**30:00:00**			**23:20:00**	**85**	**36**	**79**	**79**			
PRIVATE BOATS																
Vallejo	3/14/99	Sun	11	1:00 PM	4:00 PM	3:00	1:00 PM	2:15 PM				7		Javier,Angel	Javier, Angel	
	3/20/99[2]	Sat					2:00 PM	4:00 PM	3:00:00			18	25	Jeff, Sheila	Jeff, Sheila	
Oyster Point	3/23/99	Tues	14	12:00 PM	5:00 PM	5:00	12:00 PM	5:00 PM	5:00			4	4	Sheila, Ellen	Sheila, Ellen	
Loch Lomond	3/25/99	Thur	15	1:00 PM	4:00 PM	3:00	1:00 PM	4:00 PM	3:00			3	3	Melissa, Ellen	Mellisa,Jeff	Gloria
Richmond	3/28/99	Sun	12	12:00 PM	5:00 PM	5:00	12:00 PM	5:35 PM	5:35			10	10	Ellen, Yoko	Sheila, Melissa	
TOTAL						**16:00:00**			**16:35:00**			**42**	**42**			
PARTY BOATS																
Fisherman's Wharf	3/13/99[3]	Sat	23							0		0	0	Courtney	Courtney	
Fisherman's Wharf	3/14/99[4]	Sun	23							0		0	0	Courtney	Courtney	
San Pablo	3/14/99[5]	Sun	21			0:00:00				0		0	0	Courtney	Courtney	
TOTAL						**0:00**			**0:00**	**0**		**0**	**0**			
GRAND TOTAL						**46:00:00**			**39:55:00**			**121**	**121**			

*actual shift length includes travel time between site pairs

1Conflict with MRFSS Survey

2Continued 3/14/99 site

3Trip cancelled. No fishers.

4Trip cancelled, bad wheather

5No response to phone inquiries.

Field Summary April 1999

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Actual Shift Length Total	Census >18 yrs. Old	Census<18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Inter-viewers	On-site
Candlestick	4/30/99[1]	fRI	5B	1:00 PM	6:00 PM	5:00	1:00 PM	1:50 PM			10	1	5		Sheila, Jeff	Sheila,	
Oyster Pt.			5A				2:00 PM	3:00 PM		2:00:00	10	2	6	11		Gloria	Gloria
Coyote Point	4/2/99	Fri	4B	8:00 AM	12:00 PM	4:00	8:00 AM	9:30 AM			2		2		Sheila	Sheila	
Dumbarton			4A				10:00 AM	11:00 AM		3:00:00	0		1	3	Ellen		
McNears	4/18/99	Sun	7B	8:00 AM	1:00 PM	5:00	8:00 AM	9:30 AM			5	0	3		Javier	Javier	Gloria
Ft. Baker			7A				10:00 AM	11:00 AM		3:00:00	4	5	3	6	Angel,	Sheila, Ellen	
Berkeley	4/22/99	Thur	2B	1:00 PM	6:00 PM	5:00	1:00 PM	2:30 PM	1:30:00		8	8	9		Sheila	Sheila,Gloria	Gloria
Pt. Pinole	5/6/99[2]	Thur	2A				1:00 PM	2:30 PM	1:30:00	3:00:00	5	0	2	11	Ellen		
Alameda	4/9/99	Fri	3B	8:00 AM	1:00 PM	5:00	8:00 AM	9:00 AM			0	0	0		Angel,	Angel, Melissa	
Portview			3A				9:15 AM	10:40 AM		2:40:00	0	0	0	0	Melissa		
Ft. Point	4/4/99	Sun	6B	1:00 PM	7:00 PM	6:00	1:40 PM	3:05 PM			2	0	4		Jeff,	Jeff	
Muni Pier			6A				3:20 PM	4:25 PM		2:45:00	9	2	9	13	Javier	Javier	
Martinez	4/29/99	Thur	1B	1:00 PM	5:00 PM	4:00	1:00 PM	2:05 PM			8	0	6		Melissa	Melissa	
Vallejo			1A				2:25 PM	4:00 PM		3:00:00	14	0	10	16	Sheila	Sheila	Gloria
TOTAL						**34:00:00**				**19:25:00**	**77**	**18**	**60**	**60**			
PRIVATE BOATS																	
Oyster Point	4/3/99	Sat	14	12:00 PM	5:00 PM	5:00	10:00 AM	3:00 PM	5:00				0	0	Jeff, Yoko	Jeff, Yoko	
San Leandro	4/10/99	Sat	13	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00				1	1	Cong, Quy		
Vallejo	4/15/99	Thurs	11	1:00 PM	6:00 PM	5:00	2:00 PM	7:00 PM	5:00				12	12	Jeff, Angel	Jeff, Angel	Gloria
Loch Lomond	4/17/99	Sat	15	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00				9	9	Angel, Yoko	Sheila, Jeff	Gloria
Richmond	4/28/99	Wed	12	1:00 PM	6:00 PM	5:00	1:00 PM	3:00 PM					1		Ellen, Jeff	Jeff, Sheila	
	5/7/99[2]	Fri					4:00 PM	6:00 PM	5:00:00				1	2		Sheila, Angel	
TOTAL						**21:00:00**			**16:00:00**				**24**	**24**			
PARTY BOATS																	
Emeryville	4/3/99[3]	Sat	22										0	0		Courtney	Alyce
San Pablo	4/10/99[3]	Sat	21										0	0		Courtney	Diana
Fisherman's Wharf	4/17/99[4]	Sat	23										0	0		Courtney	Gloria
Fisherman's Wharf	4/18/99[5]	Sun	23						24:00:00				0	0		Courtney	Gloria
TOTAL													**0**	**0**			
GRAND TOTAL						**55:00:00**				**19:25:00**			**84**	**84**			

*actual shift length includes travel time between site pairs
1Reschedule due to weather
2 Reschedule to finish site
3Exit Interview,cancelled, weather
4 Attempt, cancelled: no fishers
5 Attempt, cancelled: no interviewers.

Field Summary May 1999

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. old	Census <18 yrs. Old	Attempts	Total Attempts per site pair	Inter-viewers	Actual Interviewers	On-site
Oyster Pt.	5/20/99[1]	Thur	5A	1:00 PM	6:00 PM	5:00	1:00 PM	2:00 PM		0		3		Sheila	Sheila	Gloria
Candlestick			5B				2:15 PM	2:45 PM	1:45:00	0		1	4	Jeff	Jeff	
Muni Pier	5/4/99	Tue	6A	1:00 PM	7:00 PM	6:00	12:00 PM	1:00 PM		8	0	10		Sheila	Sheila	Gloria
Ft. Point			6B				1:20 PM	2:00 PM	2:00:00	5	0	4	14	Ellen	Melissa	
Pt. Pinole	6/5/99[1]	Sat	2A	12:30 PM	7:00 PM	6:30	11:30 AM	1:30 PM		9	1	10				Gloria
Berkeley			2B				1:45 PM	3:30 PM	4:00:00	56	23	22	32	Yoko,Quy,Angel	Jeff, Sheila, Gloria,	
Berkeley	6/13/99[2]	Sun	2B				12:30 PM	2:50 PM	2:20	56		40	40		Javier, Melissa, Jeff, Sheila, Gloria	Gloria
Vallejo	5/2/99	Sun	1A	1:00 PM	7:00 PM	6:00	1:00 PM	2:30 PM		6	1	6		Jeff, Ellen	Jeff, Ellen	
Martinez			1B				2:50 PM	3:00 PM	2:00:00	7	0	7	13	Javier	Javier	
Portview	5/9/99	Sun	3A	8:00 AM	1:00 PM	5:00	8:00 AM	9:30 AM		3	3	2		Javier	Javier	
Alameda			3B				9:45 AM	11:45 AM	3:45:00	6	0	7	9	Cong	Cong	
Dumbarton	5/22/99	Sat	4A	8:00 AM	1:00 PM	5:00	9:00 AM	10:30 AM		9	0	8		Quy	Quy	
Coyote Point			4B				11:30 AM	1:00 PM	4:00:00	7	1	6	14	Cong	Cong	
Ft. Baker	5/27/99	Thur	7A	8:00 AM	1:00 PM	5:00	8:30 AM	9:30 AM		3	0	3		Sheila	Sheila	Gloria
McNears			7B				9:50 AM	10:50 AM	2:20:00	8	0	8	11	Angel	Angel	
TOTAL						**17:30:00**			**12:05:00**	**183**	**29**	**137**	**137**			
PRIVATE BOATS																
Vallejo	5/16/99	Sun	11	1:30 PM	6:30 PM	5:00	1:30 PM	6:30 PM	5:00			13	13		100 Javier, Jeff, Quy	
Oyster Point	5/11/99	Tues	14	1:30 PM	6:30 PM	5:00	1:15 PM	5:40 PM	4:25:00			3	3		100 Ellen, Angel	
Loch Lomond	5/5/99	Wed	15	4:00 PM	7:00 PM	3:00	4:00 PM	7:00 PM	3:00			0	0	Melissa, Ellen	Melissa, Ellen	Gloria
Richmond	5/8/99	Sat	12	1:30 PM	6:30 PM	5:00	1:30 PM	6:30 PM	5:00			10	10	Yoko, Jeff, Melissa	Yoko, Jeff, Melissa	
TOTAL						**8:00:00**			**8:00:00**			**26**	**26**			
PARTY BOATS																
Fisherman's Wharf	5/15/99[3]	Sat.	23							0		0	0	Courtney	Courtney	
Fisherman's Wharf	5/16/99	Sun	23				5:30 AM	7:30 AM	2:00	10		7	7	Courtney	Courtney	
Fisherman's Wharf	5/22/99[3]	Sat.	23							0		0	0	Courtney	Courtney	
Fisherman's Wharf	5/23/99[3]	Sun	23							0		0	0	Courtney	Courtney	
TOTAL										**10**		**7**	**7**			
GRAND TOTAL												**170**	**170**			

*actual shift length includes travel time between site pairs
1Conflict with MRFSS Survey
2 Rescheduled to finish 6/5/99 Berkeley site.
3 Attempts. Not able to get on boat due to denial and/or boat full.

Field Summary June 1999, Revised

SITE	Date	Day of Week	Site No.	Start Time	End Time	Shift Length	Actual Start	Actual End	Actual Shift Length*	Census >18 yrs. Old	Census<18 yrs. Old	Attempts	Total Attempts per site pair	Interviewers	Actual Interviewers	On-site
Candlestick	6/13/99[1]	Sun	5B	7:00 AM	1:00 PM	6:00	9:00 AM	11:15 AM		8	2	9		Javier, Yoko	Javier	
Oyster Pt.	7/11/99[2]	Sun	5A				11:35 AM	12:45 PM	3:45:00			8	17	Javier, Yoko	Yoko, Sheila	
Coyote Point	6/30/99	Wed	4B	2:00 PM	7:00 PM	5:00	2:15 PM	3:15 PM		1	12	3		Sheila	Sheila	
Dumbarton			4A				3:35 PM	4:00 PM	1:45:00	0	3	2	5	Gloria	Javier	Gloria
McNears	6/6/99	Sun	7B	1:00 PM	7:00 PM	6:00	1:00 PM	3:00 PM		20	4	5		Javier,Jeff	Javier, Jeff	
Ft. Baker			7A				4:00 PM	7:00 PM	6:00:00	13	5	17	22	Yoko	Yoko	
Berkeley	6/9/99	Wed	2B	7:30 AM	1:30 PM	6:00	7:25 AM	8:35 AM		3	0	5		Jeff	Jeff	Gloria
Pt. Pinole			2A				9:00 AM	10:00 AM	2:35:00	0	0	0	5	Adrienne	Gloria	
Alameda	6/25/99	Fri	3B	1:30 PM	7:30 PM	6:00	1:30 PM	2:45 PM				3		Melissa	Melissa	
Portview			3A				3:00 PM	4:00 PM	2:30:00			5	8	Adrienne	Sheila	
Ft. Point	6/20/99	Sun	6B	7:00 AM	1:00 PM	6:00	8:00 AM	9:00 AM		5	0	4		Javier	Javier, Jeff	
Muni Pier			6A				9:10 AM	10:10 AM	2:10:00	3	2	2	6	Jeff		
Martinez	6/8/99	Tues	1B	8:00 AM	1:00 PM	5:00	8:00 AM	9:00 AM		2	0	2		Jeff	Jeff	
Vallejo			1A				9:30 AM	10:20 AM	2:20:00	7	0	7	9	Sheila	Sheila	
TOTAL						**40:00:00**			**21:05:00**	**62**	**28**	**72**	**72**			
PRIVATE BOATS																
Oyster Point	6/20/99[3]	Sun	14	4:00 PM	7:00 PM	3:00	4:00 PM	7:00 PM	3:00			13	13	Cong,Quy		
San Leandro	6/19/99	Sat	13	2:00 PM	5:00 PM	3:00	2:00 PM	5:00 PM	3:00			11	11	Quy, Jeff	Quy, Jeff, Cong	
Vallejo	6/15/99	Tues	11	2:00 PM	7:00 PM	5:00	2:00 AM	7:00 AM	5:00			24	24	Jeff, Sheila	Jeff, Sheila	
Loch Lomond	6/26/99	Sat	15	2:00 PM	4:00 PM	2:00	2:00 PM	4:00 PM	2:00			7	7	Cong, Melissa	Cong, Melissa	Gloria
Richmond	6/23/99	Wed	12	2:00 PM	7:00 PM	5:00	12:00 PM	3:00 PM				9		Sheila, Jeff		
	7/8/99[2]	Thurs	12				5:00 PM	7:00 PM				3	12			
TOTAL						**18:00:00**			**#REF!**			**67**	**67**			
PARTY BOATS																
Fisherman's Wharf	6/19/99	Sat	23									0	0	Courtney		
Fisherman's Wharf	6/20/99	Sun	23									10	10	Courtney	Gloria, Courtney	Gloria
Fisherman's Wharf	7/11/99	Sun	23									0	0	Courtney	Courtney, Sheila	
TOTAL									**0**	**0**		**10**	**10**			
GRAND TOTAL						**58:00:00**			**#REF!**			**149**	**149**			

*actual shift length includes travel time between site pairs

1Conflict with MRFSSS Survey

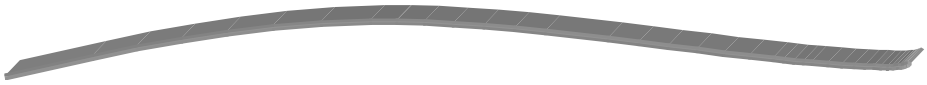
2 Reschedule to finish site

3 Reschedule to accommodate interviewers schedule

Appendix I

Coding for Text Entries

San Francisco Bay Seafood Consumption Study



Appendix I -Text Coding Key
Revised 12/5/00

Q1b Reason for declining interview
Coding of text box responses for "other"
5 = not interested; didn't want to
6 = said information would be same as another respondent
7 = just leaving
8 = first time fisher
9 = doesn't eat fish
10 = other (out of state, etc.)

Q1c Observed ethnicity of decliners
Coding of text box responses for "other"
(recode according to Q1c categories as appropriate)
8 = other Asian (other than Korean, SE Asian, e.g., Japanese)
10 = SE Asian other than Vietnamese
11 = Russian
12 = Korean

Q1d Language of decliners
Coding of text box responses for "other"
8 = other Asian other than Korean, SE Asian
10 = SE Asian other than Vietnamese
11 = Russian
12 = Korean

Q5 Disposition of catch
Coding of text box responses for "other (specify)"
1 = feed to animals, birds, etc.
2 = give to restaurants
3 = eat occasionally, eat only some fish (recode Q5 as "eat it" for angler's response)

Q11-Q13 Consumption Practices of White Croaker, Leopard Shark, and Striped Bass
Anglers who reported that they followed consumption practices (skin, cooking juices, guts, soup, raw) half the time were recorded as "more than half the time."

Q14 Species of fish not listed and for which picture were not available
1 = salmon (included in SF Bay fish consumption)
2 = SF Bay advisory species (included in SF Bay fish consumption)
3 = other fish not from SF Bay (e.g., red snapper, any freshwater fish)
4 = commercial fish
5 = SF Bay shellfish (crab, mussels, clams) (included in SF Bay shellfish consumption)
6 = non-SF Bay shellfish (squid, shrimp, oysters)

Q17 Who cooks or prepares Bay fish
Coding of text box responses for "family member (specify)"
1 = mother/parent/grandparent
2 = wife/partner/spouse/husband
3 = other (daughter, child, nephew, brother, roommate, sister, girlfriend, etc.)

Coding of text box responses for "other (specify)"
1 = roommate, girlfriend, boyfriend
2 = other (anybody, whoever catches)

Q19 Fish consumption from areas outside SF Bay

Coding of text box responses for "other" (recode to Q19 categories as appropriate)
1 = out of state
2 = not specific CA location
3 = unknown

Q23-Q24 Awareness and comprension of health advisory

To determine whether anglers were aware of the health advisory and their understanding of the advisory, we asked a two-part question. In the first part (Q23), we asked anglers if they had heard or seen health advisory information about eating Bay fish. We then recorded whether the respondent said Yes, No, Don't Know, or refused to answer. In the second part (Q24), we assessed the anglers' comprehension of the health advisory by asking "What did the information say about fish from the Bay?" (We excluded respondents who answered no to the first part). Responses were categorized in the following ways:

Q24 What did information say?

Coding of text responses
1 = Did not express an awareness of current Bay fish advisory
2 = Expressed some knowledge of contaminated fish or waters respondents may have implied awareness of health protective measures, but did not actively state any. (i.e. make you sick, possible kill)
3 = Expressed some knowledge of health protective recommendations
4 = Answered regarding shellfish, not current fish advisory

Respondents who showed no awareness of the current advisory in the second part of the question (Q24) were re-categorized as having no awareness in the first part (Q23). This recategorization of awareness resulted in a 4% drop in awareness across respondent groups, as shown in Table I.1 below. The recategorized response was used for the analysis presented in Section IV.E.

Table I.1. Comparison of Claimed and Actual Awareness of Health Advisory

	RESPONDENTS N=1227*		CONSUMERS N=1054*		NON-CONSUMERS N=173*	
	No.	%	No.	%	No.	%
Claimed to be Aware of Health Advisory in First Part of Questions	771	63	657	62	325	66
Actually Aware of Health Advisory Based on Recategorization in Second Part of Question	722	59	616	58	106	61

*Party boat anglers were excluded because they were not asked health advisory questions.

Q24b Changes in fish eating habits

Coding of text responses for "other (specify)"
1= Claimed to have stopped eating Bay-caught fish entirely after hearing of advisory
2 = Claimed to have engaged in a health protective measures after hearing of advisory. Health protective measures include eating less, preparing or cooking food in a protective manner, and eating different species of fish.
3 = Claimed to eat only uncontaminated fish after hearing of advisory
4 = Claimed not to have consumed above the limit before hearing of advisory. Respondents replied either that they didn't eat much before, or didn't eat any before learning of the advisory.
5 = Does not believe contamination poses a significant problem
6 = Generally no, have not changed behaviors after hearing of advisory
7 = Not specific to current Bay fish advisory

Q25 Best way for angler to get information

Coding of text responses for "other (specify)"
1 = one-on-one contact from educator, includes Department of Fish and Game, interviewers, others
2 = Direct mailings to fishers
3 = Information in bait & sports shops
4 = Internet
5 = Fish and Game
6 = other/miscellaneous

Q26 Ethnicity

Coding of text responses for "Pacific Islander (specify)"
1 = Guamanian
2 = Samoan
3 = Hawaiian

Coding of text responses for "Other Asian (specify)"
1= South East Asian (other than Vietnamese)
2 = other mixed Asian
3 = Japanese
4 = Korean

Coding of text responses for "Other (specify)"
1 = mixed ethnicity (unspecified)
2 = Russian
3 = Middle Eastern

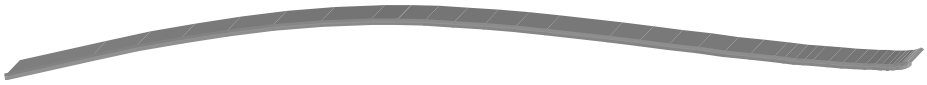
If an angler reported mixed ethnicity, for example African American and Chinese, he was coded using the first listed ethnicity (African American).

If respondent refused to answer Q26 (ethnicity), interviewers recorded observed ethnicity. Where possible, Q26 responses were recoded.

Appendix J

Defining Consumers and Derivation of Consumption Rates

San Francisco Bay Seafood Consumption Study



Appendix J - Defining Consumers and Deriving Consumption Rates

In this appendix we provide a more detailed discussion of how two groups, consumers and recent consumers, were defined and how consumption rates were calculated in this study. We also describe the shape of the consumption rate distribution and discuss why the consumption rate data were log transformed. Finally, we discuss how consumption rates were weighted across modes.

A. Definition of Consumers

One of the study's central goals was to characterize the population that is exposed to chemicals from consumption of Bay fish. Thus, we have focused much of our analysis and discussion on the subset of the angler population called consumers. Consumers are anglers who reported that they eat Bay fish. Anglers who reported that they do not eat Bay fish (i.e., non-consumers) were excluded from the consumer group.

To define a consumer, we looked at responses to several questions. Respondents were first asked a single, general question (Appendix E, Question 6a): "Do you eat fish that you or someone you know catches from the SF Bay?" They were then asked a series of question about whether they ate specific species of Bay fish (Questions 11-14). We attempted to define consumers as inclusively as possible. Anglers who reported they ate Bay fish in any of the above questions were defined as consumers. Some anglers, however, provided inconsistent responses to these questions. For example, they answered no to the general question, but when asked about specific species of fish, they answered yes to at least once species. Anglers with inconsistent responses were defined as consumers if any of their responses indicated that they ate SF Bay fish.

The one exception to this definition was the angler's responses to the survey question (Question 5) that asked what the angler usually did with the fish he or she caught from SF Bay. Respondents could indicate that they usually ate the fish, gave it to family or friends, traded or sold it, etc. This question was never used to determine whether an angler was a consumer or not because this questions was less reliable than subsequent questions. In other words, if an angler answered this question by indicating he or she usually ate the fish he caught, but later in the survey did not report eating Bay fish or did not identify that he or she ate specific species of Bay fish, he was defined as a non-consumer of Bay fish.

The shaded area of Table J1 describes the survey questions and possible responses that were used to categorize respondents as consumers. Out of 1331 respondents, 179 anglers were categorized as non-consumers. The remaining 1152 anglers we defined as consumers. Most consumers (961 or 83%) provided consistent responses to questions on whether they ate Bay fish. Some consumers (153 or 13%) who answered inconsistently but were still categorized as consumers. In addition, a small number of anglers who were fishing for the first time and (38 or 3%) reported that they planned to consume their catch were also included as consumers even though they had no past consumption of Bay fish.

Table J1. Definition of Consumers (Shaded Areas) N=1152

		Eats specific species of Bay fish (Questions 11-14)		
		Yes	No[a]	
Eats Bay fish (Question 6a)	Yes	961	96	
	No[a]	57	Non-consumers= 179	
			First-time fishers=38[b]	
				1331 Respondents

[a] respondent could also have answered don't know, refused to answer, or the response could have been missing

[b] Anglers who were fishing for the first time and also planned to consume their catch.

B. Definition of Recent Consumer

Recent consumers are defined as: 1) a subset of consumers, and 2) anglers who reported eating Bay fish in the last four weeks. Consumers were first asked a single, general question (Question 8a): "In the last four weeks, did you eat fish that you caught or someone you know caught from the SF Bay?" Then they were asked a series of question on whether they had eaten specific species of fish from SF Bay in the last four weeks. (Questions about whether the angler reported recent consumption of specific species of Bay fish were asked in Questions 11-14). The definition of recent consumers was not analogous to the definition of consumers. If anglers reported recent consumption of any specific species of Bay fish in the last four weeks they were defined as recent consumers; the general question (Q8a) was never used to define recent consumers (Table J2). Out of 1152 consumers, 537 were defined as recent consumers.

It should be noted that consumption rates (based on a four week recall) could not be derived for all 537 anglers who were defined as recent consumers. This occurred because some recent consumers provided incomplete information on their consumption rates. For example, some anglers reported that they had recent consumption of specific species of Bay fish yet they did not report the number of time they consumed that species in the previous four weeks (meal frequency). Also some recent consumers did not provide information on their portion size. Both meal frequency and portion size were needed to calculate a consumption rate. As a result, consumption rate estimates could only be derived for a subset of recent consumers (n=501). In addition, some anglers failed to report information on their fishing frequency, which was used to adjust data for avidity bias. Thus, avidity bias adjusted consumption rate data could only be estimated for an even smaller subset (n=465).

Table J2. Definition of Recent Consumers (Shaded Areas) N=537

		Ate specific species of Bay fish in the last four weeks (Questions 11-14)		
		Yes	No[a]	
Ate Bay fish in the last four weeks (Question 8a)	Yes	445	43	
	No[a]	92	572	
				1152 Consumers

[a] respondent could also have answered don't know, refused to answer, or the response could have been missing

C. Deriving Consumption Rates Based on a 4 Week Recall

As discussed in the previous section, anglers could be defined as recent consumers in two ways: 1) based on a single general question or 2) based on a series of questions about specific fish species. Similarly, consumption rates (based on a 4 week recall) could be derived in two ways. The questionnaire allowed for consumption rates to be derived in two ways, from the single general question (Q8a), or consumption rates could be derived by summing the total number of times the anglers ate specific species of Bay fish in the last four weeks. When we compared the distributions for these two consumption rates, we found them to be very similar. The correlation between the two consumption rates was high (n=424, r=0.78).

Rather than present two similar consumption rate results based on a four-week recall in the report, we chose to limit our analyses to the consumption rate derived by summing individual species. We selected this rate for two reasons. First by asking respondents about specific species with the aid of color pictures, we may have helped the respondent to remember all species that had been eaten. In fact, more respondents reported a consumption rate based on the sum of individual species (n=501) compared to the consumption rate based on a single question (n=435). Second, we wanted to calculate consumption rates based on only advisory species. This consumption rate could only be derived using species specific consumption rates.

D. Shape of the Consumption Rate Distribution

Estimation of population means and statistical tests of consumption rate differences between groups assume normal distributions in each group being compared. Statistical tests are generally reliable as long as the normality assumption is not badly violated (Kleinbaum, Kupper, and Muller 1988, Armitage and Berry 1987). We used a number of approaches to assess how the consumption rate data reported in Section IV.D.1 were distributed and whether they required transformation. Following Hill's (1995)

methodology, we found that the standard deviations were larger than the mean, which indicates a high degree of variability in the distribution. The standard deviation is usually a fraction of the mean in a normal distribution (Table J3). The skewness and kurtosis, which are indicators of normality, were positive. Both are zero in a normal distribution. A positive skewness indicates a distribution with a tail to the right. A positive kurtosis indicates heaviness of the tails. The geometric mean is much closer to the median than is the arithmetic mean, indicative of a log normal distribution.

Table J3. Descriptive Statistics of SF Bay Fish Consumption Rate (g/d) (Unadjusted)

	4 week Recall	12 Month Recall
	N=501	N=1019
Mean (Standard Deviation)	28.0 (39.5)	11.0 (35.7)
Geometric Mean	16.5	1.2
Median	16.0	2.5
Skewness	3.9	7.4
Kurtosis	19.9	70.9

Figures J1a and J1b show histograms of the distribution of consumption rate for recent consumers of SF Bay fish based on a four week recall. Above each histogram is a normal quantile plot (SAS JMP 2000), in which points derived from a normal distribution will lie along the diagonal line, or at least within the dotted-line confidence bounds. In Figure J1a, the distribution of consumption rate is grossly non-normal, and has the long upper tail characteristic of a lognormal distribution. In Figure J2b, applying a log transformation to the data markedly improves the fit to the normal distribution, as nearly all points lie within the confidence bounds of the normal quantile plot.

Because the SF Bay angler population is comprised of different ethnic groups whose consumption rate distributions may be distinct, the distribution of the total combined data may not be lognormally distributed, even if the subgroups are. We therefore examined these distributions for the major ethnic groups in Figures J2 to J5. Similar to the overall consumption rate distribution of recent consumers, the major ethnic groups show grossly non-normal consumption rate distributions and applying the log transformation greatly improves the fit to the normal distribution. As would be expected, the log transformed data for the individual ethnic groups fit the normal distribution better than the data for the overall population of recent consumers.

More complicated transformations (such as the negative reciprocal of the 10^{th} root) were found to improve the normal distribution fit slightly for some of the ethnic groups. But for ease of presentation, consistency across groups, familiarity, and comparison to other

studies, the natural log transformation was used for the overall population of recent consumers and all of the ethnic groups.

Figure J1a. Consumption Rate of Recent Consumers (n = 501)

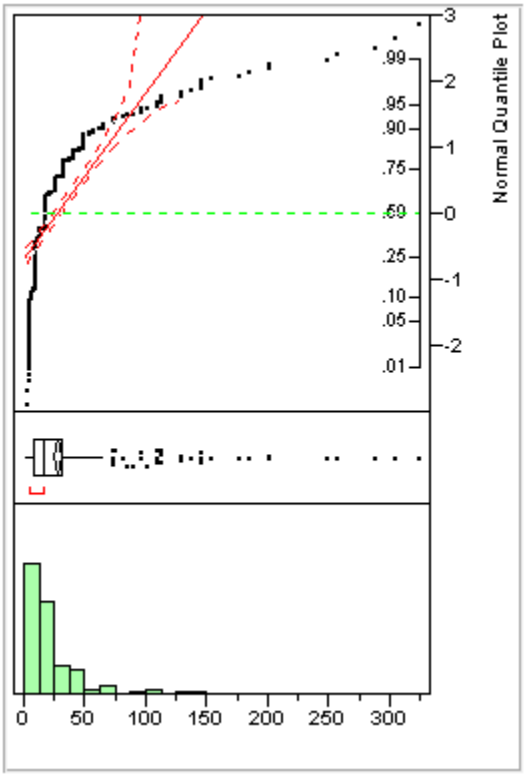


Figure J1b. Log Consumption Rate of Recent Consumers (n=501)

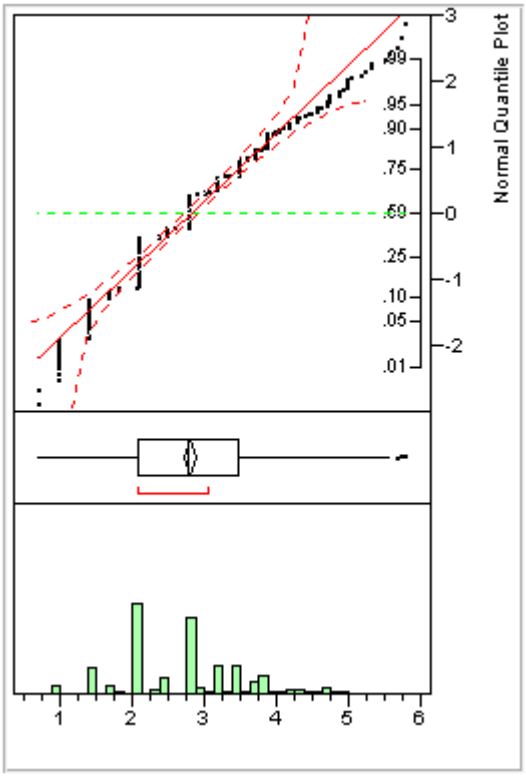


Figure J2a. African-American Consumption Rate (n = 43)

Figure J2b. Log African American Consumption Rate (n=43)

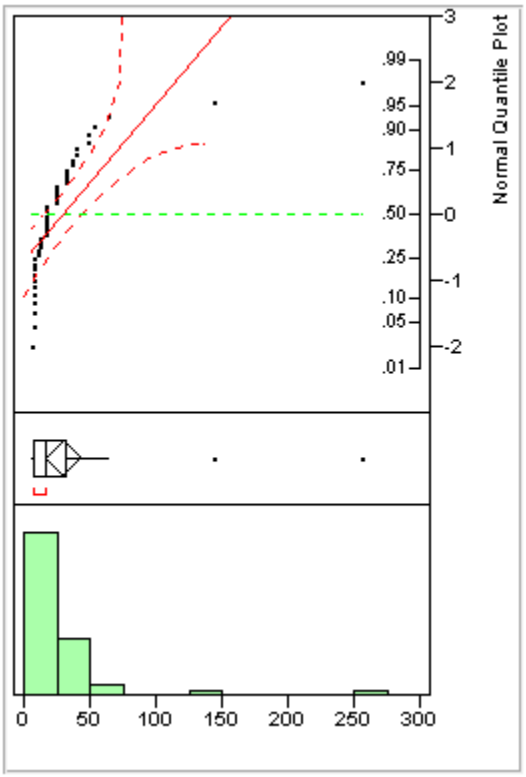


Figure J3a. Asian Consumption Rate (n = 213)

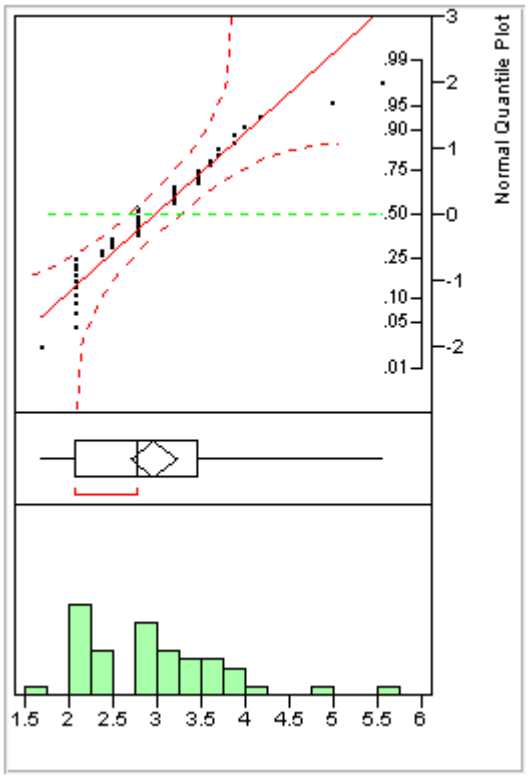


Figure J3b. Log Asian Consumption Rate (n=213)

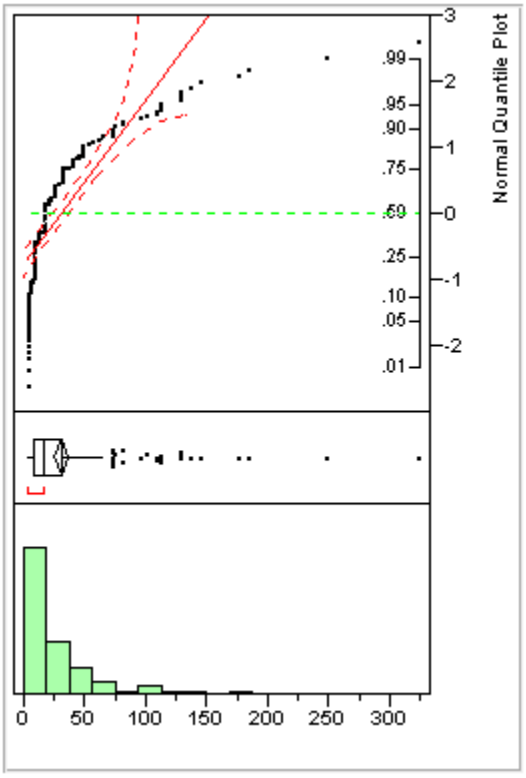


Figure J4a. Caucasian Consumption Rate (n = 163)

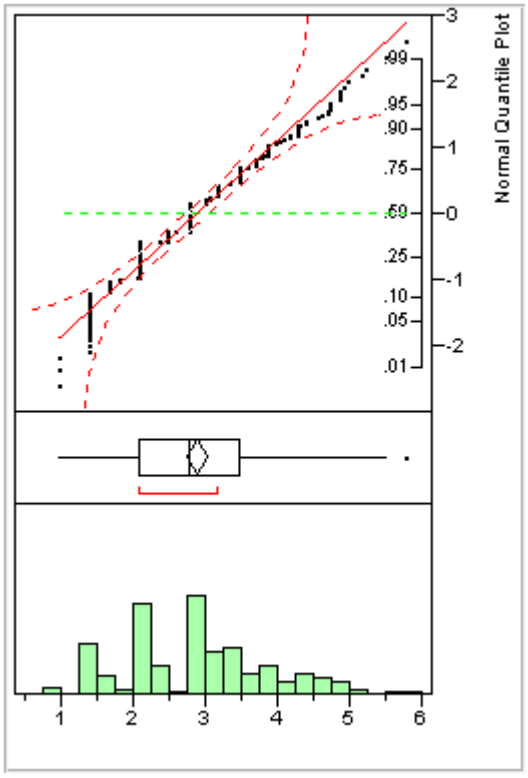


Figure J4b. Log Caucasian Consumption Rate (n=163)

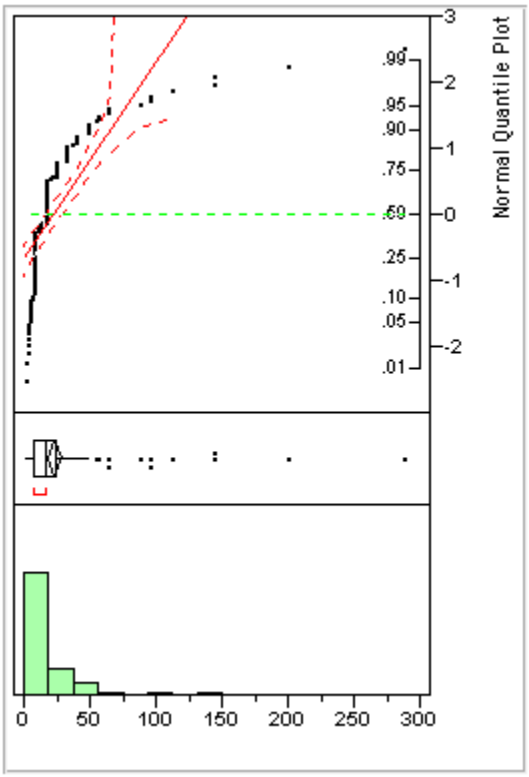


Figure J5a. Latino Consumption Rate (n = 56)

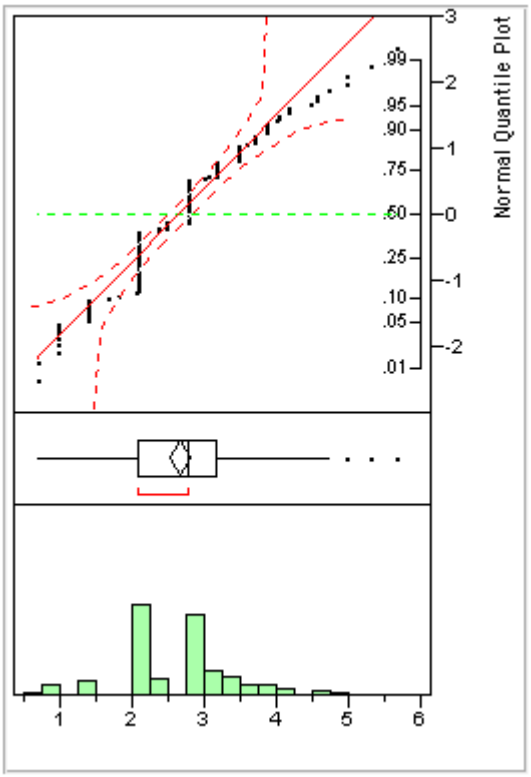
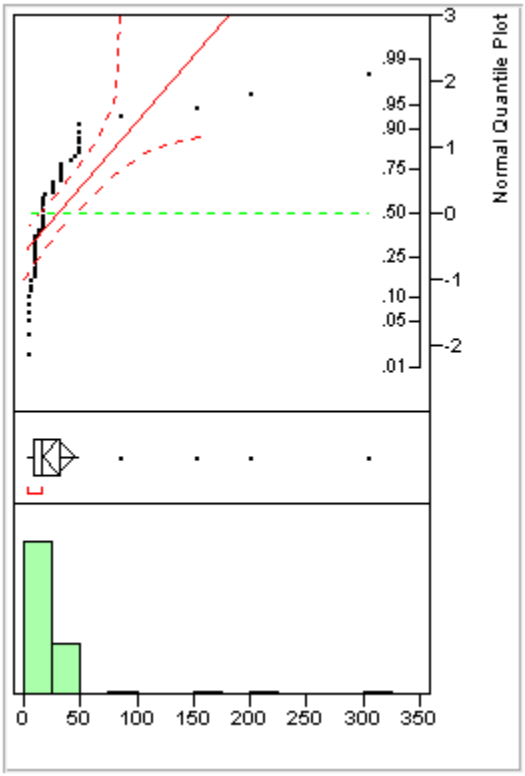
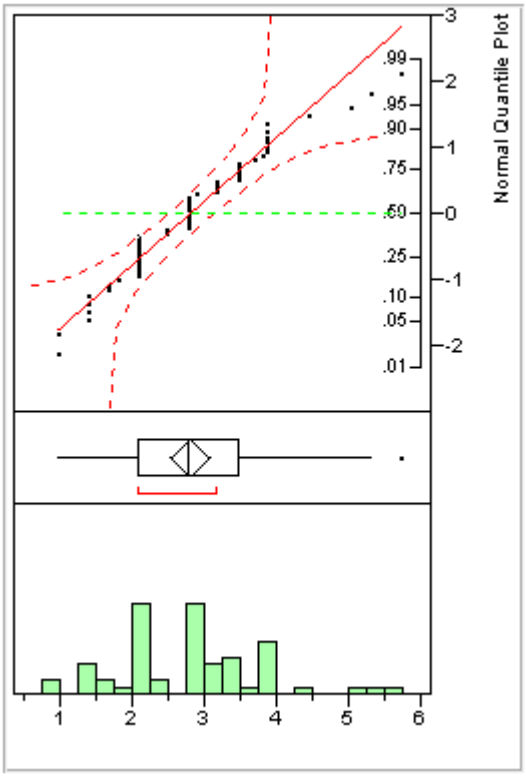


Figure J5b. Log Latino Consumption Rate (n=56)





E. Consumption Rate Estimate Weighted by Mode

In the sampling plan, we sought to derive consumption rates that could be applied across all fishing modes. To do this, we set sampling targets for the fishing modes that were based on estimates of the relative amount of fishing activity in those modes, shown in Table J4. (This was also discussed in Section II.B.3 and Appendix D). Consumption rate estimates for recent consumers reported in Table 4 (of the report) were based on a sample of recent consumers that was slightly different than the original sampling targets. As shown in Table J4, we planned to interview more shore-based and party boat anglers, and fewer private boat anglers, than we actually did.

Table J4. Sample Target Interviews by Mode Compared to Actual Sample

Mode	Sampling Target Interviews Based on Fishing Activity	Actual Sample of Recent Consumers	
	N=500	Unadjusted N=501	Adjusted N=465
Shore-Based	62%	58.3%	57.0%
Private Boat	28%	34.3%	35.0%
Party Boat	10%	7.4%	8.0%
Total	100%	100%	100%

To determine if differences by mode between the sampling targets and the actual sample could have caused any bias in consumption rate, we recalculated consumption rates by weighting the geometric means for each mode by the sample targets (Table J5).

Table J5. Consumption Rate Weighted by Sample Targets for Fishing Mode

Mode	Unadjusted Geometric Mean Consumption Rate (g/d)	Avidity Bias Adjusted Geometric Mean Consumption Rate (g/d)
Unweighted by Mode	16.5	14.0
Weighted by Sample Targets Based on the Relative Fishing Activity for Each Mode	16.5	14.1

We found that the consumption rates weighted by the sample targets are nearly identical to the original, unweighted values. We conclude that there is no bias in consumption rate due to differences between the sampling targets and the actual sample.

Appendix J References

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Hill, Martin (1995). Comparing Michigan Freshwater Fish Consumption with California Saltwater Fish Consumption: A Modified Replication of Murray and Burmaster (1994). Memo to J. Pollock and M. Gassell.

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Appendix K

Data Tables for Section IV Results

San Francisco Bay Seafood Consumption Study

Appendix K- Data Tables for Section IV. Results

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Table K1. Declines by Mode (unadjusted)

A. Reason for Declining	Pier		Beach and Bank		Private Boats		Party Boats		Total	
	n	%	n	%	n	%	n	%	n	%
Language Problem	125	44	7	25	9	11	3	37	144	35
No Time	64	22	8	29	54	66	3	37	129	32
Not Interested	52	18	9	32	7	9	1	13	69	17
Other	27	9	2	7	8	8	1	13	38	9
Missing/Don't Know	20	7	2	7	5	6	0	0	27	7
Total	288	100	28	100	83	100	8	100	407	100

B. Observed Ethnicity of Decliners (major groups)	Pier		Beach and Bank		Private Boats		Party Boats		Total	
	n	%	n	%	n	%	n	%	n	%
African American	12	4	1	4	3	4	0	0	16	4
Latino/Hispanic	16	5	7	27	7	9	0	0	30	7
Caucasian	52	17	4	15	47	64	5	64	108	27
Asian	171	58	14	54	16	22	3	36	204	50
Native American	1	0	0	0	0	0	0	0	1	0
Missing/Don't Know	47	16	0	0	1	1	0	0	48	12
Total	299	100	26	100	74	100	8	100	407	100

C. Observed Ethnicity of Decliners (with Asian subgroups)	Pier		Beach and Bank		Private Boats		Party Boats		Total	
	n	%	n	%	n	%	n	%	n	%
African American	12	4	1	4	3	4	0	0	16	4
Latino/Hispanic	16	5	7	27	7	9	0	0	30	7
Caucasian	52	17	4	15	47	64	5	64	108	27
Chinese	38	13	3	12	2	3	1	12	44	11
Filipino	39	13	0	0	2	3	1	12	42	10
Vietnamese	33	11	8	31	6	8	0	0	47	12
SouthEast Asian (not Vietnamese)	4	2	1	4	0	0	0	0	5	1
Korean	18	6	0	0	0	0	0	0	18	4
Asian - unknown	39	13	2	7	6	8	1	12	48	12
Native American	1	0	0	0	0	0	0	0	1	0
Missing/Don't Know	47	16	0	0	1	1	0	0	48	12
Total	271	91	18	69	64	87	8	100	361	89

D. Observed Language of Decliners	Pier		Beach and Bank		Private Boats		Party Boats		Total	
	n	%	n	%	n	%	n	%	n	%
English	117	38	10	42	61	88	5	64	193	48
Spanish	8	3	4	17	2	3	0	0	14	3
Vietnamese	12	4	7	29	5	7	0	0	24	6
Cantonese	8	3	2	8	1	1	0	0	11	3
Mandarin	0	0	0	0	0	0	1	12	1	0
Tagalog	14	4	0	0	1	1	1	12	16	4
SouthEast Asian (not Vietnamese)	2	1	1	4	0	0	0	0	3	1
Russian	8	3	0	0	0	0	0	0	8	2
Korean	13	4	0	0	0	0	0	0	13	3
Other Asian	6	2	0	0	0	0	0	0	6	1
Missing/Don't Know	117	38	0	0	0	0	1	12	118	29
Total	305	100	24	100	70	100	8	100	407	100

Table K2. Reason for Declines by Observed Ethnicity (unadjusted)

Reason for Declining	Caucasian		African American		Latino/ Hispanic		Chinese		Vietnamese		Filipino		Other Asian[1]		Other[2]		Missing/ Don't Know		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Language Problem	7	7	0	0	10	33	25	58	30	65	13	31	46	65	4	80	9	19	144	36
No Time	54	51	7	43	10	33	5	11	8	17	13	31	12	17	1	20	19	40	129	32
Not Interested	18	17	5	31	6	21	9	20	3	6	9	22	4	6	0	0	11	23	65	16
Appeared Threatening	4	4	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5	1
First Time Fishing	2	2	0	0	2	7	1	2	1	2	0	0	0	0	0	0	0	0	6	1
Don't Eat Fish	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	1
Other	7	7	2	13	1	3	1	2	2	4	1	2	3	4	0	0	3	6	20	5
Missing/Don't Know	9	9	2	13	1	3	3	7	3	6	6	14	5	7	0	0	4	8	33	8
Total	104	100	16	100	30	100	44	100	47	100	42	100	71	100	5	100	48	100	407	100

1 Other Asian includes Korean (n=18), SE Asian (n=5), and unknown Asian (n=48).

2 Other includes Russian (n=4) and Native American (n=1).

Table K3. Ethnicity (major groups) by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	25	9	8	7	18	19	11	6	4	4	10	14	47	9	8
Latino/Hispanic	36	13	14	10	26	32	11	6	4	2	5	6	59	11	11
Caucasian	41	15	14	5	13	14	99	54	63	25	62	63	170	32	38
Asian	161	57	61	17	43	35	47	26	24	8	20	16	233	43	40
Other	7	3	2	0	0	0	3	2	1	0	0	0	10	2	1
Missing/Don't Know/Declined	7	3	1	0	0	0	10	6	4	1	3	1	18	3	2
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Chi-square statistic not valid due to small cell sizes.

B. Consumers

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	63	11	12	11	14	12	22	6	6	8	8	9	104	9	9
Latino/Hispanic	97	17	20	20	25	28	27	7	7	7	7	6	151	13	14
Caucasian	121	21	21	14	17	16	233	60	66	63	64	65	431	38	43
Asian	273	46	45	34	42	42	77	19	14	16	17	14	400	35	30
Other	15	3	1	1	1	0	10	3	2	1	1	2	27	2	2
Missing/Don't Know/Declined	14	2	1	1	1	2	21	5	5	3	3	4	39	3	2
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Chi-square p-value < 0.0001.[2]

C. Respondents

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	73	11	11	16	16	14	28	6	6	8	8	8	125	9	9
Latino/Hispanic	113	16	18	23	23	28	29	7	7	7	7	5	172	13	14
Caucasian	174	25	28	21	21	21	257	60	66	68	65	67	520	40	44
Asian	302	43	40	36	37	35	82	19	14	17	16	15	437	33	28
Other	19	3	2	2	2	1	10	2	2	1	1	2	32	2	2
Missing/Don't Know/Declined	14	2	1	1	1	1	27	6	5	3	3	3	45	3	3
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Chi-square p-value < 0.0001.[2]

1 Adjusted for avidity bias.
2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K4. Ethnicity (with Asian subgroups) by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	25	9	8	7	18	19	11	6	4	4	10	14	47	9	8
Latino/Hispanic	36	13	14	10	25	32	11	6	4	2	5	6	59	11	11
Caucasian	41	15	14	5	13	14	99	55	62	25	62	63	170	32	38
Chinese	21	8	6	3	8	10	8	4	3	3	8	6	35	6	5
Filipino	70	25	24	3	8	9	9	5	4	2	5	2	84	16	13
Vietnamese	40	14	20	4	10	6	21	12	13	0	0	0	65	12	14
Pacific Isalnder	8	3	2	5	13	5	1	1	1	0	0	0	14	2	1
Other Asian	22	8	9	2	5	5	8	4	4	3	8	8	35	6	7
Other	7	2	2	0	0	0	3	2	1	0	0	0	10	2	1
Missing/Don't Know/Declined	7	3	1	0	0	0	10	5	4	1	2	1	18	4	2
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Chi-square statistic not valid due to small cell sizes.

B. Consumers

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	63	11	12	11	13	12	22	6	6	8	8	9	104	9	9
Latino/Hispanic	97	17	20	20	25	28	27	7	7	7	7	6	151	13	14
Caucasian	121	20	21	14	17	16	233	60	66	63	65	65	431	38	43
Chinese	40	7	5	4	5	5	15	4	3	4	4	2	63	6	4
Filipino	120	21	20	12	15	23	17	4	2	8	8	7	157	14	12
Vietnamese	62	11	11	7	9	5	27	7	6	0	0	0	96	8	7
Pacific Isalnder	12	2	2	8	10	6	5	1	1	1	1	2	26	2	2
Other Asian	39	7	7	3	4	2	13	3	3	3	3	3	58	5	5
Other	15	2	1	1	1	0	10	3	2	1	1	2	27	2	1
Missing/Don't Know/Declined	14	2	1	1	1	3	21	5	4	3	3	4	39	3	3
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Chi-squre p-value < 0.0001[2]

C. Respondents

Ethnicity	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Black/African American	73	11	11	16	16	14	28	6	6	8	8	8	125	9	9
Latino/Hispanic	113	16	18	23	24	28	29	8	7	7	7	5	172	13	13
Caucasian	174	25	28	21	21	21	257	59	66	68	65	66	520	39	45
Chinese	48	7	6	4	4	4	17	4	3	4	4	2	73	6	4
Filipino	127	18	17	12	12	18	18	4	2	8	7	7	165	13	11
Vietnamese	64	9	8	7	7	4	27	6	5	0	0	0	98	7	6
Pacific Isalnder	15	2	2	9	9	6	5	1	1	1	1	2	30	2	2
Other Asian	48	7	7	4	4	3	15	4	3	4	4	4	71	5	5
Other	19	3	2	2	2	1	10	2	2	1	1	2	32	3	2
Missing/Don't Know/Declined	14	2	1	1	1	1	27	6	5	3	3	4	45	3	3
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Chi-squre p-value < 0.0001[2]

1 Adjusted for avidity bias.
2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K5. Ethnicity by Mode Among Consumers (unadjusted & adjusted)

A. Ethnicity (major groups)	Pier			Beach and Bank			Private Boats			Party Boats			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	63	61	56	11	10	9	22	21	23	8	8	12	104	100
Latino/Hispanic	97	64	60	20	13	14	27	18	21	7	5	5	151	100
Caucasian	121	28	21	14	3	3	233	54	58	63	15	18	431	100
Asian	273	68	66	34	9	10	77	19	18	16	4	6	400	100
Other	15	55	35	1	4	2	10	37	49	1	4	14	27	100
Total[2]	569	51	44	80	7	7	369	33	37	95	9	12	1113	100

Chi-square p-value < 0.0001[3]

1 Adjusted for avidity bias.
2 Information missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

B. Ethnicity (with Asian subgorups)	Pier			Beach and Bank			Private Boats			Party Boats			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	63	61	56	11	10	9	22	21	23	8	8	12	104	100
Latino/Hispanic	97	64	60	20	13	14	27	18	21	7	5	5	151	100
Caucasian	121	28	21	14	3	3	233	54	58	63	15	18	431	100
Chinese	40	64	56	4	6	10	15	24	27	4	6	7	63	100
Filipino	120	76	72	12	8	13	17	11	7	8	5	8	157	100
Vietnamese	62	65	64	7	7	5	27	28	31	0	0	0	96	100
Pacific Islander	12	46	50	8	31	26	5	19	12	1	4	12	26	100
Other Asian	39	67	68	3	5	4	13	23	21	3	5	7	58	100
Other	15	55	35	1	4	2	10	37	49	1	4	14	27	100
Total[2]	569	51	44	80	7	7	369	33	37	95	9	12	1113	100

Chi-square p-value < 0.0001[3]

1 Adjusted for avidity bias.
2 Information missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K6. Sites by Ethnicity (major groups) Among Respondents (unadjusted)

Sites	African American		Latino/ Hispanic		Caucasian		Asian		Other		Missing/ Don't Know		Total	
	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%
Piers/Beach and Bank:														
Vallejo Waterfront	19	21	11	12	27	29	30	33	4	4	1	1	92	100
Martinez Shoreline Park	1	2	2	4	39	76	7	14	1	2	1	2	51	100
Point Pinole Shoreline Park	5	11	6	13	5	11	29	63	0	0	1	2	46	100
Berkeley Pier	22	17	17	13	23	18	59	46	5	4	4	3	130	100
Port View Park	16	52	1	3	2	6	12	39	0	0	0	0	31	100
Alameda Rockwall	0	0	4	16	6	24	14	56	1	4	0	0	25	100
Dumbarton Bridge Pier	2	4	13	23	19	34	21	37	0	0	1	2	56	100
Coyote Point	1	3	8	24	6	18	17	52	1	3	0	0	33	100
Oyster Point	3	6	17	31	11	20	18	33	4	7	1	2	54	100
Candlestick Point	2	7	7	25	2	7	16	57	1	4	0	0	28	100
San Franciso Muni Pier	2	4	10	22	8	20	23	52	1	2	1	2	45	100
Fort Point Pier	4	8	3	6	6	12	35	66	3	6	1	2	52	100
Fort Baker Pier	8	11	10	14	22	30	33	44	0	0	1	1	74	100
McNear's Beach	4	5	27	35	19	25	24	31	0	0	3	4	77	100
Piers/Beach/Bank Total	89	11	136	17	195	25	338	43	21	3	15	2	794	100
Private Boats:														
Vallejo Marina	7	5	12	9	86	63	19	14	5	4	8	6	137	100
Richmond Marina	16	13	6	5	62	49	34	27	2	2	6	5	126	100
San Leandro Marina	1	2	4	7	38	64	9	16	2	3	4	7	58	100
Oyster Point Marina	3	7	5	12	16	38	15	36	1	2	2	5	42	100
Lock Lomond Marina	1	1	2	3	55	79	5	7	0	0	7	10	70	100
Private Boats Total	28	6	29	7	257	59	82	19	10	2	27	6	433	100
Party Boats:														
San Pablo Yacht Harbor	1	8	0	0	11	84	1	8	0	0	0	0	13	100
Emeryville Marina	5	9	7	13	31	54	11	20	1	2	1	2	56	100
San Francisco Fisherman's Wharf	2	6	0	0	26	74	5	14	0	0	2	6	35	100
Party Boats Total	8	8	7	7	68	65	17	16	1	1	3	3	104	100
Total	125	9	172	13	520	39	437	33	32	2	45	3	1331	100

Table K7. Sites by Asian Ethnicity Among Respondents (unadjusted)

Sites	Chinese		Filipino		Vietnamese		Pacific Islander		SE Asian[1]		Mixed Asian		Japanese		Korean		Missing		Total	
	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%	n	row%
Piers/Beach and Bank:																				
Vallejo Waterfront	2	7	22	73	0	0	5	17	0	0	0	0	1	3	0	0	0	0	30	100
Martinez Shoreline Park	1	14	2	29	2	29	1	14	0	0	1	14	0	0	0	0	0	0	7	100
Point Pinole Shoreline Park	4	14	7	24	6	21	0	0	2	7	2	7	2	7	5	17	1	3	29	100
Berkeley Pier	11	19	14	24	26	43	3	5	0	0	0	0	3	5	1	2	1	2	59	100
Port View Park	0	0	2	17	5	41	3	25	2	17	0	0	0	0	0	0	0	0	12	100
Alameda Rockwall	1	7	9	65	1	7	0	0	1	7	1	7	0	0	0	0	1	7	14	100
Dumbarton Bridge Pier	4	19	10	47	5	24	1	5	0	0	0	0	0	0	0	0	1	5	21	100
Coyote Point	0	0	7	41	6	35	2	12	0	0	1	6	1	6	0	0	0	0	17	100
Oyster Point	2	11	9	50	4	22	3	17	0	0	0	0	0	0	0	0	0	0	18	100
Candlestick Point	1	6	7	44	8	50	0	0	0	0	0	0	0	0	0	0	0	0	16	100
San Franciso Muni Pier	8	35	9	40	1	4	1	4	2	9	0	0	1	4	0	0	1	4	23	100
Fort Point Pier	9	26	16	44	3	9	1	3	3	9	0	0	1	3	1	3	1	3	35	100
Fort Baker Pier	4	12	18	55	1	3	4	12	4	12	0	0	0	0	1	3	1	3	33	100
McNear's Beach	5	21	7	29	3	13	0	0	1	4	0	0	0	0	8	33	0	0	24	100
Piers/Beach/Bank Total	52	15	139	42	71	21	24	7	15	4	5	1	9	3	16	5	7	2	338	100
Private Boats:																				
Vallejo Marina	0	0	7	37	4	21	4	21	0	0	0	0	1	5	1	5	2	11	19	100
Richmond Marina	6	18	5	15	15	43	0	0	0	0	0	0	3	9	2	6	3	9	34	100
San Leandro Marina	0	0	0	0	8	89	0	0	0	0	0	0	1	11	0	0	0	0	9	100
Oyster Point Marina	7	46	6	40	0	0	1	7	0	0	0	0	0	0	0	0	1	7	15	100
Lock Lomond Marina	4	78	0	2	0	0	0	0	0	0	0	0	0	0	1	20	0	0	5	100
Private Boats Total	17	21	18	22	27	33	5	6	0	0	0	0	5	6	4	5	6	7	82	100
Party Boats:																				
San Pablo Yacht Harbor	0	0	0	0	0	0	0	0	0	0	1	100	0	0	0	0	0	0	1	100
Emeryville Marina	2	18	7	64	0	0	0	0	0	0	1	9	0	0	1	9	0	0	11	100
San Francisco Fisherman's Wharf	2	40	1	20	0	0	1	20	0	0	0	0	1	20	0	0	0	0	5	100
Party Boats Total	4	24	8	46	0	0	1	6	0	0	2	12	1	6	1	6	0	0	17	100
Total	73	17	165	38	98	22	30	7	15	3	7	2	15	3	21	5	13	3	437	100

1 Southeast Asian other than Vietnamese.

Table K8. Interview Language by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Interview Language	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
English	221	80	77	29	74	72	157	86	87	40	100	100	447	84	83
Spanish	22	8	10	6	15	15	0	0	0	0	0	0	28	5	5
Vietnamese	17	6	8	1	3	3	10	6	6	0	0	0	28	5	6
Cantonese	11	4	3	2	5	2	3	2	1	0	0	0	16	3	2
Mandarin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missing/Don't Know/Declined	6	2	2	1	3	8	11	6	6	0	0	0	18	3	4
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Chi-square statistic not valid due to small cell sizes.

B. Consumers

Interview Language	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
English	485	83	82	67	82	81	352	90	92	95	97	95	999	87	87
Spanish	39	7	8	9	11	11	2	1	1	0	0	0	50	4	4
Vietnamese	22	4	4	2	3	4	10	2	2	0	0	0	34	3	3
Cantonese	12	2	2	2	3	1	3	1	0	0	0	0	17	2	1
Mandarin	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Missing/Don't Know/Declined	24	4	4	1	1	3	23	6	5	3	3	5	51	4	5
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Chi-square statistic not valid due to small cell sizes.

C. Respondents

Interview Language	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
English	589	85	86	84	85	85	392	91	92	104	100	100	1169	88	88
Spanish	41	6	6	10	10	9	2	0	1	0	0	0	53	4	4
Vietnamese	22	3	3	2	2	3	10	2	2	0	0	0	34	3	2
Cantonese	12	2	1	2	2	1	3	1	0	0	0	0	17	1	1
Mandarin	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Missing/Don't Know/Declined	29	4	4	1	1	2	26	6	5	0	0	0	56	4	5
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Chi-square statistic not valid due to small cell sizes.

1 Adjusted for avidity bias.

Table K9. Sites by Interview Language Among Respondents (unadjusted)

Sites	English		Spanish		Vietnamese		Cantonese		Mandarin		Missing		Total		Total Non-English	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	row%
Piers/Beach and Bank:																
Vallejo Waterfront	88	8	1	2	0	0	0	0	0	0	3	5	92	7	1	1
Martinez Shoreline Park	47	4	1	2	0	0	0	0	0	0	3	5	51	4	1	2
Point Pinole Shoreline Park	35	3	4	8	4	12	2	12	0	0	1	2	46	3	10	22
Berkeley Pier	101	9	4	8	12	34	2	12	0	0	11	18	130	11	18	14
Port View Park	29	2	1	2	1	3	0	0	0	0	0	0	31	2	2	6
Alameda Rockwall	22	2	2	4	0	0	1	6	0	0	0	0	25	2	3	12
Dumbarton Bridge Pier	51	4	1	2	2	6	1	6	0	0	1	2	56	4	4	7
Coyote Point	25	2	3	6	4	12	0	0	0	0	1	2	33	2	7	21
Oyster Point	48	4	3	6	0	0	1	6	0	0	2	4	54	4	4	7
Candlestick Point	26	2	2	4	0	0	0	0	0	0	0	0	28	2	2	7
San Franciso Muni Pier	33	3	5	9	0	0	4	22	1	50	2	4	45	3	10	22
Fort Point Pier	46	4	1	2	1	3	3	18	0	0	1	2	52	4	5	10
Fort Baker Pier	64	5	5	9	0	0	0	0	1	50	4	7	74	6	6	8
McNear's Beach	58	5	18	32	0	0	0	0	0	0	1	2	77	6	18	23
Piers/Beach/Bank Total	673	57	51	96	24	70	14	82	2	100	30	53	794	60	91	11
Private Boats:																
Vallejo Marina	134	12	1	2	0	0	0	0	0	0	2	4	137	11	1	1
Richmond Marina	111	9	0	0	5	15	0	0	0	0	10	17	126	9	5	4
San Leandro Marina	50	4	1	2	5	15	0	0	0	0	2	4	58	4	6	10
Oyster Point Marina	32	3	0	0	0	0	3	18	0	0	7	13	42	3	3	7
Lock Lomond Marina	65	6	0	0	0	0	0	0	0	0	5	9	70	5	0	0
Private Boats Total	392	34	2	4	10	30	3	18	0	0	26	47	433	32	15	3
Party Boats:																
San Pablo Yacht Harbor	13	1	0	0	0	0	0	0	0	0	0	0	13	1	0	0
Emeryville Marina	56	5	0	0	0	0	0	0	0	0	0	0	56	4	0	0
San Francisco Fisherman's Wharf	35	3	0	0	0	0	0	0	0	0	0	0	35	3	0	0
Party Boats Total	104	9	0	0	0	0	0	0	0	0	0	0	104	8	0	0
Total	1169	100	53	100	34	100	17	100	2	100	56	100	1331	100	106	8
Percent of Total		88		4		3		1		0		4		100		8

Table K10. Income by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Income	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< $20,000/year	89	32	33	8	21	27	20	11	11	2	5	8	119	22	21
$20,000 - $45,000/year	81	30	26	15	38	25	34	19	19	8	20	16	138	26	22
> $45,000/year	73	26	28	13	33	36	91	50	55	26	65	69	203	38	44
Missing/Don't Know/Declined	34	12	13	3	8	12	36	20	15	4	10	7	77	14	13
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

B. Consumers

Income	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< $20,000/year	159	27	26	14	17	16	41	11	10	3	3	5	217	19	16
$20,000 - $45,000/year	187	32	34	31	38	38	71	18	18	20	21	15	309	27	26
> $45,000/year	166	29	30	29	36	32	205	52	56	63	64	68	463	40	45
Missing/Don't Know/Declined	71	12	10	7	9	14	73	19	16	12	12	12	163	14	13
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

C. Respondents

Income	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< $20,000/year	182	26	24	16	16	13	42	10	9	3	3	4	243	18	16
$20,000 - $45,000/year	216	32	31	35	35	37	77	18	18	20	19	14	348	26	25
> $45,000/year	211	30	33	38	39	35	231	53	57	68	65	69	548	42	46
Missing/Don't Know/Declined	86	12	12	10	10	15	83	19	16	13	13	13	192	14	13
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

1 Adjusted for avidity bias.

2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K11. Ethnicity by Income Among Consumers (unadjusted & adjusted)

A. Ethnicity (major groups)	< $20,000			$20,000 - $45,000			> $45,000			Missing			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	18	17	19	32	31	27	43	41	40	11	11	14	104	100
Latino/Hispanic	44	29	25	48	32	32	43	28	32	16	11	11	151	100
Caucasian	44	10	8	108	25	20	222	52	60	57	13	12	431	100
Asian	106	27	25	110	28	34	132	33	30	52	12	11	400	100
Other	3	11	9	7	26	19	14	52	62	3	11	10	27	100
Total[2]	215	19	17	305	27	27	454	41	45	139	13	11	1113	100

Mantel-Haenszel Chi-square p-value = 0.2017[3]

1 Adjusted for avidity bias.
2 Ethnicity data missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

B. Ethnicity (with Asian subgorups)	< $20,000			$20,000 - $45,000			> $45,000			Missing			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	18	17	19	32	31	27	43	41	40	11	11	14	104	100
Latino/Hispanic	44	29	25	48	32	32	43	28	32	16	11	11	151	100
Caucasian	44	10	8	108	25	20	222	52	60	57	13	12	431	100
Chinese	14	22	18	17	27	35	22	35	36	10	16	11	63	100
Filipino	39	25	23	40	25	34	60	38	35	18	12	8	157	100
Vietnamese	41	43	47	23	24	24	19	20	19	13	13	10	96	100
Pacific Islander	1	4	4	13	50	73	9	35	16	3	11	7	26	100
Other Asian	11	19	10	17	29	36	22	38	38	8	14	16	58	100
Other	3	11	9	7	26	19	14	52	62	3	11	10	27	100
Total[2]	215	19	17	305	27	27	454	41	45	139	13	11	1113	100

Mantel-Haenszel Chi-square p-value = 0.0116[3]

1 Adjusted for avidity bias.
2 Ethnicity data missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K12. Education by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Education	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< 12th Grade	58	21	20	10	26	22	18	10	11	0	0	0	86	16	15
Completed HS or GED	85	31	31	11	28	33	56	31	30	11	28	22	163	30	29
Some college/trade sch.	83	30	30	12	31	30	42	23	25	14	34	34	151	28	28
>= 4 years college	42	15	15	6	15	15	42	23	23	12	30	36	102	19	21
Missing/Don't Know/Declined	9	3	4	0	0	0	23	13	11	3	8	8	35	7	7
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

B. Consumers

Education	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< 12th Grade	113	20	20	18	22	26	30	8	8	2	2	0	163	14	13
Completed HS or GED	193	33	33	28	35	34	111	28	27	24	24	23	356	31	30
Some college/trade sch.	169	29	30	24	30	30	116	30	30	30	31	34	339	29	30
>= 4 years college	89	15	14	10	12	7	83	21	23	37	38	37	219	19	20
Missing/Don't Know/Declined	19	3	3	1	1	3	50	13	12	5	5	6	75	7	7
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

C. Respondents

Education	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
< 12th Grade	125	18	18	19	19	21	30	7	7	2	2	0	176	13	12
Completed HS or GED	235	34	35	37	38	38	120	28	27	25	24	21	417	32	31
Some college/trade sch.	195	28	28	28	28	29	128	30	31	33	32	35	384	29	30
>= 4 years college	120	17	17	13	13	7	97	22	23	39	37	38	269	20	21
Missing/Don't Know/Declined	20	3	2	2	2	5	58	13	12	5	5	6	85	6	6
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Mantel-Haenszel Chi-square p-value < 0.0001.[2]

1 Adjusted for avidity bias.

2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K13. Ethnicity by Education Level Among Consumers (unadjusted & adjusted)

A. Ethnicity (major groups)	<12th Grade			High School/GED			Some College			>=4 years College			Missing			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	8	8	6	38	37	38	34	33	36	19	18	14	5	4	6	104	100
Latino/Hispanic	54	36	37	60	40	37	25	17	18	7	5	6	5	2	2	151	100
Caucasian	25	6	6	140	32	28	143	33	34	98	23	26	25	6	6	431	100
Asian	69	17	17	109	27	29	121	30	32	82	21	18	19	5	4	400	100
Other	3	11	14	5	19	27	12	44	34	5	19	20	2	7	5	27	100
Total[2]	159	14	14	352	32	31	335	30	31	211	19	20	56	5	4	1113	100

Mantel-Haenszel Chi-square p-value = 0.0277[3].

1 Adjusted for avidity bias.
2 Ethnicity data missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

B. Ethnicity (with Asian subgorups)	<12th Grade			High School/GED			Some College			>=4 years College			Missing			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	8	8	6	38	37	38	34	33	36	19	18	14	5	4	6	104	100
Latino/Hispanic	54	36	37	60	40	37	25	17	18	7	5	6	5	2	2	151	100
Caucasian	25	6	6	140	32	28	143	33	34	98	23	26	25	6	6	431	100
Chinese	15	24	11	14	22	19	14	22	28	16	25	39	4	7	3	63	100
Filipino	19	12	13	42	27	25	54	34	39	37	24	20	5	3	3	157	100
Vietnamese	27	28	32	28	29	34	23	24	20	11	11	6	7	8	8	96	100
Pacific Islander	3	12	14	9	35	40	9	34	26	5	19	20	0	0	0	26	100
Other Asian	5	9	9	16	28	33	21	36	38	13	22	15	3	5	5	58	100
Other	3	11	14	5	19	27	12	44	34	5	19	20	2	7	5	27	100
Total[2]	159	14	14	352	32	31	335	30	31	211	19	20	56	5	4	1113	100

Mantel-Haenszel Chi-square p-value = 0.1053[3].

1 Adjusted for avidity bias.
2 Ethnicity data missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K14. Gender by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Gender	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Male	247	89	89	36	92	94	157	87	84	34	84	84	474	88	87
Female	23	8	7	3	8	6	11	6	9	5	13	15	42	8	9
Missing/Don't Know/Declined	7	3	4	0	0	0	13	7	7	1	3	1	21	4	4
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Chi-square statistic not valid due to small cell sizes.

B. Consumers

Gender	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Male	522	89	89	75	93	89	326	84	82	85	87	87	1008	88	86
Female	50	9	9	6	7	11	29	7	8	10	10	9	95	8	9
Missing/Don't Know/Declined	11	2	2	0	0	0	35	9	10	3	3	4	49	4	5
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Chi-square p-value = 0.8750.[2]

C. Respondents

Gender	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Male	624	90	89	90	91	89	362	84	83	91	87	88	1167	88	86
Female	58	8	9	9	9	11	31	7	8	10	10	9	108	8	9
Missing/Don't Know/Declined	13	2	2	0	0	0	40	9	9	3	3	3	56	4	5
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Chi-square p-value = 0.9214.[2]

1 Adjusted for avidity bias.
2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K15. Age by Gender Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Age	Male			Female			Missing			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	271	57	59	24	57	44	3	14	12	298	55	55
46-65 years	154	32	32	15	36	47	0	0	0	169	31	32
65+ years	47	10	9	2	5	7	2	10	5	51	10	9
Missing/Don't Know/Declined	2	1	0	1	2	2	16	76	83	19	4	4
Total	474	100	100	42	100	100	21	100	100	537	100	100

Mantel-Haenszel Chi-square p-value = 0.5665.[2]

B. Consumers

Age	Male			Female			Missing			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	629	62	62	57	60	55	8	16	17	694	60	59
46-65 years	293	29	30	31	33	39	2	4	5	326	28	30
65+ years	82	8	8	5	5	3	2	4	1	89	8	7
Missing/Don't Know/Declined	4	1	0	2	2	3	37	76	77	43	4	4
Total	1008	100	100	95	100	100	49	100	100	1152	100	100

Mantel-Haenszel Chi-square p-value = 0.8359.[2]

C. Respondents

Age	Male			Female			Missing			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	747	64	64	68	63	57	9	16	16	824	62	61
46-65 years	324	28	29	33	30	37	2	4	4	359	27	28
65+ years	92	8	7	5	5	3	2	4	2	99	7	7
Missing/Don't Know/Declined	4	<1	0	2	2	3	43	76	78	49	4	4
Total	1167	100	100	108	100	100	56	100	100	1331	100	100

Mantel-Haenszel Chi-square p-value = 0.6270.[2]

1 Adjusted for avidity bias.
2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K16. Age by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Age	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	157	57	58	29	74	81	94	52	51	18	45	45	298	55	55
46-65 years	85	31	29	9	23	18	57	31	34	18	45	44	169	31	32
65+ years	29	10	10	1	3	1	18	10	9	3	7	10	51	10	9
Missing/Don't Know/Declined	6	2	3	0	0	0	12	7	6	1	3	1	19	4	4
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Mantel-Haenszel Chi-square p-value = 0.3730.[2]

B. Consumers

Age	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	363	62	62	63	78	78	215	55	55	53	54	50	694	60	59
46-65 years	164	28	30	16	20	18	112	29	29	34	35	37	326	28	30
65+ years	46	8	7	2	2	4	33	8	8	8	8	9	89	8	7
Missing/Don't Know/Declined	10	2	1	0	0	0	30	8	8	3	3	4	43	4	4
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Mantel-Haenszel Chi-square p-value = 0.1566.[2]

C. Respondents

Age	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45 years	444	64	63	77	78	79	244	57	57	59	56	54	824	62	61
46-65 years	188	27	29	19	19	18	118	27	28	34	33	34	359	27	28
65+ years	52	7	6	3	3	3	36	8	7	8	8	9	99	7	7
Missing/Don't Know/Declined	11	2	2	0	0	0	35	8	8	3	3	3	49	4	4
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Mantel-Haenszel Chi-square p-value = 0.1803.[2]

1 Adjusted for avidity bias.

2 Missing/Don't Know/Declined not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K17. Age by Weekend/Weekday Among Consumers and Respondents (unadjusted & adjusted)

A. Consumers

Age	Weekend			Weekday			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45	458	65	64	236	53	51	694	60	59
46-65	197	28	29	129	29	30	326	28	30
+65 years	29	4	4	60	13	13	89	8	7
Missing/Don't Know/Declined	20	3	3	23	5	6	43	4	4
Total	704	100	100	448	100	100	1152	100	100

B. Respondents

Age	Weekend			Weekday			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
18-45	546	67	66	278	54	52	824	62	61
46-65	213	26	27	146	28	31	359	27	28
+65 years	31	4	4	68	13	11	99	7	7
Missing/Don't Know/Declined	23	3	3	26	5	6	49	4	4
Total	813	100	100	518	100	100	1331	100	100

1 Adjusted for avidity bias.

Table K18. Season of Interview by Mode Among Recent Consumers, Consumers and Respondents (unadjusted & adjusted)

A. Recent Consumers

Season	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Winter	32	12	10	11	28	28	35	19	20	0	0	0	78	15	14
Spring	53	19	26	3	8	11	27	15	15	1	3	5	84	16	18
Summer	106	38	36	20	51	44	78	43	40	23	57	57	227	41	41
Fall	86	31	28	5	13	17	41	23	25	16	40	38	148	28	27
Total	277	100	100	39	100	100	181	100	100	40	100	100	537	100	100

Chi-squre p-value < 0.0001.[2]

B. Consumers

Season	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Winter	94	16	19	23	28	29	85	22	26	0	0	0	202	17	20
Spring	114	20	25	6	7	11	81	21	24	7	7	12	208	18	22
Summer	227	39	32	37	46	45	141	36	30	53	54	51	458	40	35
Fall	148	25	24	15	19	15	83	21	20	38	39	37	284	25	23
Total	583	100	100	81	100	100	390	100	100	98	100	100	1152	100	100

Chi-squre p-value < 0.0001.[2]

C. Respondents

Season	Pier			Beach and Bank			Private Boats			Party Boats			Total		
	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]	n	%	%adj[1]
Winter	110	16	18	28	28	31	97	22	27	0	0	0	235	18	20
Spring	142	20	25	7	7	9	88	20	22	7	7	11	244	18	21
Summer	273	40	35	47	48	43	154	36	31	56	54	53	530	40	36
Fall	170	24	22	17	17	17	94	22	20	41	39	36	322	24	23
Total	695	100	100	99	100	100	433	100	100	104	100	100	1331	100	100

Chi-squre p-value < 0.0001.[2]

1 Adjusted for avidity bias.
2 Chi-square statistic was calculated for unadjusted data only.

Table K19. Ethnicity by Season of Interview Among Consumers (unadjusted & adjusted)

A. Ethnicity (major groups)	Winter			Spring			Summer			Fall			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	23	22	27	13	13	14	43	41	32	25	24	27	104	100
Latino/Hispanic	40	26	30	29	19	24	45	30	26	37	25	20	151	100
Caucasian	65	15	18	82	19	23	180	42	36	104	24	23	431	100
Asian	57	14	15	71	18	22	169	42	38	103	26	25	400	100
Other	3	11	9	5	19	22	13	48	46	6	22	23	27	100
Total[2]	188	17	20	200	18	22	450	40	35	275	25	23	1113	100

Chi-square p-value = 0.0572[3]

1 Adjusted for avidity bias.
2 Information missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

B. Ethnicity (with Asian subgorups)	Winter			Spring			Summer			Fall			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	23	22	27	13	13	14	43	41	32	25	24	27	104	100
Latino/Hispanic	40	26	30	29	19	24	45	30	26	37	25	20	151	100
Caucasian	65	15	18	82	19	22	180	42	37	104	24	23	431	100
Chinese	13	21	26	13	21	31	21	33	24	16	25	19	63	100
Filipino	18	11	13	23	15	15	70	45	42	46	29	30	157	100
Vietnamese	12	12	13	14	15	23	50	52	48	20	21	16	96	100
Pacific Islander	6	23	31	10	38	40	7	27	11	3	12	18	26	100
Other Asian	8	14	7	11	19	29	21	36	32	18	31	32	58	100
Other	3	11	9	5	19	22	13	48	46	6	22	23	27	100
Total[2]	188	17	20	200	18	22	450	40	35	275	25	23	1113	100

Chi-square p-value = 0.0116[3]

1 Adjusted for avidity bias.
2 Information missing for 39 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K20. Ethnicity by Years Eating SF Bay Fish Among Consumers (unadjusted & adjusted)

A. Ethnicity (major groups)	< 1 year			1 - 5 years			6 - 10 years			11 - 20 years			21 - 30 years			30+ years			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	6	6	6	23	23	26	10	10	9	28	29	22	16	16	17	16	16	20	99	100
Latino/Hispanic	28	21	18	56	41	44	19	14	13	13	9	11	11	8	9	9	7	5	136	100
Caucasian	24	6	3	82	21	22	48	12	14	82	21	21	55	14	14	106	26	26	397	100
Asian	63	17	15	147	40	45	63	17	16	52	14	13	19	5	4	23	7	7	367	100
Other	2	9	5	6	27	24	1	4	3	5	23	15	3	14	19	5	23	34	22	100
Total[2]	123	12	9	314	31	32	141	14	14	180	18	18	104	10	11	159	15	16	1021	100

Mantel-Haenszel Chi-square p-value <0.0001[3]

1 Adjusted for avidity bias.
2 Information missing for 131 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

B. Ethnicity (with Asian subgroups)	< 1 year			1 - 5 years			6 - 10 years			11 - 20 years			21 - 30 years			30+ years			Total	
	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%	adj row%[1]	n	row%
Black/African American	6	6	6	23	23	26	10	10	9	28	29	22	16	16	17	16	16	20	99	100
Latino/Hispanic	28	21	18	56	41	44	19	14	13	13	9	11	11	8	9	9	7	5	136	100
Caucasian	24	6	3	82	21	22	48	12	14	82	21	21	55	14	14	106	26	26	397	100
Chinese	12	21	15	24	41	43	9	15	12	5	9	12	3	5	6	5	9	12	58	100
Filipino	20	14	13	55	38	39	24	17	17	27	19	23	10	7	4	7	5	4	143	100
Vietnamese	12	14	12	47	53	63	19	22	19	8	9	4	1	1	0	1	1	2	88	100
Pacific Islander	8	32	29	6	24	34	2	8	3	4	16	7	4	16	23	1	4	4	25	100
Other Asian	11	21	21	15	28	35	9	17	16	8	15	9	1	2	2	9	17	17	53	100
Other	2	9	5	6	27	24	1	4	3	5	23	15	3	14	19	5	23	34	22	100
Total[2]	123	12	9	314	31	32	141	14	14	180	18	18	104	10	11	159	15	16	1021	100

Mantel-Haenszel Chi-square p-value <0.0001[3]

1 Adjusted for avidity bias.
2 Information missing for 131 Consumers.
3 Missing not included in Chi-square statistic. Chi-square statistic was calculated for unadjusted data only.

Table K21. Fish Fate for Recent Consumers, Consumers, Non-Consumers, and Respondents[1] (unadjusted)

Fish Fate	Recent Consumers n=537		Consumers n=1152		Non-Consumers n=179		Respondents n=1331	
	Yes (n)	%	Yes (n)	%	Yes (n)	%	Yes (n)	%
Eat It	503	94	1035	90	20	11	1055	79
Give to Family/Friends	285	53	543	47	77	43	620	47
Trade o Sell It	9	2	15	1	1	<1	16	1
Use for Bait	34	6	66	6	4	2	70	5
Catch and Release	165	31	366	32	110	61	476	36
Other	1	<1	2	<1	6	3	8	1

1 Respondents may choose more than one category.

Table K22. Household Members Who Eat SF Bay Fish by Mode[1] (unadjusted)

A. Recent Consumers

Household Eaters	Pier n=277		Beach and Bank n=39		Private Boats n=181		Party Boats n=40		Total n=537	
	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	162	58	24	62	87	48	13	33	286	53
Children between ages 6-17	85	31	15	38	45	25	2	5	147	27
People 65 or older	69	25	5	13	39	22	12	30	125	23
Children under age of 6	55	20	12	31	18	10	3	8	88	16
Women currently pregnant/breastfeeding	13	5	2	5	3	2	0	0	18	3
Missing/Don't Know/Declined	0	0	0	0	0	0	0	0	0	0

B. Consumers

Household Eaters	Pier n=583		Beach and Bank n=81		Private Boats n=390		Party Boats n=98		Total n=1152	
	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	292	50	45	56	163	42	34	35	534	46
Children between ages 6-17	153	26	24	30	93	24	10	10	280	24
People 65 or older	106	18	10	12	67	17	19	19	202	18
Children under age of 6	81	14	17	21	40	10	6	6	144	13
Women currently pregnant/breastfeeding	16	3	2	3	7	2	1	1	26	2
Missing/Don't Know/Declined	3	1	0	0	1	<1	0	0	4	<1

C. Non-Consumers

Household Eaters	Pier n=112		Beach and Bank n=18		Private Boats n=43		Party Boats n=6		Total n=179	
	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	12	11	2	11	7	16	2	33	23	13
Children between ages 6-17	5	4	0	0	3	7	1	17	9	5
People 65 or older	7	6	2	11	2	5	1	17	12	7
Children under age of 6	3	3	0	0	2	5	1	17	6	3
Women currently pregnant/breastfeeding	1	1	0	0	0	0	0	0	1	1
Missing/Don't Know/Declined	2	2	0	0	1	2	0	0	3	2

D. Respondents

Household Eaters	Pier n=695		Beach and Bank n=99		Private Boats n=433		Party Boats n=104		Total n=1331	
	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	304	44	47	47	170	39	36	35	557	42
Children between ages 6-17	158	23	24	24	96	22	11	11	289	22
People 65 or older	113	16	12	12	69	16	20	19	214	16
Children under age of 6	84	12	17	17	42	10	7	7	150	11
Women currently pregnant/breastfeeding	17	2	2	2	7	2	1	1	27	2
Missing/Don't Know/Declined	5	1	0	0	2	<1	0	0	7	1

1 Respondents may choose more than one category.

Table K23. Household Members Who Eat SF Bay Fish by Ethnicity[1] (unadjusted)

A. Recent Consumers

Household Eaters	African American n=47		Latino/Hispanic n=59		Caucasian n=170		Asian n=233		Other n=10		Total[3] n=519	
	n	%	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	28	60	36	61	67	39	143	61	6	60	280	54
Children between ages 6-17	15	32	22	37	30	18	75	32	2	20	144	28
People 65 or older	3	6	7	12	35	21	73	31	3	30	121	23
Children under age of 6	13	28	13	22	12	72	44	19	4	40	86	17
Women currently pregnant/breastfeeding	3	6	4	7	3	0	8	3	0	0	18	3
Missing/Don't Know/Declined	0	0	0	0	0	0	0	0	0	0	0	0

B. Consumers

Household Eaters	African American n=104		Latino/Hispanic n=151		Caucasian n=431		Asian n=400		Other n=27		Total[4] n=1113	
	n	%	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	53	51	79	50	169	39	216	54	11	41	528	47
Children between ages 6-17	38	37	41	27	79	18	110	28	8	30	276	25
People 65 or older	8	8	15	10	67	16	101	25	6	22	197	18
Children under age of 6	22	21	27	18	31	7	55	14	5	19	140	13
Women currently pregnant/breastfeeding	6	6	6	4	5	1	8	2	0	0	25	2
Missing/Don't Know/Declined	0	0	1	1	0	0	2	1	1	4	4	<1

C. Non-Consumers

Household Eaters	African American n=21		Latino/Hispanic n=21		Caucasian n=89		Asian n=37		Other n=5		Total[5] n=173	
	n	%	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	3	14	3	14	9	10	8	22	0	0	23	13
Children between ages 6-17	1	5	1	5	5	6	2	5	0	0	9	5
People 65 or older	2	10	1	5	3	3	5	14	1	20	12	7
Children under age of 6	0	0	1	5	5	6	0	0	0	0	6	3
Women currently pregnant/breastfeeding	1	5	0	0	0	0	0	0	0	0	1	1
Missing/Don't Know/Declined	0	0	1	5	2	2	0	0	0	0	3	2

D. Respondents

Household Eaters	African American n=125		Latino/Hispanic n=172		Caucasian n=520		Asian n=437		Other n=32		Total[2] n=1286	
	n	%	n	%	n	%	n	%	n	%	n	%
Women between ages 18-45	56	45	79	46	178	34	224	51	11	34	548	43
Children between ages 6-17	39	31	42	24	84	16	112	26	8	25	285	22
People 65 or older	10	8	16	9	70	13	106	24	7	22	209	16
Children under age of 6	22	18	28	16	36	7	55	13	5	16	146	11
Women currently pregnant/breastfeeding	7	6	6	3	5	1	8	2	0	0	26	2
Missing/Don't Know/Declined	0	0	2	1	2	1	2	1	1	3	7	1

1 Respondents may choose more than one category.
2 Ethnicity data missing for 45 Respondents.
3 Ethnicity data missing for 18 Consumers.
4 Ethnicity data missing for 39 Recent Consumers.
5 Ethnicity data missing for 6 Non-Consumers.

Table K24. Who Cooks or Prepares SF Bay Fish by Mode[1] (unadjusted)

A. Recent Consumers

Who Cooks or Prepares	Pier n=277		Beach and Bank n=39		Private Boats n=181		Party Boats n=40		Total n=537	
	n	%	n	%	n	%	n	%	n	%
Self	173	62	29	74	116	64	25	63	343	64
Wife/Partner/Spouse/Husband	87	31	6	15	60	33	12	30	165	31
Mother/Parent/Grandparent	35	13	6	15	22	12	8	20	71	13
Other Family Member	27	10	6	15	4	2	1	3	38	7
Friend	13	5	1	3	5	3	1	3	20	4
Roommate/Girlfriend/Boyfriend	1	0	1	3	2	1	0	0	4	1
Other	2	1	0	0	4	2	2	5	8	1
Missing/Don't Know/Declined	0	0	0	0	0	0	0	0	0	0

B. Consumers

Who Cooks or Prepares	Pier n=583		Beach and Bank n=81		Private Boats n=390		Party Boats n=98		Total n=1152	
	n	%	n	%	n	%	n	%	n	%
Self	356	61	59	73	260	67	60	61	735	64
Wife/Partner/Spouse/Husband	173	30	15	19	119	31	22	22	329	29
Mother/Parent/Grandparent	71	12	12	15	37	9	14	14	134	12
Other Family Member	32	5	7	9	10	3	1	1	50	4
Friend	22	4	3	4	6	2	3	3	34	3
Roommate/Girlfriend/Boyfriend	2	<1	1	1	3	1	0	0	6	1
Other	11	2	0	0	5	1	2	2	18	2
Missing/Don't Know/Declined	1	<1	0	0	0	0	0	0	1	<1

C. Non-Consumers

Who Cooks or Prepares	Pier n=112		Beach and Bank n=18		Private Boats n=43		Party Boats n=6		Total n=179	
	n	%	n	%	n	%	n	%	n	%
Self	16	14	3	17	6	14	1	17	26	15
Wife/Partner/Spouse/Husband	16	14	2	11	6	14	1	17	25	14
Mother/Parent/Grandparent	7	6	0	0	2	5	1	17	10	6
Other Family Member	2	2	1	6	0	0	0	0	3	2
Friend	0	0	1	6	0	0	0	0	1	1
Roommate/Girlfriend/Boyfriend	2	2	0	0	0	0	0	0	2	1
Other	4	4	1	6	3	7	1	17	9	5
Missing/Don't Know/Declined	1	1	0	0	1	2	0	0	2	1

D. Respondents

Who Cooks or Prepares	Pier n=695		Beach and Bank n=99		Private Boats n=433		Party Boats n=104		Total n=1331	
	n	%	n	%	n	%	n	%	n	%
Self	372	54	62	63	266	61	61	35	761	57
Wife/Partner/Spouse/Husband	189	27	17	17	125	29	23	22	354	27
Mother/Parent/Grandparent	78	11	12	12	39	9	15	14	144	11
Other Family Member	34	5	8	8	10	2	0	0	52	4
Friend	22	3	4	4	6	1	3	3	35	3
Roommate/Girlfriend/Boyfriend	4	1	1	1	3	1	0	0	8	1
Other	15	2	1	1	8	2	3	3	27	2
Missing/Don't Know/Declined	2	<1	0	0	1	<1	0	0	3	<1

1 Respondents may choose more than one category.

Table K25. Who Cooks or Prepares SF Bay Fish by Ethnicity[1] (unadjusted)

A. Recent Consumers

Who Cooks or Prepares	African Amercian n=47		Latino/Hispanic n=59		Caucasian n=170		Asian n=233		Other n=10		Total[4] n=519	
	n	%	n	%	n	%	n	%	n	%	n	%
Self	40	85	40	68	120	71	126	54	7	70	333	64
Wife/Partner/Spouse/Husband	6	13	19	32	45	26	90	39	3	30	163	31
Mother/Parent/Grandparent	3	6	4	7	21	12	40	17	1	10	69	13
Other Family Member	2	4	9	15	5	3	20	9	0	0	36	7
Friend	1	2	1	2	10	6	6	3	0	0	18	3
Roommate/Girlfriend/Boyfriend	1	2	1	2	1	1	1	1	0	0	4	1
Other	0	0	2	3	3	2	2	1	0	0	7	1
Missing/Don't Know/Declined	0	0	0	0	0	0	0	0	0	0	0	0

B. Consumers

Who Cooks or Prepares	African Amercian n=104		Latino/Hispanic n=151		Caucasian n=431		Asian n=400		Other n=27		Total[3] n=1113	
	n	%	n	%	n	%	n	%	n	%	n	%
Self	84	81	93	62	300	70	224	56	16	59	717	64
Wife/Partner/Spouse/Husband	19	18	51	34	111	26	133	33	10	37	324	29
Mother/Parent/Grandparent	6	6	15	10	43	10	66	17	1	4	131	12
Other Family Member	4	4	8	5	10	2	26	7	0	0	48	4
Friend	1	1	3	2	17	4	10	3	0	0	31	3
Roommate/Girlfriend/Boyfriend	1	1	1	1	2	1	2	1	0	0	6	1
Other	0	0	5	3	6	1	6	2	0	0	17	2
Missing/Don't Know/Declined	0	0	1	1	0	0	0	0	0	0	1	<1

C. Non-Consumers

Who Cooks or Prepares	African Amercian n=21		Latino/Hispanic n=21		Caucasian n=89		Asian n=37		Other n=5		Total[5] n=173	
	n	%	n	%	n	%	n	%	n	%	n	%
Self	4	19	2	10	13	15	6	16	1	20	26	15
Wife/Partner/Spouse/Husband	2	10	3	14	10	11	10	27	0	0	25	14
Mother/Parent/Grandparent	0	0	1	5	3	3	6	16	0	0	10	6
Other Family Member	1	5	0	0	0	0	2	5	0	0	3	2
Friend	1	5	0	0	0	0	0	0	0	0	1	1
Roommate/Girlfriend/Boyfriend	0	0	0	0	2	2	0	0	0	0	2	1
Other	1	5	1	5	4	5	2	5	0	0	8	5
Missing/Don't Know/Declined	0	0	1	5	1	1	0	0	0	0	2	1

D. Respondents

Who Cooks or Prepares	African Amercian n=125		Latino/Hispanic n=172		Caucasian n=520		Asian n=437		Other n=32		Total[2] n=1286	
	n	%	n	%	n	%	n	%	n	%	n	%
Self	88	70	95	55	313	60	230	53	17	53	743	58
Wife/Partner/Spouse/Husband	21	17	54	31	121	23	143	33	10	31	349	27
Mother/Parent/Grandparent	6	5	16	9	46	9	72	16	1	3	141	11
Other Family Member	5	4	8	5	9	2	28	6	0	0	50	4
Friend	2	2	3	2	17	3	10	2	0	0	32	2
Roommate/Girlfriend/Boyfriend	1	1	1	1	4	1	2	1	0	0	8	1
Other	1	1	6	3	10	2	8	2	0	0	25	2
Missing/Don't Know/Declined	0	0	2	1	1	1	0	0	0	0	3	<1

1 Respondents may choose more than one category.
2 Ethnicity data missing for 45 Respondents.
3 Ethnicity data missing for 18 Consumers.
4 Ethnicity data missing for 39 Recent Consumers.

Table K26. Portion Size Responses (unadjusted & adjusted)

Portion Size	Recent Consumers			Consumers			Respondents		
	n	%	adj%	n	%	adj%	n	%	adj%
1/2 of model	104	19	19	222	19	18	255	19	19
1 model	269	50	51	592	51	54	669	50	52
1 1/2 of model	43	8	8	77	7	7	81	6	6
2 times model	38	7	6	78	7	6	87	7	6
Other response	76	15	14	160	14	13	179	13	13
Missing/Don't Know/Declined	7	1	2	23	2	2	60	5	4
Total	537	100	100	1152	100	100	1331	100	100

Table K27a. Portion Size (in ounces) Among Consumers (unadjusted & adjusted)

	N	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Consumers- unadjusted[1]	1129	7.69	3.67	1.00	4.00	4.00	6.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00
Consumers - unadjusted[2]	975	7.69	3.63	1.60	4.00	4.00	6.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00
Consumers - adjusted[2]	975	7.66	3.38	1.60	4.00	4.00	8.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00

1 Portion size data missing for 23 consumers (2%).
2 Portion size and fishing frequency data missing for 177 consumers (15%).

Table K27b. Portion Size (in ounces) Among Recent Consumers (unadjusted & adjusted)

	N	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Recent Consumers - unadjusted[1]	530	7.77	4.05	2.00	4.00	4.00	6.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00
Recent Consumers - unadjusted[2]	490	7.77	4.06	2.00	4.00	4.00	6.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00
Recent Consumers - adjusted[2]	490	7.68	3.76	2.00	4.00	4.00	6.00	8.00	8.00	8.00	8.00	8.00	12.00	16.00	48.00

1 Portion size data missing for 7 recent consumers (1%).
2 Portion size and fishing frequency data missing for 47 recent consumers (9%).

Table K28. Meal Frequency Among Recent Consumers Based on 4-Week Recall (unadjusted & adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Recent Consumers - unadjusted[1]	512	2.37	3.53	4.32	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	11.00	32.00
Recent Consumers - unadjusted[2]	473	2.40	3.57	4.34	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	12.00	32.00
Recent Consumers - adjusted[2]	473	2.04	2.87	3.38	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	8.00	32.00

1 Meal frequency data missing for 25 recent consumers (5%).
2 Meal frequency and fishing frequency data missing for 64 recent consumers (12%).

Table K29. Consumption Rate (g/d) Among Recent Consumers Based on 4-Week Recall (unadjusted & adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Recent Consumers - unadjusted[1]	501	16.55	28.08	39.63	2.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	36.00	56.00	108.00	324.00
Recent Consumers - unadjusted[2]	465	16.76	28.75	40.74	2.00	5.30	8.00	8.00	12.00	16.00	16.00	24.00	40.00	64.00	108.00	324.00
Recent Consumers - adjusted[2]	465	13.97	23.02	32.05	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.00	32.00	48.00	80.00	324.00

1 Consumption rate data missing for 36 recent consumers (7%).
2 Consumption rate and fishing frequency data missing for 72 recent consumers (13%).

Table K30a. Consumption Rate (g/d) Among Consumers Based on 4-Week Recall (unadjusted & adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Consumers - unadjusted[1]	1116	0.00	12.60	30.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	8.00	16.00	32.00	53.20	324.00
Consumers - unadjusted[2]	1080	0.00	12.39	30.30	0.00	0.00	0.00	0.00	0.00	0.00	4.00	8.00	16.00	32.00	52.60	324.00
Consumers - adjusted[2]	1080	0.00	6.30	19.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	16.00	32.00	324.00

1 Consumption rate data missing for 36 consumers (3%).
2 Consumption rate and fishing frequency data missing for 72 consumers (6%).

Table K30b. Consumption Rate (g/d) Among Consumers Based on 12-Month Recall (unadjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Consumers - unadjusted[1]	1019	1.20	11.00	35.70	0.00	0.00	0.60	0.90	1.60	2.50	3.70	6.80	11.00	22.10	44.20	638.20

1 Consumption rate data missing for 133 consumers (12%).

Table K31a. Per Angler Consumption Rate (g/d) Based on 4-Week Recall (unadjusted & adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Respondents - unadjusted[1]	1295	0.00	10.87	28.18	0.00	0.00	0.00	0.00	0.00	0.00	6.00	8.00	16.00	32.00	48.00	324.00
Respondents - unadjusted[2]	1259	0.00	10.62	28.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	16.00	32.00	48.00	324.00
Respondents - adjusted[2]	1259	0.00	5.31	18.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.33	16.00	24.00	324.00

1 Consumption rate data missing for 36 all respondents (3%).
2 Consumption rate and fishing frequency data missing for 72 all respondents (5%).

Table K31b. Per Angler Consumption Rate (g/d) Based on 12-Month Recall (unadjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Respondents - unadjusted[1]	1198	0.40	9.30	33.10	0.00	0.00	0.00	0.40	0.90	1.80	3.10	4.90	7.70	18.40	36.80	638.20

1 Consumption rate data missing for 133 all respondents (10%).

Table K32. Portion Size (ounces) Among Consumers by Demographic Factors (unadjusted & adjusted)

	Unadjusted			Adjusted		
Demographic Factor	N	Mean	95% CI[1]	N	Mean	95% CI[1]
Total[2]	1129	7.69	7.48, 7.91	975	7.66	7.45, 7.88
Mode:						
Piers	572	7.40	7.10, 7.70	482	7.35	7.04, 7.66
Beach and Bank	81	7.93	7.04, 8.82	72	7.38	6.49, 8.27
Private Boats	381	8.08	7.70, 8.46	342	7.98	7.65, 8.32
Party Boats	95	7.67	7.04, 8.30	79	7.93	7.18, 8.68
Ethnicity (major groups):						
African American	103	8.85	8.15, 9.56	94	9.02	8.26, 9.79
Latino/Hispanic	151	8.03	7.43, 8.62	132	8.22	7.56, 8.89
Caucasian	426	7.98	7.63, 8.33	384	7.77	7.47, 8.07
Asian	386	6.86	6.50, 7.23	314	6.71	6.33, 7.10
Other Asian	27	8.74	7.66, 9.82	21	8.61	7.35, 9.86
Asian Subgroups:						
Chinese	60	7.38	6.18, 8.59	44	7.17	5.56, 8.78
Filipino	153	6.61	6.09, 7.13	129	6.71	6.20, 7.22
Vietnamese	95	6.47	5.82, 7.11	70	6.12	5.37, 6.87
Pacific Islander	24	8.83	7.04, 10.63	23	8.40	6.98, 9.81
Other	54	6.82	5.87, 7.78	48	6.73	5.76, 7.71
Annual Income:						
< $ 20,000	214	7.25	6.65, 7.84	180	7.15	6.65, 7.66
$ 20 - $ 45,000	302	7.88	7.47, 8.30	264	7.86	7.44, 8.29
> $ 45,000	457	7.77	7.48, 8.06	403	7.77	7.46, 8.08
Education:						
<12th Grade	161	7.56	6.83, 8.29	135	7.39	6.77, 8.01
HS/GED	346	7.75	7.35, 8.14	305	7.66	7.26, 8.06
Some College	335	7.80	7.44, 8.15	287	7.95	7.58, 8.32
> 4 Years College	218	7.35	6.95, 7.75	190	7.30	6.92, 7.69
Season Interviewed:						
Winter	200	7.63	7.12, 8.14	180	7.71	7.18, 8.24
Spring	204	7.34	6.90, 7.79	189	7.19	6.76, 7.62
Summer	446	7.72	7.35, 8.09	359	7.64	7.28, 8.00
Fall	279	7.95	7.53, 8.36	247	8.10	7.68, 8.52
Age:						
18-45 years	681	7.81	7.55, 8.07	572	7.85	7.57, 8.12
46-65 years	321	7.80	7.36, 8.24	289	7.63	7.25, 8.01
65+ years	88	6.16	5.53, 6.79	80	6.22	5.65, 6.79
Gender:						
Male	992	7.76	7.54, 7.99	858	7.76	7.54, 7.99
Female	92	6.75	5.95, 7.56	76	6.58	5.78, 7.37

1 CI = Confidence Interval
2 Portion size data missing for 23 Consumers.

Table K33. Meal Frequency (last 4 weeks) Among Recent Consumers by Demographic Factors (unadjusted & adjusted)

	Unadjusted			Adjusted		
Demographic Factor	N	Geom Mean	95% CI[1]	N	Geom Mean	95% CI[1]
Total	512	2.37	2.21, 2.55	473	2.04	1.90, 2.18
Mode:						
Piers	263	2.51	2.26, 2.78	238	2.20	1.99, 2.44
Beach and Bank	37	2.43	1.82, 3.24	32	2.14	1.58, 2.90
Private Boats	175	2.20	1.96, 2.46	166	1.81	1.64, 2.01
Party Boats	37	2.25	1.82, 2.80	37	2.15	1.72, 2.70
Ethnicity (major groups):						
African American	43	2.22	1.77, 2.79	41	2.01	1.59, 2.53
Latino/Hispanic	56	2.26	1.81, 2.81	52	1.82	1.49, 2.22
Caucasian	164	2.00	1.79, 2.23	159	1.72	1.56, 1.91
Asian	222	2.78	2.48, 3.12	196	2.48	2.22, 2.78
Other	9	2.73	1.39, 5.37	7	2.60	1.24, 5.46
Asian Subgroups:						
Chinese	33	2.86	2.19, 3.73	27	2.43	1.86, 3.18
Filipino	80	3.05	2.46, 3.79	72	3.08	2.52, 3.77
Vietnamese	62	2.57	2.14, 3.08	53	2.38	1.92, 2.94
Pacific Islander	14	3.46	1.87, 6.42	13	2.02	1.22, 3.37
Other Asian	33	2.28	1.70, 3.06	31	1.90	1.44, 2.50
Annual Income:						
< $ 20,000	114	2.50	2.15, 2.91	104	2.11	1.81, 2.45
$ 20 - $ 45,000	132	2.46	2.15, 2.82	122	2.06	1.81, 2.34
> $ 45,000	195	2.43	2.15, 2.75	181	2.06	1.84, 2.31
Education:						
<12th Grade	82	2.70	2.25, 3.24	75	2.38	1.99, 2.84
HS/GED	156	2.25	1.99, 2.54	146	1.91	1.70, 2.14
Some College	143	2.38	2.08, 2.71	128	2.10	1.85, 2.38
> 4 Years College	98	2.49	2.08, 3.00	94	1.98	1.67, 2.35
Season Interviewed:						
Winter	77	2.20	1.84, 2.62	71	1.76	1.49, 2.07
Spring	81	2.02	1.69, 2.42	77	1.76	1.47, 2.10
Summer	215	2.46	2.21, 2.75	193	2.24	2.02, 2.50
Fall	139	2.56	2.23, 2.95	132	2.10	1.85, 2.38
Age:						
18-45 years	284	2.31	2.10, 2.53	261	2.02	1.85, 2.21
46-65 years	163	2.42	2.13, 2.75	150	1.97	1.74, 2.23
65+ years	46	2.86	2.21, 3.70	44	2.39	1.91, 3.00
Gender:						
Male	450	2.35	2.18, 2.53	418	2.00	1.86, 2.15
Female	41	2.79	2.10, 3.69	35	2.29	1.80, 2.91

1 CI = Confidence Interval

Table K34a. Meal Frequency in Last Four Weeks Among Recent Consumers by Demographic Factors (unadjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	512	2.37	3.53	4.32	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	11.00	32.00
Mode:																
Piers	263	2.51	3.92	5.09	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	8.00	12.00	32.00
Beach and Bank	37	2.43	3.81	5.04	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	5.00	8.00	17.00	27.00
Private Boats	175	2.20	3.06	3.06	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	6.00	10.00	19.00
Party Boats	37	2.25	2.73	1.64	1.00	1.00	1.00	1.00	2.00	3.00	3.00	3.00	4.00	5.00	6.00	7.00
Ethnicity (major groups):																
African American	43	2.22	3.02	3.01	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	5.00	8.00	16.00
Latino/Hispanic	56	2.26	3.43	4.54	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	6.00	19.00	25.00
Caucasian	164	2.00	2.70	2.82	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	25.00
Asian	222	2.78	4.24	5.08	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	6.00	8.00	14.00	32.00
Other	9	2.73	4.00	4.15	1.00	1.00	1.00	2.00	2.00	2.00	3.00	3.00	9.00	13.00	13.00	13.00
Asian Subgroups:																
Chinese	33	2.86	3.73	2.79	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	6.00	8.00	10.00	11.00
Filipino	80	3.05	5.21	6.81	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	6.00	13.00	24.50	32.00
Vietnamese	62	2.57	3.29	2.36	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	5.00	7.00	9.00	10.00
Pacific Islander	14	3.46	6.21	7.90	1.00	1.00	1.00	2.00	2.00	2.50	4.00	6.00	9.00	23.00	25.00	25.00
Other Asian	33	2.28	3.33	3.64	1.00	1.00	1.00	1.00	2.00	2.00	2.00	4.00	5.00	6.00	14.00	17.00
Annual Income:																
< $ 20,000	114	2.50	3.60	3.78	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	8.00	11.00	25.00
$ 20 - $ 45,000	132	2.46	3.51	4.07	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	9.00	27.00
> $ 45,000	195	2.43	3.89	5.23	1.00	1.00	1.00	1.00	2.00	2.00	2.50	3.00	5.00	8.00	14.00	32.00

Table K34a. (cont.) Meal Frequency in Last Four Weeks Among Recent Consumers by Demographic Factors (unadjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	512	2.37	3.53	4.32	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	11.00	32.00
Education:																
<12th Grade	82	2.70	3.94	4.44	1.00	1.00	1.00	2.00	2.00	3.00	4.00	4.00	6.00	8.00	11.00	27.00
HS/GED	156	2.25	3.16	3.53	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	7.00	9.00	31.00
Some College	143	2.38	3.55	4.57	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	5.00	6.00	13.00	28.00
> 4 Years College	98	2.49	4.07	5.32	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	9.00	16.00	32.00
Season Interviewed:																
Winter	77	2.20	3.08	3.09	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	8.00	9.00	19.00
Spring	81	2.02	3.09	4.14	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	12.00	25.00
Summer	215	2.46	3.60	4.20	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	11.00	32.00
Fall	139	2.56	3.94	5.11	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	5.00	8.00	12.00	31.00
Age:																
18-45 years	284	2.31	3.38	4.12	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	9.00	32.00
46-65 years	163	2.42	3.66	4.66	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	8.00	12.00	31.00
65+ years	46	2.86	4.28	4.73	1.00	1.00	1.00	2.00	2.00	2.50	3.00	5.00	6.00	8.00	12.00	25.00
Gender:																
Male	450	2.35	3.46	4.13	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	7.00	11.00	31.00
Female	41	2.79	4.54	6.37	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	5.00	7.00	19.00	32.00

Table K34b. Meal Frequency in Last Four Weeks Among Recent Consumers by Demographic Factors (adjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	473	2.04	2.87	3.38	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	8.00	32.00
Mode:																
Piers	238	2.20	3.29	4.23	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	6.00	9.00	32.00
Beach and Bank	32	2.14	3.15	3.58	1.00	1.00	1.00	1.00	1.00	2.00	2.00	4.00	5.00	7.00	7.00	27.00
Private Boats	166	1.81	2.39	2.40	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	8.00	19.00
Party Boats	37	2.15	2.68	1.79	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	6.00	7.00	7.00
Ethnicity (major groups):																
African American	41	2.01	2.75	2.82	1.00	1.00	1.00	1.00	1.00	2.00	3.00	3.00	3.00	5.00	8.00	16.00
Latino/Hispanic	52	1.82	2.49	2.83	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	6.00	7.00	25.00
Caucasian	159	1.72	2.26	2.48	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	6.00	25.00
Asian	196	2.48	3.59	4.11	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	6.00	9.00	32.00
Other	7	2.60	3.61	3.55	1.00	1.00	2.00	2.00	2.00	2.00	2.00	3.00	3.00	9.00	13.00	13.00
Asian Subgroups:																
Chinese	27	2.43	3.04	2.20	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	4.00	6.00	8.00	11.00
Filipino	72	3.08	4.78	5.94	1.00	1.00	2.00	2.00	2.00	3.00	4.00	4.00	5.00	12.00	22.00	32.00
Vietnamese	53	2.38	3.18	2.44	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	6.00	9.00	10.00
Pacific Islander	13	2.02	3.19	4.67	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	6.00	9.00	23.00
Other Asian	31	1.90	2.62	2.69	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	4.00	6.00	6.00	17.00
Annual Income:																
< $ 20,000	104	2.11	2.94	2.86	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	9.00	25.00
$ 20 - $ 45,000	122	2.06	2.83	3.26	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	5.00	7.00	27.00
> $ 45,000	181	2.06	3.01	3.89	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	3.00	6.00	8.00	32.00

Table K34b. (cont.) Meal Frequency in Last Four Weeks Among Recent Consumers by Demographic Factors (adjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	473	2.04	2.87	3.38	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	8.00	32.00
Education:																
<12th Grade	75	2.38	3.27	3.18	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	5.00	6.00	8.00	27.00
HS/GED	146	1.91	2.55	2.54	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	7.00	31.00
Some College	128	2.10	2.90	3.48	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	4.00	6.00	7.00	28.00
> 4 Years College	94	1.98	3.14	4.43	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	6.00	11.00	32.00
Season Interviewed:																
Winter	71	1.76	2.32	2.15	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	4.00	4.00	8.00	19.00
Spring	77	1.76	2.79	4.31	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	5.00	12.00	25.00
Summer	193	2.24	3.06	3.07	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	4.00	6.00	7.00	32.00
Fall	132	2.10	2.94	3.59	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	3.00	6.00	8.00	31.00
Age:																
18-45 years	261	2.02	2.79	2.93	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	8.00	32.00
46-65 years	150	1.97	2.94	4.22	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	3.00	4.00	8.00	31.00
65+ years	44	2.39	3.14	2.48	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	6.00	8.00	19.00
Gender:																
Male	418	2.00	2.83	3.41	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	6.00	8.00	31.00
Female	35	2.29	3.01	3.11	1.00	1.00	1.00	2.00	2.00	2.00	3.00	3.00	4.00	7.00	7.00	32.00

Table K35. Consumption Rate Among Recent Consumers by Demographic Factors (unadjusted & adjusted)

	Unadjusted			Adjusted		
Demographic Factor	N	Geom Mean	95% CI[1]	N	Geom Mean	95% CI[1]
Total	501	16.55	15.20, 18.02	465	13.97	12.84, 15.20
Mode:						
Piers	255	16.33	14.41, 18.51	233	13.81	12.17, 15.69
Beach and Bank	37	21.34	15.54, 29.32	32	17.45	12.08, 25.22
Private Boats	172	16.27	14.15, 18.71	163	13.37	11.72, 15.24
Party Boats	37	15.18	11.58, 19.90	37	14.70	10.93, 19.77
Ethnicity (major groups):						
African American	43	19.41	15.03, 25.07	41	17.84	13.91, 22.87
Latino/Hispanic	56	16.56	12.57, 21.83	52	13.34	10.23, 17.40
Caucasian	163	14.43	12.55, 16.58	158	12.06	10.54, 13.79
Asian	213	17.78	15.51, 20.39	190	15.44	13.39, 17.80
Other	9	25.00	13.09, 47.75	7	27.47	13.72, 55.02
Asian Subgroups:						
Chinese	31	19.75	13.93, 28.01	26	15.25	9.87, 23.57
Filipino	77	17.36	13.53, 22.29	70	17.82	13.99, 22.70
Vietnamese	60	15.85	12.74, 19.72	51	14.51	11.18, 18.83
Pacific Islander	13	37.25	19.48, 71.23	12	22.42	11.23, 44.73
Other Asian	32	15.61	10.74, 22.70	31	12.64	8.75, 18.27
Annual Income:						
< $ 20,000	110	16.27	13.37, 19.81	101	13.21	10.92, 16.00
$ 20 - $ 45,000	127	17.31	14.69, 20.41	119	13.44	11.43, 15.82
> $ 45,000	194	17.40	15.10, 20.05	180	14.83	12.88, 17.08
Education:						
<12th Grade	79	18.85	14.97, 23.74	73	15.49	12.49, 19.21
HS/GED	151	15.89	13.58, 18.60	142	13.28	11.36, 15.51
Some College	140	16.20	13.98, 18.78	126	14.42	12.32, 16.88
> 4 Years College	98	17.57	14.29, 21.61	94	13.50	11.05, 16.50
Season Interviewed:						
Winter	76	15.32	12.18, 19.25	70	11.13	8.82, 14.06
Spring	80	13.59	10.78, 17.12	76	11.21	8.86, 14.19
Summer	209	17.14	15.09, 19.45	189	15.56	13.75, 17.61
Fall	136	18.39	15.65, 21.62	130	15.56	13.38, 18.11
Age:						
18-45 years	276	16.59	14.79, 18.61	256	14.75	13.16, 16.53
46-65 years	161	16.93	14.60, 19.64	148	12.78	11.04, 14.80
65+ years	45	15.55	11.32, 21.35	43	12.90	9.52, 17.48
Gender:						
Male	440	16.59	15.16, 18.16	410	13.69	12.50, 14.98
Female	40	17.27	12.57, 23.73	35	15.24	11.60, 20.03

1 CI = Confidence Interval

Table K36a. Consumption Rates (g/d) Among Recent Consumers by Demographic Factors (unadjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	501	16.55	28.08	39.63	2.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	36.00	56.00	108.00	324.00
Mode:																
Piers	255	16.33	28.62	39.79	2.67	4.00	8.00	8.00	12.00	16.00	19.00	32.00	40.00	56.00	108.00	304.00
Beach and Bank	37	21.34	36.97	57.28	4.00	8.00	12.00	16.00	16.00	16.00	24.00	28.00	48.00	108.00	136.00	324.00
Private Boats	172	16.27	26.92	38.09	2.00	8.00	8.00	8.00	12.00	16.00	16.00	24.00	32.00	56.00	96.00	288.00
Party Boats	37	15.18	20.84	18.12	4.00	4.00	8.00	8.00	12.00	16.00	21.44	24.00	32.00	40.00	72.00	84.00
Ethnicity (major groups):																
African American	43	19.41	29.86	42.43	5.36	8.00	8.00	10.67	16.00	16.00	24.00	32.00	36.00	48.00	64.00	256.00
Latino/Hispanic	56	16.56	30.73	50.26	2.67	4.00	8.00	8.00	12.00	16.00	16.08	32.00	40.00	48.00	152.00	304.00
Caucasian	163	14.43	23.23	33.91	2.00	5.33	8.00	8.00	10.64	16.00	16.00	16.00	32.00	48.00	64.00	288.00
Asian	213	17.78	30.71	40.83	2.67	4.00	8.00	8.00	16.00	16.00	21.44	32.00	42.00	72.00	112.00	324.00
Other	9	25.00	34.22	30.99	8.00	8.00	8.00	16.00	24.00	24.00	32.00	36.00	52.00	108.00	108.00	108.00
Asian Subgroups:																
Chinese	31	19.75	30.46	31.69	4.00	6.00	8.00	8.00	16.00	24.00	24.00	32.00	42.00	64.00	128.00	128.00
Filipino	77	17.36	33.89	52.92	2.67	4.00	8.00	8.00	12.00	16.00	21.33	32.00	45.00	72.00	144.00	324.00
Vietnamese	60	15.85	22.49	20.94	2.67	4.64	8.00	11.33	16.00	16.00	16.00	24.00	32.08	48.00	72.00	108.00
Pacific Islander	13	37.25	58.15	52.45	4.00	16.00	16.00	16.00	24.00	32.00	64.00	96.00	100.00	108.00	184.00	184.00
Other Asian	32	15.61	27.58	34.36	4.00	4.00	8.00	8.00	8.00	14.00	16.00	24.00	40.00	72.00	112.00	136.00
Annual Income:																
< $ 20,000	110	16.27	30.30	47.77	2.67	4.00	8.00	8.00	12.00	16.00	16.00	32.00	34.08	66.00	112.00	304.00
$ 20 - $ 45,000	127	17.31	28.18	39.69	2.67	5.33	8.00	8.00	16.00	16.00	24.00	32.00	36.00	48.00	100.00	324.00

Table K36a. (cont.) Consumption Rates (g/d) Among Recent Consumers by Demographic Factors (unadjusted)

	N	Geom Mean	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	501	16.55	28.08	39.63	2.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	36.00	56.00	108.00	324.00
Education:																
<12th Grade	79	18.85	32.88	44.93	2.67	4.00	8.00	12.00	16.00	16.00	24.00	32.00	48.00	72.00	128.00	288.00
HS/GED	151	15.89	27.12	39.52	2.00	5.33	8.00	8.00	10.72	16.00	16.00	24.00	32.00	48.00	108.00	304.00
Some College	140	16.20	24.99	30.91	2.67	5.36	8.00	8.00	14.67	16.00	16.00	24.00	32.00	50.00	90.00	200.00
> 4 Years College	98	17.57	32.23	48.70	4.00	4.00	8.00	8.00	12.00	16.00	20.00	28.00	48.00	72.00	128.00	324.00
Season Interviewed:																
Winter	76	15.32	27.54	42.82	2.00	4.00	8.00	8.00	10.64	16.00	16.00	24.00	32.00	64.00	108.00	304.00
Spring	80	13.59	25.53	38.33	2.67	4.00	6.67	8.00	8.00	12.67	16.00	17.00	32.00	60.00	128.00	200.00
Summer	209	17.14	27.72	37.40	2.00	5.36	8.00	8.00	16.00	16.00	20.00	24.00	40.00	48.00	84.00	288.00
Fall	136	18.39	30.44	42.12	2.67	5.36	8.00	10.64	16.00	16.00	24.00	32.00	40.00	64.00	108.00	324.00
Age:																
18-45 years	276	16.59	28.02	38.48	2.00	5.33	8.00	8.00	12.00	16.00	16.00	26.80	40.00	56.00	112.00	324.00
46-65 years	161	16.93	28.33	40.29	2.00	4.00	8.00	8.00	16.00	16.00	18.00	24.00	32.00	56.00	96.00	288.00
65+ years	45	15.55	28.54	47.09	2.67	4.00	5.32	8.00	11.36	16.00	22.67	28.00	32.08	64.00	72.00	304.00
Gender:																
Male	440	16.59	27.93	39.64	2.00	4.64	8.00	8.00	12.00	16.00	16.00	24.00	36.00	55.00	104.00	324.00
Female	40	17.27	30.58	42.80	4.00	5.33	8.00	8.00	12.00	16.00	18.00	24.00	32.00	90.00	140.00	200.00

Table K36b. Consumption Rates (g/d) Among Recent Consumers by Demographic Factors (adjusted) Appendix K

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	465	13.97	23.02	32.05	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.00	32.00	48.00	80.00	324.00
Mode:																
Piers	233	13.81	23.87	34.00	2.67	4.00	5.36	8.00	8.00	12.00	16.00	24.00	32.00	48.00	72.00	304.00
Beach and Bank	32	17.45	31.05	44.75	4.00	4.00	8.00	8.00	16.00	16.00	16.00	24.00	40.00	112.00	112.00	324.00
Private Boats	163	13.37	20.90	29.40	2.00	6.00	8.00	8.00	8.00	16.00	16.00	16.00	24.00	48.00	80.00	288.00
Party Boats	37	14.70	22.05	22.20	4.00	4.00	8.00	8.00	10.64	12.00	16.00	24.00	32.00	72.00	84.00	84.00
Ethnicity (major groups):																
African American	41	17.84	26.71	38.33	5.36	8.00	8.00	10.67	12.00	16.00	16.00	24.00	36.00	48.00	64.00	256.00
Latino/Hispanic	52	13.34	22.04	29.52	2.67	4.00	6.00	8.00	8.00	16.00	16.00	16.08	32.00	48.00	84.00	304.00
Caucasian	158	12.06	18.91	26.95	2.00	4.00	8.00	8.00	8.00	10.72	16.00	16.00	16.00	36.00	56.00	288.00
Asian	190	15.44	26.70	36.00	2.67	4.00	8.00	8.00	8.00	16.00	16.00	24.00	40.00	72.00	108.00	324.00
Other	7	27.47	34.62	25.49	8.00	8.00	24.00	24.00	24.00	32.00	32.00	36.00	36.00	52.00	108.00	108.00
Asian Subgroups:																
Chinese	26	15.25	27.75	34.84	4.00	4.00	6.00	8.00	8.00	12.00	24.00	24.00	40.00	80.00	128.00	128.00
Filipino	70	17.82	32.70	48.80	2.67	5.33	8.00	8.00	13.30	16.00	20.00	24.00	40.00	72.00	176.00	324.00
Vietnamese	51	14.51	21.80	20.70	2.67	4.00	8.00	8.00	12.00	16.00	16.00	24.00	40.00	48.00	72.00	108.00
Pacific Islander	12	22.42	37.95	44.17	4.00	4.00	16.00	16.00	16.00	24.00	24.00	24.00	64.00	96.00	184.00	184.00
Other Asian	31	12.64	22.04	27.62	4.00	4.00	4.00	8.00	8.00	8.00	16.00	16.00	32.00	72.00	72.00	136.00
Annual Income:																
< $ 20,000	101	13.21	21.90	27.80	2.67	4.00	5.33	8.00	8.00	12.00	16.00	16.00	32.16	48.00	72.00	304.00
$ 20 - $ 45,000	119	13.44	21.69	32.90	2.67	4.00	8.00	8.00	8.00	12.00	16.00	18.00	32.00	40.00	56.00	324.00
> $ 45,000	180	14.83	25.25	35.34	2.00	5.33	8.00	8.00	8.00	16.00	16.00	24.00	31.92	56.00	108.00	256.00

Table K36b. (cont.) Consumption Rates (g/d) Among Recent Consumers by Demographic Factors (adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Total	465	13.97	23.02	32.05	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.00	32.00	48.00	80.00	324.00
Education:																
<12th Grade	73	15.49	24.19	28.70	2.67	4.00	8.00	8.00	12.00	16.00	16.00	32.00	32.16	48.00	64.00	288.00
HS/GED	142	13.28	21.48	27.95	2.00	4.00	8.00	8.00	8.00	12.00	16.00	16.00	32.00	48.00	72.00	304.00
Some College	126	14.42	22.65	29.02	2.67	5.33	8.00	8.00	10.64	16.00	16.00	20.00	24.00	45.00	84.00	200.00
> 4 Years College	94	13.50	25.02	42.09	4.00	4.00	6.00	8.00	8.00	12.00	16.00	18.00	24.00	53.20	96.00	324.00
Season Interviewed:																
Winter	70	11.13	19.41	28.18	2.00	4.00	4.00	8.00	8.00	8.00	12.00	16.00	24.00	48.00	80.00	304.00
Spring	76	11.21	22.12	37.56	2.67	4.00	4.00	8.00	8.00	8.00	16.00	16.00	24.00	40.00	144.00	200.00
Summer	189	15.56	23.90	30.56	2.00	7.92	8.00	8.00	12.00	16.00	16.00	24.00	32.00	48.00	72.00	288.00
Fall	130	15.56	24.35	32.10	2.67	5.36	8.00	8.00	12.00	16.00	16.00	21.40	32.00	64.00	96.00	324.00
Age:																
18-45 years	256	14.75	24.20	32.20	2.00	5.33	8.00	8.00	8.00	12.00	16.00	24.00	36.00	48.00	84.00	324.00
46-65 years	148	12.78	21.04	32.90	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.00	24.00	32.00	64.00	288.00
65+ years	43	12.90	20.76	24.44	2.67	4.00	4.00	8.00	8.00	16.00	16.00	24.00	32.00	64.00	72.00	304.00
Gender:																
Male	410	13.69	22.68	32.30	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.10	32.00	48.00	72.00	324.00
Female	35	15.24	22.28	26.79	4.00	6.00	8.00	8.00	12.00	16.00	16.00	16.00	24.00	53.20	84.00	200.00

Table K37a. Consumers With Consumption Above and Below the Health Advisory (unadjusted & adjusted)

	Above Advisory			Below Advisory		
	n	%	adj%	n	%	adj%
Total	164	15	9	952	85	91
Mode						
Pier	84	51	46	477	50	43
Beach and Bank	10	6	7	69	7	7
Private Boats	53	32	30	328	35	39
Party Boats	17	11	17	78	8	11
Ethnicity (major groups)						
Black/African American	18	11	12	82	9	10
Latino/Hispanic	18	11	10	130	14	14
Caucasian	41	25	24	383	40	46
Asian	78	48	49	302	32	26
Other	4	2	3	22	2	1
Missing/DK/Refuse	5	3	2	33	3	3
Ethnicity (with Asian subgroups)						
Black/African American	18	11	12	82	9	10
Latino/Hispanic	18	11	10	130	14	14
Caucasian	41	25	24	383	40	46
Chinese	16	10	9	43	4	3
Filipino	29	18	19	121	13	11
Vietnamese	15	9	12	76	8	6
Pacific Islander	7	4	2	18	2	2
Other Asian	11	7	7	44	5	4
Other	4	2	3	22	2	1
Missing/DK/Refuse	5	3	2	33	3	3
Income						
< $20,000/year	34	21	18	174	18	16
$20,000 - $45,000/year	47	29	22	251	26	26
> $45,000/year	68	41	51	386	41	45
Missing/DK/Refuse	15	9	9	141	15	13
Education						
< 12th Grade	29	18	17	127	13	13
Completed HS or GED	48	29	26	296	31	30
Some college/trade sch.	46	28	31	282	30	30
>= 4 years college	34	21	21	181	19	20
Missing/DK/Refuse	7	4	5	66	7	7
Gender						
Male	146	89	87	828	87	86
Female	13	8	9	80	8	9
Missing/DK/Refuse	5	3	4	44	5	5
Age						
18-45 years	91	56	61	581	61	59
46-65 years	51	31	25	267	28	30
65+ years	18	11	11	65	7	7
Missing/DK/Refuse	4	2	3	39	4	4
Season Interviewed						
Winter	22	14	12	178	19	21
Spring	20	12	15	184	19	23
Summer	64	39	41	376	40	34
Fall	58	35	32	214	22	22

Table K37b. Consumers With Consumption Above and Below the Health Advisory (row%) (unadjusted & adjusted)

	Above Advisory			Below Advisory		
	n	row%	adjrow%	n	row%	adjrow%
Total	164	15	9	952	85	91
Mode						
Pier	84	15	9	477	85	91
Beach and Bank	10	13	9	69	87	91
Private Boats	53	14	6	328	86	94
Party Boats	17	18	13	78	82	87
Ethnicity (major groups)						
Black/African American	18	18	11	82	82	89
Latino/Hispanic	18	12	6	130	88	94
Caucasian	41	10	5	383	90	95
Asian	78	21	15	302	79	85
Other	4	15	17	22	85	83
Missing/DK/Refuse	5	13	6	33	87	94
Ethnicity (with Asian subgroups)						
Black/African American	18	18	11	82	82	89
Latino/Hispanic	18	12	6	130	88	94
Caucasian	41	10	5	383	90	95
Chinese	16	27	21	43	73	79
Filipino	29	19	14	121	81	86
Vietnamese	15	16	14	76	84	86
Pacific Islander	7	28	10	18	72	90
Other Asian	11	20	14	44	80	86
Other	4	15	17	22	85	83
Missing/DK/Refuse	5	13	6	33	87	94
Income						
< $20,000/year	34	16	10	174	84	90
$20,000 - $45,000/year	47	16	7	251	84	93
> $45,000/year	68	15	10	386	85	90
Missing/DK/Refuse	15	10	6	141	90	94
Education						
< 12th Grade	29	19	11	127	81	89
Completed HS or GED	48	14	7	296	86	93
Some college/trade sch.	46	14	9	282	86	91
>= 4 years college	34	16	9	181	84	91
Missing/DK/Refuse	7	10	6	66	90	94
Gender						
Male	146	15	9	828	85	91
Female	13	14	8	80	86	92
Missing/DK/Refuse	5	10	8	44	90	92
Age						
18-45 years	91	14	9	581	86	91
46-65 years	51	16	7	267	84	93
65+ years	18	22	14	65	78	86
Missing/DK/Refuse	4	9	6	39	91	94
Season Interviewed						
Winter	22	11	5	178	89	95
Spring	20	10	6	184	90	94
Summer	64	15	10	376	85	90
Fall	58	21	12	214	79	88

Table K38. Consumers With Consumption Above the 95th Percentile (unadjusted & adjusted)

	Above 95th Percentile			Below 95th Percentile		
	n	%	adj%	n	%	adj%
Total	53	5	3	1063	95	97
Mode						
Pier	28	53	40	533	51	43
Beach and Bank	5	9	11	74	7	7
Private Boats	18	34	33	363	34	38
Party Boats	2	4	16	93	9	12
Ethnicity (major groups)						
Black/African American	3	6	6	97	9	9
Latino/Hispanic	4	8	9	144	13	14
Caucasian	12	23	28	412	38	45
Asian	30	57	53	350	34	28
Other	1	2	1	25	2	2
Missing/DK/Refuse	3	6	3	35	3	3
Ethnicity (with Asian subgroups)						
Black/African American	3	6	6	97	9	9
Latino/Hispanic	4	8	9	144	13	14
Caucasian	12	23	28	412	38	45
Chinese	4	8	8	55	5	3
Filipino	11	21	19	139	13	12
Vietnamese	5	9	12	86	8	7
Pacific Islander	6	11	4	19	2	2
Other Asian	4	8	12	51	5	5
Other	1	2	1	25	2	2
Missing/DK/Refuse	3	6	3	35	3	3
Income						
< $20,000/year	13	25	18	195	19	16
$20,000 - $45,000/year	11	21	13	287	27	26
> $45,000/year	25	47	57	429	40	45
Missing/DK/Refuse	4	8	11	152	14	13
Education						
< 12th Grade	11	21	13	145	14	13
Completed HS or GED	13	25	27	331	31	30
Some college/trade sch.	12	23	27	316	30	30
>= 4 years college	14	26	23	201	19	20
Missing/DK/Refuse	3	6	9	70	7	6
Gender						
Male	44	83	77	930	88	86
Female	5	9	10	88	8	9
Missing/DK/Refuse	4	8	13	45	4	5
Age						
18-45 years	28	53	57	644	61	59
46-65 years	17	32	23	301	28	30
65+ years	5	9	11	78	8	7
Missing/DK/Refuse	3	6	9	40	4	4
Season Interviewed						
Winter	9	17	12	191	18	21
Spring	9	17	19	195	18	22
Summer	18	34	34	422	40	35
Fall	17	32	35	255	24	23

Table K39. Consumers of White Croaker, Leopard Shark, and Striped Bass by Demographics Factors (unadjusted)

Consumers	N	White Croaker		Leopard Shark		Striped Bass	
		Yes (n)	Yes (%)	Yes (n)	Yes (%)	Yes (n)	Yes (%)
Total	1152	318	28	231	20	903	78
Mode							
Piers	583	216	37	119	20	443	76
Beach and Bank	81	33	41	17	21	65	80
Private Boats	390	62	16	81	21	316	81
Party Boats	98	7	7	14	14	79	81
Chi-Square p-value		<0.0001		0.5291		0.1989	
Ethnicity (major groups)							
African American	104	35	34	21	20	86	83
Latino	151	44	29	22	15	111	74
Caucasian	431	43	10	97	23	346	80
Asian	400	185	46	74	19	309	77
Other	27	4	15	9	33	22	81
Missing/DK/Refuse	39	7	18	8	21	29	74
Chi-Square p-value		<0.0001		0.0986		0.3286	
Ethnicity (with Asian subgroups)							
African American	104	35	34	21	20	86	83
Latino	151	44	29	22	15	111	74
Caucasian	431	43	10	97	23	346	80
Chinese	63	33	52	18	29	47	75
Filipino	157	66	42	15	10	126	80
Vietnamese	96	51	53	32	33	75	78
Pacific Islander	26	10	38	3	12	20	77
Other Asian	58	25	43	6	10	41	71
Other	27	4	15	9	33	22	81
Missing/DK/Refuse	39	7	18	8	21	29	74
Chi-Square p-value		<0.0001		<0.0001		0.4941	
Income							
<$20,000	217	94	43	56	26	175	81
$20,000-$45,000	309	100	32	66	21	248	80
>$45,000	463	87	19	87	19	371	80
Missing/DK/Refuse	163	37	23	22	13	109	67
Mantel-Haenszel Chi-Square p-value		<0.0001		0.0348		0.9119	
Education							
<12th Grade	163	62	38	39	24	122	75
HS or GED	356	106	30	87	24	286	80
Some College	339	83	24	66	19	267	79
>=4 yrs. College	219	53	24	29	13	175	80
Missing/DK/Refuse	75	14	19	10	13	53	71
Mantel-Haenszel Chi-Square p-value		0.0013		0.0017		0.4691	
Season Interviewed							
Winter	202	60	30	50	25	156	77
Spring	208	55	26	42	20	167	80
Summer	458	114	25	91	20	246	54
Fall	284	89	31	48	17	234	82
Chi-Square p-value		0.2554		0.2431		0.1147	

Data not adjusted for avidity bias.

Table K40. Recent Consumption of Seven SF Bay Species by Demographic Factors (unadjusted)

Recent Consumers	N	White Croaker Yes (%)	Leopard Shark Yes (%)	Striped Bass Yes (%)	Halibut Yes (%)	Jacksmelt Yes (%)	Sturgeon Yes (%)	Surfperch[1] Yes (%)
Total	537	16	6	54	24	17	17	13
Mode								
Piers	277	22	6	56	10	24	12	21
Beach and Bank	39	13	10	46	18	41	10	21
Private Boats	181	10	6	50	35	6	29	2
Party Boats	40	3	8	63	73	3	10	3
Chi-Square p-value		0.0688	0.3137	0.2251	<0.0001	<0.0001	<0.0001	<0.0001
Ethnicity (major groups)								
African American	47	15	6	60	28	13	9	21
Latino	59	19	7	49	20	17	22	7
Caucasian	170	2	5	51	39	3	28	2
Asian	233	25	6	55	14	29	9	22
Other	10	10	0	50	20	30	30	20
Missing/DK/Refuse	18	28	17	61	17	11	22	6
Chi-Square p-value		0.1540	0.7374	0.9067	<0.0001	<0.0001	<0.0001	<0.0001
Ethnicity (with Asian subgroups)								
African American	47	15	6	60	28	13	9	21
Latino	59	19	7	49	20	17	22	7
Caucasian	170	2	5	51	39	3	28	2
Chinese	35	40	6	43	17	29	0	14
Filipino	84	21	4	58	10	24	10	35
Vietnamese	65	18	11	58	15	37	12	9
Pacific Islander	14	36	0	50	14	50	7	36
Other Asian	35	29	6	54	20	17	9	17
Other	10	10	0	50	20	30	30	20
Missing/DK/Refuse	18	28	17	61	17	11	22	6
Chi-Square p-value		0.1576	0.7225	0.5886	<0.0001	<0.0001	<0.0001	Not Valid
Income								
<$20,000	119	27	8	57	12	22	12	16
$20,000-$45,000	138	13	4	61	19	20	18	14
>$45,000	203	12	6	50	34	12	22	10
Missing/DK/Refuse	77	14	6	45	26	18	10	16
Mantel-Haenszel Chi-Square p-value		0.6343	0.9165	0.1475	<0.0001	0.0196	0.0208	0.1293
Education								
<12th Grade	86	28	8	51	14	26	14	15
HS or GED	163	17	6	54	21	16	19	12
Some College	151	9	7	54	26	17	19	13
>=4 yrs. College	102	15	4	54	31	16	18	18
Missing/DK/Refuse	35	17	9	54	34	11	6	6
Mantel-Haenszel Chi-Square p-value		0.2724	0.7844	0.7027	0.0028	0.138	0.5786	0.4793
Season Interviewed								
Winter	78	26	8	37	13	8	40	21
Spring	84	13	0	39	13	19	26	18
Summer	227	12	8	54	35	24	8	11
Fall	148	19	6	70	20	11	14	10
Chi-Square p-value		0.0866	0.0361	<0.0001	<0.0001	0.0015	<0.0001	<0.0001

Data not adjusted for avidity bias.
1 All species of surfperch (Black perch, Walleye surfperch, Shiner surfperch, etc.) are included.

Table K41. Fish Parts Consumed and Fish Preparation Practices Among Consumers of White Croaker, Leopard Shark, and Striped Bass (unadjusted & adjusted)

	Overall[1]									Never Eats White Croaker Leopard Shark,Striped Bass[2]			Total
	greater than 1/2 time			less than 1/2 time			never eats fish part						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Skin	230	20	18	67	6	6	667	58	62	188	16	14	1152
Guts	14	1	1	8	1	0	942	82	85	188	16	14	1152
Cooking Juices	163	14	14	108	9	10	693	60	62	188	16	14	1152
Soup	107	9	9	191	17	16	666	58	61	188	16	14	1152
Raw	22	2	1	70	6	6	872	76	79	188	16	14	1152

	White Croaker Consumers									Never Eats White Croaker[3]			Total
	greater than 1/2 time			less than 1/2 time			never eats fish part						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Skin	120	10	9	35	3	3	163	14	14	834	72	74	1152
Guts	3	0	0	4	0	0	311	27	26	834	72	74	1152
Cooking Juices	59	5	4	32	3	3	227	20	19	834	72	74	1152
Soup	39	3	3	77	7	6	202	18	17	834	72	74	1152
Raw	1	0	0	5	0	0	312	27	26	834	72	74	1152

	Leopard Shark Consumers									Never Eats Leopard Shark[4]			Total
	greater than 1/2 time			less than 1/2 time			never eats fish part						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Skin	4	0	0	5	0	1	222	19	20	921	80	79	1152
Guts	3	0	0	1	0	0	227	20	21	921	80	79	1152
Cooking Juices	18	2	1	21	2	2	192	17	18	921	80	79	1152
Soup	11	1	1	28	2	2	192	17	18	921	80	79	1152
Raw	2	0	0	8	1	1	221	19	20	921	80	79	1152

	Striped Bass Consumers									Never Eats Striped Bass[5]			Total
	greater than 1/2 time			less than 1/2 time			never eats fish part						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Skin	190	16	14	59	5	6	654	57	60	249	22	20	1152
Guts	9	1	1	3	0	0	891	77	79	249	22	20	1152
Cooking Juices	144	13	13	96	8	9	663	58	58	249	22	20	1152
Soup	86	7	7	166	14	14	651	57	59	249	22	20	1152
Raw	19	2	1	61	5	5	823	71	74	249	22	20	1152

1 Consumers who reported consuming either White Croaker, Leopard Shark, or Striped Bass.
2 Includes 6 consumers who are missing White Croaker, Leopard Shark, and Striped Bass data.
3 Includes 13 consumers who are missing White Croaker data.
4 Includes 19 consumers who are missing Leopard Shark data.
5 Includes 8 consumers who are missing Striped Bass data.

Table K42a. Consumption of Striped Bass Skin by Demographic Factors (unadjusted & adjusted)

Skin Consumption	Consumes Striped Bass									Does Not Consume Striped Bass[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats skin						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	131	22	23	44	8	10	268	46	45	140	24	22	583
Beach and Bank	18	22	20	2	2	2	45	56	57	16	20	21	81
Private Boats	33	8	7	11	3	4	272	70	73	74	19	17	390
Party Boats	8	8	5	2	2	4	69	70	73	19	19	19	98
Total	190	16	14	59	5	6	654	57	60	249	22	20	1152
Ethnicity (major groups)													
African Americans	25	24	22	6	6	11	55	53	48	18	17	19	104
Latinos/Hispanics	19	13	13	7	5	5	85	56	51	40	26	31	151
Caucasians	24	6	5	9	2	2	313	73	75	85	20	17	431
Asians	118	30	28	32	8	10	159	40	43	91	23	19	400
Other	3	11	4	2	7	2	17	63	75	5	19	19	27
Missing	1	3	2	3	8	6	25	64	68	10	26	24	39
Total	190	16	14	59	5	6	654	57	60	249	22	20	1152
Ethnicity (with Asian subgroups)													
African Americans	25	24	22	6	6	11	55	53	48	18	17	19	104
Latinos/Hispanics	19	13	13	7	5	5	85	56	51	40	26	31	151
Caucasians	24	6	5	9	2	2	313	73	75	85	20	17	431
Chinese	20	32	33	4	6	7	23	37	46	16	25	13	63
Filipino	48	31	30	12	8	13	66	42	46	31	20	12	157
Vietnamese	32	33	32	10	10	13	33	34	38	21	22	17	96
Pacific Islander	10	38	19	0	0	0	10	38	46	6	23	35	26
Other Asian	8	14	16	6	10	6	27	47	42	17	29	36	58
Other	3	11	4	2	7	2	17	63	75	5	19	19	27
Missing	1	3	2	3	8	6	25	64	68	10	26	24	39
Total	190	16	14	59	5	6	654	57	60	249	22	20	1152
Income													
< $20,000	48	22	22	19	9	11	108	50	51	42	19	16	217
$20,000 - $45,000	68	22	18	12	4	5	168	54	55	61	20	22	309
> $45,000	51	11	10	20	4	5	300	65	68	92	20	17	463
Missing	23	14	11	8	5	7	78	48	53	54	33	29	163
Total	190	16	14	59	5	6	654	57	60	249	22	20	1152
Education													
< 12th Grade	48	29	25	6	4	6	68	42	42	41	25	27	163
HS/GED	59	17	13	24	7	8	203	57	61	70	20	19	356
Some College	45	13	13	18	5	6	204	60	59	72	21	23	339
>= 4 Years College	31	14	13	8	4	4	136	62	68	44	20	14	219
Missing	7	9	8	3	4	5	43	57	69	22	29	17	75
Total	190	16	14	59	5	6	654	57	60	249	22	20	1152

1 Includes 8 consumers who are missing Striped Bass data.

Table K42b. Consumption of Striped Bass Guts by Demographic Factors (unadjusted & adjusted)

Guts Consumption	Consumes Striped Bass									Does Not Consume Striped Bass[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats guts						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	5	1	1	2	0	0	436	75	76	140	24	22	583
Beach and Bank	0	0	0	0	0	0	65	80	79	16	20	21	81
Private Boats	4	1	1	1	0	0	311	80	81	74	19	17	390
Party Boats	0	0	0	0	0	0	79	81	81	19	19	19	98
Total	9	1	1	3	0	0	891	77	79	249	22	20	1152
Ethnicity (major groups)													
African Americans	1	1	1	0	0	0	85	82	80	18	17	19	104
Latinos/Hispanics	1	1	2	1	1	1	109	72	67	40	26	31	151
Caucasians	2	0	0	0	0	0	344	80	83	85	20	17	431
Asians	5	1	2	1	0	0	303	76	80	91	23	19	400
Other	0	0	0	1	4	2	21	78	79	5	19	19	27
Missing	0	0	0	0	0	0	29	74	76	10	26	24	39
Total	9	1	1	3	0	0	891	77	79	249	22	20	1152
Ethnicity (with Asian subgroups)													
African Americans	1	1	1	0	0	0	85	82	80	18	17	19	104
Latinos/Hispanics	1	1	2	1	1	1	109	72	67	40	26	31	151
Caucasians	2	0	0	0	0	0	344	80	83	85	20	17	431
Chinese	2	3	9	0	0	0	45	71	78	16	25	13	63
Filipino	1	1	0	1	1	0	124	79	88	31	20	12	157
Vietnamese	1	1	3	0	0	0	74	77	80	21	22	17	96
Pacific Islander	0	0	0	0	0	0	20	77	65	6	23	35	26
Other Asian	1	2	0	0	0	0	40	69	64	17	29	36	58
Other	0	0	0	1	4	2	21	78	79	5	19	19	27
Missing	0	0	0	0	0	0	29	74	76	10	26	24	39
Total	9	1	1	3	0	0	891	77	79	249	22	20	1152
Income													
< $20,000	1	0	1	1	0	0	173	80	82	42	19	16	217
$20,000 - $45,000	2	1	1	2	1	0	244	79	77	61	20	22	309
> $45,000	3	1	1	0	0	0	368	79	82	92	20	17	463
Missing	3	2	2	0	0	0	106	65	69	54	33	29	163
Total	9	1	1	3	0	0	891	77	79	249	22	20	1152
Education													
< 12th Grade	1	1	2	1	1	0	120	74	72	41	25	27	163
HS/GED	1	0	0	0	0	0	285	80	81	70	20	19	356
Some College	2	1	0	1	0	0	264	78	77	72	21	23	339
>= 4 Years College	3	1	2	0	0	0	172	79	84	44	20	14	219
Missing	2	3	3	1	1	0	50	67	80	22	29	17	75
Total	9	1	1	3	0	0	891	77	79	249	22	20	1152

1 Includes 8 consumers who are missing Striped Bass data.

Table K42c. Consumption of Striped Bass Cooking Juices by Demographic Factors (unadjusted & adjusted)

Cooking Juices Consumption	Consumes Striped Bass									Does Not Consume Striped Bass[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats juice						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	82	14	16	46	8	8	315	54	53	140	24	22	583
Beach and Bank	9	11	12	12	15	18	44	54	49	16	20	21	81
Private Boats	35	9	7	32	8	9	249	64	66	74	19	17	390
Party Boats	18	18	19	6	6	6	55	56	57	19	19	19	98
Total	144	13	13	96	8	9	663	58	58	249	22	20	1152
Ethnicity (major groups)													
African Americans	7	7	10	3	3	3	76	73	67	18	17	19	104
Latinos/Hispanics	18	12	14	11	7	8	82	54	47	40	26	31	151
Caucasians	36	8	9	17	4	6	293	68	68	85	20	17	431
Asians	79	20	21	57	14	17	173	43	44	91	23	19	400
Other	3	11	4	4	15	2	15	56	74	5	19	19	27
Missing	1	3	2	4	10	4	24	62	70	10	26	24	39
Total	144	13	13	96	8	9	663	58	58	249	22	20	1152
Ethnicity (with Asian subgroups)													
African Americans	7	7	10	3	3	3	76	73	67	18	17	19	104
Latinos/Hispanics	18	12	14	11	7	8	82	54	47	40	26	31	151
Caucasians	36	8	9	17	4	6	293	68	68	85	20	17	431
Chinese	17	27	35	3	5	5	27	43	46	16	25	13	63
Filipino	27	17	14	24	15	22	75	48	52	31	20	12	157
Vietnamese	21	22	21	19	20	23	35	36	38	21	22	17	96
Pacific Islander	3	12	28	4	15	6	13	50	31	6	23	35	26
Other Asian	11	19	23	7	12	10	23	40	32	17	29	36	58
Other	3	11	4	4	15	2	15	56	74	5	19	19	27
Missing	1	3	2	4	10	4	24	62	70	10	26	24	39
Total	144	13	13	96	8	9	663	58	58	249	22	20	1152
Income													
< $20,000	26	12	12	28	13	14	121	56	58	42	19	16	217
$20,000 - $45,000	39	13	14	24	8	10	185	60	54	61	20	22	309
> $45,000	60	13	13	37	8	9	274	59	61	92	20	17	463
Missing	19	12	12	7	4	4	83	51	56	54	33	29	163
Total	144	13	13	96	8	9	663	58	58	249	22	20	1152
Education													
< 12th Grade	20	12	11	17	10	13	85	52	49	41	25	27	163
HS/GED	44	12	13	17	5	6	225	63	63	70	20	19	356
Some College	30	9	9	42	12	11	195	58	58	72	21	23	339
>= 4 Years College	41	19	20	14	6	8	120	55	58	44	20	14	219
Missing	9	12	14	6	8	11	38	51	58	22	29	17	75
Total	144	13	13	96	8	9	663	58	58	249	22	20	1152

1 Includes 8 consumers who are missing Striped Bass data.

Table K42d. Consumption of Striped Bass in Soup by Demographic Factors (unadjusted & adjusted)

Soup Consumption	Consumes Striped Bass									Does Not Consume Striped Bass[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats soup						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	56	10	10	103	18	20	284	49	48	140	24	22	583
Beach and Bank	4	5	7	17	21	24	44	54	48	16	20	21	81
Private Boats	20	5	4	37	9	8	259	66	71	74	19	17	390
Party Boats	6	6	8	9	9	9	64	65	65	19	19	19	98
Total	86	7	7	166	14	14	651	57	59	249	22	20	1152
Ethnicity (major groups)													
African Americans	0	0	0	4	4	5	82	79	76	18	17	19	104
Latinos/Hispanics	10	7	7	26	17	16	75	50	45	40	26	31	151
Caucasians	9	2	3	29	7	8	308	71	72	85	20	17	431
Asians	65	16	17	98	25	27	146	37	38	91	23	19	400
Other	2	7	4	5	19	15	15	56	61	5	19	19	27
Missing	0	0	0	4	10	3	25	64	73	10	26	24	39
Total	86	7	7	166	14	14	651	57	59	249	22	20	1152
Ethnicity (with Asian subgroups)													
African Americans	0	0	0	4	4	5	82	79	76	18	17	19	104
Latinos/Hispanics	10	7	7	26	17	16	75	50	45	40	26	31	151
Caucasians	9	2	3	29	7	8	308	71	72	85	20	17	431
Chinese	4	6	5	10	16	18	33	52	63	16	25	13	63
Filipino	28	18	18	49	31	34	49	31	36	31	20	12	157
Vietnamese	22	23	22	23	24	23	30	31	38	21	22	17	96
Pacific Islander	2	8	16	4	15	16	14	54	33	6	23	35	26
Other Asian	9	16	15	12	21	24	20	34	25	17	29	36	58
Other	2	7	4	5	19	15	15	56	61	5	19	19	27
Missing	0	0	0	4	10	3	25	64	73	10	26	24	39
Total	86	7	7	166	14	14	651	57	59	249	22	20	1152
Income													
< $20,000	22	10	10	48	22	23	105	48	51	42	19	16	217
$20,000 - $45,000	27	9	10	45	15	14	176	57	53	61	20	22	309
> $45,000	26	6	5	59	13	12	286	62	66	92	20	17	463
Missing	11	7	6	14	9	10	84	52	55	54	33	29	163
Total	86	7	7	166	14	14	651	57	59	249	22	20	1152
Education													
< 12th Grade	14	9	8	28	17	22	80	49	43	41	25	27	163
HS/GED	24	7	6	53	15	13	209	59	62	70	20	19	356
Some College	20	6	6	52	15	14	195	58	58	72	21	23	339
>= 4 Years College	19	9	8	29	13	15	127	58	63	44	20	14	219
Missing	9	12	12	4	5	7	40	53	64	22	29	17	75
Total	86	7	7	166	14	14	651	57	59	249	22	20	1152

1 Includes 8 consumers who are missing Striped Bass data.

Table K42e. Consumption of Striped Bass Raw by Demographic Factors (unadjusted & adjusted)

Raw Consumption	Consumes Striped Bass									Does Not Consume Striped Bass[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats raw						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	11	2	1	36	6	8	396	68	68	140	24	22	583
Beach and Bank	0	0	0	7	9	3	58	72	76	16	20	21	81
Private Boats	7	2	2	16	4	3	293	75	78	74	19	17	390
Party Boats	1	1	0	2	2	2	76	78	79	19	19	19	98
Total	19	2	1	61	5	5	823	71	74	249	22	20	1152
Ethnicity (major groups)													
African Americans	0	0	0	0	0	0	86	83	81	18	17	19	104
Latinos/Hispanics	2	1	1	9	6	8	100	66	60	40	26	31	151
Caucasians	4	1	1	6	1	2	336	78	80	85	20	17	431
Asians	12	3	3	42	11	10	255	64	69	91	23	19	400
Other	1	4	2	2	7	7	19	70	72	5	19	19	27
Missing	0	0	0	2	5	6	27	69	70	10	26	24	39
Total	19	2	1	61	5	5	823	71	74	249	22	20	1152
Ethnicity (with Asian subgroups)													
African Americans	0	0	0	0	0	0	86	83	81	18	17	19	104
Latinos/Hispanics	2	1	1	9	6	8	100	66	60	40	26	31	151
Caucasians	4	1	1	6	1	2	336	78	80	85	20	17	431
Chinese	0	0	0	5	8	13	42	67	73	16	25	13	63
Filipino	3	2	1	12	8	8	111	71	79	31	20	12	157
Vietnamese	3	3	4	7	7	5	65	68	74	21	22	17	96
Pacific Islander	1	4	1	5	19	7	14	54	56	6	23	35	26
Other Asian	5	9	9	13	22	20	23	40	35	17	29	36	58
Other	1	4	2	2	7	7	19	70	72	5	19	19	27
Missing	0	0	0	2	5	6	27	69	70	10	26	24	39
Total	19	2	1	61	5	5	823	71	74	249	22	20	1152
Income													
< $20,000	4	2	2	9	4	6	162	75	76	42	19	16	217
$20,000 - $45,000	4	1	1	21	7	6	223	72	71	61	20	22	309
> $45,000	10	2	1	22	5	4	339	73	77	92	20	17	463
Missing	1	1	1	9	6	7	99	61	64	54	33	29	163
Total	19	2	1	61	5	5	823	71	74	249	22	20	1152
Education													
< 12th Grade	1	1	2	8	5	5	113	69	67	41	25	27	163
HS/GED	5	1	1	17	5	4	264	74	76	70	20	19	356
Some College	6	2	1	14	4	5	247	73	72	72	21	23	339
>= 4 Years College	6	3	1	18	8	9	151	69	76	44	20	14	219
Missing	1	1	2	4	5	4	48	64	77	22	29	17	75
Total	19	2	1	61	5	5	823	71	74	249	22	20	1152

1 Includes 8 consumers who are missing Striped Bass data.

Table K43a. Consumption of White Croaker Skin by Demographic Factors (unadjusted & adjusted)

Skin Consumption	Consumes White Croaker									Does Not Consume White Croaker[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats skin						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	83	14	15	29	5	6	104	18	19	367	63	59	583
Beach and Bank	13	16	14	1	1	2	19	23	24	48	59	61	81
Private Boats	24	6	5	3	1	1	35	9	9	328	84	86	390
Party Boats	0	0	0	2	2	1	5	5	4	91	93	95	98
Total	120	10	9	35	3	3	163	14	14	834	72	74	1152
Ethnicity (major groups)													
African Americans	12	12	11	7	7	8	16	15	19	69	66	62	104
Latinos/Hispanics	10	7	7	7	5	6	27	18	16	107	71	70	151
Caucasians	9	2	2	2	0	1	32	7	7	388	90	90	431
Asians	86	22	21	18	5	4	81	20	21	215	54	53	400
Other	2	7	2	0	0	0	2	7	7	23	85	91	27
Missing	1	3	2	1	3	0	5	13	9	32	82	89	39
Total	120	10	9	35	3	3	163	14	14	834	72	74	1152
Ethnicity (with Asian subgroups)													
African Americans	12	12	11	7	7	8	16	15	19	69	66	62	104
Latinos/Hispanics	10	7	7	7	5	6	27	18	16	107	71	70	151
Caucasians	9	2	2	2	0	1	32	7	7	388	90	90	431
Chinese	19	30	28	4	6	3	10	16	15	30	48	54	63
Filipino	25	16	20	8	5	5	33	21	20	91	58	55	157
Vietnamese	24	25	28	5	5	5	22	23	22	45	47	45	96
Pacific Islander	8	31	16	0	0	0	2	8	7	16	62	77	26
Other Asian	10	17	9	1	2	2	14	24	35	33	57	54	58
Other	2	7	2	0	0	0	2	7	7	23	85	91	27
Missing	1	3	2	1	3	0	5	13	9	32	82	89	39
Total	120	10	9	35	3	3	163	14	14	834	72	74	1152
Income													
< $20,000	45	21	21	9	4	5	40	18	19	123	57	56	217
$20,000 - $45,000	36	12	12	11	4	5	53	17	18	209	68	65	309
> $45,000	26	6	4	11	2	2	50	11	9	376	81	85	463
Missing	13	8	7	4	2	2	20	12	13	126	77	78	163
Total	120	10	9	35	3	3	163	14	14	834	72	74	1152
Education													
< 12th Grade	35	21	20	4	2	4	23	14	13	101	62	63	163
HS/GED	42	12	10	10	3	3	54	15	15	250	70	71	356
Some College	20	6	6	17	5	4	46	14	13	256	76	77	339
>= 4 Years College	18	8	6	4	2	2	31	14	14	166	76	79	219
Missing	5	7	5	0	0	0	9	12	13	61	81	82	75
Total	120	10	9	35	3	3	163	14	14	834	72	74	1152

1 Includes 13 Consumers who are missing White Croaker data.

Table K43b. Consumption of White Croaker Guts by Demographic Factors (unadjusted & adjusted)

Guts Consumption	Consumes White Croaker									Does Not Consume White Croaker[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats guts						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	1	0	1	3	1	0	212	36	40	367	63	59	583
Beach and Bank	0	0	0	0	0	0	33	41	39	48	59	61	81
Private Boats	2	1	1	1	0	0	59	15	13	328	84	86	390
Party Boats	0	0	0	0	0	0	7	7	5	91	93	95	98
Total	3	0	0	4	0	0	311	27	26	834	72	74	1152
Ethnicity (major groups)													
African Americans	0	0	0	0	0	0	35	34	38	69	66	62	104
Latinos/Hispanics	1	1	1	1	1	0	42	28	28	107	71	70	151
Caucasians	0	0	0	0	0	0	43	10	10	388	90	90	431
Asians	2	1	1	3	1	1	180	45	45	215	54	53	400
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	0	0	0	0	0	0	7	18	11	32	82	89	39
Total	3	0	0	4	0	0	311	27	26	834	72	74	1152
Ethnicity (with Asian subgroups)													
African Americans	0	0	0	0	0	0	35	34	38	69	66	62	104
Latinos/Hispanics	1	1	1	1	1	0	42	28	28	107	71	70	151
Caucasians	0	0	0	0	0	0	43	10	10	388	90	90	431
Chinese	0	0	0	0	0	0	33	52	46	30	48	54	63
Filipino	0	0	0	0	0	0	66	42	45	91	58	45	157
Vietnamese	2	2	2	0	0	0	49	51	52	45	47	77	96
Pacific Islander	0	0	0	1	4	0	9	35	23	16	62	54	26
Other Asian	0	0	0	2	3	4	23	40	43	33	57	91	58
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	0	0	0	0	0	0	7	18	11	32	82	89	39
Total	3	0	0	4	0	0	311	27	26	834	72	74	1152
Income													
< $20,000	1	0	1	2	1	0	91	42	42	123	57	56	217
$20,000 - $45,000	1	0	0	1	0	0	98	32	35	209	68	65	309
> $45,000	1	0	0	1	0	0	85	18	15	376	81	85	463
Missing	0	0	0	0	0	0	37	23	22	126	77	78	163
Total	3	0	0	4	0	0	311	27	26	834	72	74	1152
Education													
< 12th Grade	1	1	2	0	0	0	61	37	35	101	62	63	163
HS/GED	1	0	0	1	0	0	104	29	29	250	70	71	356
Some College	0	0	0	3	1	1	80	24	23	256	76	77	339
>= 4 Years College	1	0	1	0	0	0	52	24	20	166	76	79	219
Missing	0	0	0	0	0	0	14	19	18	61	81	82	75
Total	3	0	0	4	0	0	311	27	26	834	72	74	1152

1 Includes 13 Consumers who are missing White Croaker data.

Table K43c. Consumption of White Croaker Cooking Juices by Demographic Factors (unadjusted & adjusted)

Cooking Juices Consumption	Consumes White Croaker									Does Not Consume White Croaker[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats juice						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	34	6	7	19	3	4	163	28	30	367	63	59	583
Beach and Bank	7	9	5	4	5	5	22	27	29	48	59	61	81
Private Boats	18	5	2	9	2	2	35	9	9	328	84	86	390
Party Boats	0	0	0	0	0	0	7	7	5	91	93	95	98
Total	59	5	4	32	3	3	227	20	19	834	72	74	1152
Ethnicity (major groups)													
African Americans	1	1	1	0	0	0	34	33	38	69	66	62	104
Latinos/Hispanics	4	3	3	5	3	4	35	23	23	107	71	70	151
Caucasians	7	2	2	2	0	1	34	8	8	388	90	90	431
Asians	46	12	10	25	6	7	114	29	29	215	54	53	400
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	1	3	2	0	0	0	6	15	9	32	82	89	39
Total	59	5	4	32	3	3	227	20	19	834	72	74	1152
Ethnicity (with Asian subgroups)													
African Americans	1	1	4	0	0	0	34	33	38	69	66	62	104
Latinos/Hispanics	4	3	3	5	3	4	35	23	23	107	71	70	151
Caucasians	7	2	2	2	0	1	34	8	8	388	90	90	431
Chinese	14	22	20	2	3	3	17	27	23	30	48	54	63
Filipino	10	6	6	8	5	7	48	31	32	91	58	55	157
Vietnamese	18	19	17	11	11	13	22	23	24	45	47	45	96
Pacific Islander	3	12	5	2	8	3	5	19	16	16	62	77	26
Other Asian	1	2	0	2	3	7	22	38	40	33	57	54	58
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	1	3	2	0	0	0	6	15	9	32	82	89	39
Total	59	5	4	32	3	3	227	20	19	834	72	74	1152
Income													
< $20,000	14	6	7	14	6	8	66	30	29	123	57	56	217
$20,000 - $45,000	21	7	5	11	4	4	68	22	26	209	68	65	309
> $45,000	14	3	3	6	1	1	67	14	12	376	81	85	463
Missing	10	6	4	1	1	1	26	16	18	126	77	78	163
Total	59	5	4	32	3	3	227	20	19	834	72	74	1152
Education													
< 12th Grade	17	10	9	11	7	7	34	21	21	101	62	63	163
HS/GED	18	5	5	5	1	2	83	23	23	250	70	71	356
Some College	7	2	2	12	4	4	64	19	18	256	76	77	339
>= 4 Years College	15	7	6	3	1	2	35	16	14	166	76	79	219
Missing	2	3	2	1	1	2	11	15	15	61	81	82	75
Total	59	5	4	32	3	3	227	20	19	834	72	74	1152

1 Includes 13 Consumers who are missing White Croaker data.

Table K43d. Consumption of White Croaker in Soup by Demographic Factors (unadjusted & adjusted)

Soup Consumption	Consumes White Croaker									Does Not Consume White Croaker[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats soup						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	25	4	5	45	8	7	146	25	29	367	63	59	583
Beach and Bank	4	5	6	13	16	17	16	20	17	48	59	61	81
Private Boats	10	3	1	19	5	5	33	8	8	328	84	86	390
Party Boats	0	0	0	0	0	0	7	7	5	91	93	95	98
Total	39	3	3	77	7	6	202	18	17	834	72	74	1152
Ethnicity (major groups)													
African Americans	0	0	0	1	1	2	34	33	36	69	66	62	104
Latinos/Hispanics	2	1	1	10	7	5	32	21	24	107	71	70	151
Caucasians	3	1	1	4	1	1	36	8	8	388	90	90	431
Asians	34	9	9	57	14	14	94	24	23	215	54	53	400
Other	0	0	0	1	4	2	3	11	7	23	85	91	27
Missing	0	0	0	4	10	4	3	8	6	32	82	89	39
Total	39	3	3	77	7	6	202	18	17	834	72	74	1152
Ethnicity (with Asian subgroups)													
African Americans	0	0	0	1	1	2	34	33	36	69	66	62	104
Latinos/Hispanics	2	1	1	10	7	5	32	21	24	107	71	70	151
Caucasians	3	1	1	4	1	1	36	8	8	388	90	90	431
Chinese	4	6	7	11	17	16	18	29	23	30	48	54	63
Filipino	9	6	7	17	11	13	40	25	26	91	58	54	157
Vietnamese	15	16	15	19	20	20	17	18	20	45	47	45	96
Pacific Islander	2	8	10	4	15	4	4	15	10	16	62	77	26
Other Asian	4	7	9	6	10	12	15	26	25	33	57	54	58
Other	0	0	0	1	4	2	3	11	7	23	85	91	27
Missing	0	0	0	4	10	4	3	8	6	32	82	89	39
Total	39	3	3	77	7	6	202	18	17	834	72	74	1152
Income													
< $20,000	12	6	8	27	12	13	55	25	24	123	57	56	217
$20,000 - $45,000	10	3	3	24	8	7	66	21	25	209	68	65	309
> $45,000	9	2	2	18	4	3	60	13	11	376	81	85	463
Missing	8	5	4	8	5	5	21	13	14	126	77	78	163
Total	39	3	3	77	7	6	202	18	17	834	72	74	1152
Education													
< 12th Grade	12	7	5	20	12	10	30	18	21	101	62	63	163
HS/GED	12	3	5	24	7	5	70	20	20	250	70	71	356
Some College	5	1	2	19	6	5	59	17	17	256	76	77	339
>= 4 Years College	8	4	2	10	5	6	35	16	13	166	76	79	219
Missing	2	3	1	4	5	6	8	11	11	61	81	82	75
Total	39	3	3	77	7	6	202	18	17	834	72	74	1152

1 Includes 13 Consumers who are missing White Croaker data.

Table K43e. Consumption of White Croaker Raw by Demographic Factors (unadjusted & adjusted)

Raw Consumption	Consumes White Croaker									Does Not Consume White Croaker[1]			Total
	greater than 1/2 time			less than 1/2 time			never eats raw						
	n	%	adj%	n	%	adj%	n	%	adj%	n	%	adj%	n
Mode													
Piers	1	0	0	3	1	0	212	36	40	367	63	59	583
Beach and Bank	0	0	0	1	1	1	32	40	38	48	59	61	81
Private Boats	0	0	0	1	0	0	61	16	14	328	84	86	390
Party Boats	0	0	0	0	0	0	7	7	5	91	93	95	98
Total	1	0	0	5	0	0	312	27	26	834	72	74	1152
Ethnicity (major groups)													
African Americans	0	0	0	0	0	0	35	34	38	69	66	62	104
Latinos/Hispanics	1	1	0	4	3	1	39	26	28	107	71	70	151
Caucasians	0	0	0	0	0	0	43	10	10	388	90	90	431
Asians	0	0	0	1	0	0	184	46	46	215	54	53	400
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	0	0	0	0	0	0	7	18	11	32	82	89	39
Total	1	0	0	5	0	0	312	27	26	834	72	74	1152
Ethnicity (with Asian subgroups)													
African Americans	0	0	0	0	0	0	35	34	38	69	66	62	104
Latinos/Hispanics	1	1	0	4	3	1	39	26	28	107	71	70	151
Caucasians	0	0	0	0	0	0	43	10	10	388	90	90	431
Chinese	0	0	0	0	0	0	33	52	46	30	48	54	63
Filipino	0	0	0	1	1	0	65	41	45	91	58	55	157
Vietnamese	0	0	0	0	0	0	51	53	55	45	47	45	96
Pacific Islander	0	0	0	0	0	0	10	38	23	16	62	77	26
Other Asian	0	0	0	0	0	0	25	43	46	33	57	54	58
Other	0	0	0	0	0	0	4	15	9	23	85	91	27
Missing	0	0	0	0	0	0	7	18	11	32	82	89	39
Total	1	0	0	5	0	0	312	27	26	834	72	74	1152
Income													
< $20,000	1	0	0	4	2	1	89	41	43	123	57	56	217
$20,000 - $45,000	0	0	0	0	0	0	100	32	35	209	68	65	309
> $45,000	0	0	0	1	0	0	86	19	15	376	81	85	463
Missing	0	0	0	0	0	0	37	23	22	126	77	78	163
Total	1	0	0	5	0	0	312	27	26	834	72	74	1152
Education													
< 12th Grade	0	0	0	1	1	1	61	37	36	101	62	63	163
HS/GED	1	0	0	2	1	0	103	29	29	250	70	71	356
Some College	0	0	0	1	0	0	82	24	23	256	76	77	339
>= 4 Years College	0	0	0	1	0	0	52	24	21	166	76	79	219
Missing	0	0	0	0	0	0	14	19	18	61	81	82	75
Total	1	0	0	5	0	0	312	27	26	834	72	74	1152

1 Includes 13 Consumers who are missing White Croaker data.

Table K44. Recent Consumption of Fish from Areas Outside of San Francisco Bay and from Stores or Restaurants (unadjusted & adjusted)

	All Respondents (n=1331)			Consumers (n=1152)			Recent Consumers (n=537)		
	n	%	adj%	n	%	adj%	n	%	adj%
Fish from areas outside SF Bay:[1]	309	23	23	273	24	23	119	24	25
Ocean (Outside of SF Bay)	128	41	41	111	41	40	55	46	43
Lake/Reservoir	92	30	34	83	30	35	30	25	27
River	60	19	15	56	21	17	23	19	26
Delta	58	19	17	50	18	17	21	18	17
Other	52	17	15	48	18	15	23	19	11
Fish from a store or restaurant	710	53	57	625	54	58	256	48	50

1 Percentages of those who had consumption from areas outside SF Bay. Percentages do not sum to 100% because respondents could indicate more than one area.

Table K45a. Consumption Rates (g/d) for Fish from Other Sources (unadjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
All Respondents																
Fish Outside SF Bay[1]	309	13.98	21.41	27.60	2.00	5.33	8.00	8.00	8.00	16.00	16.00	18.00	24.00	48.00	64.00	200.00
Commercial Fish[2]	710	16.32	26.62	41.13	1.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	32.00	64.00	84.00	672.00
Consumers of SF Bay Fish																
Fish Outside SF Bay[1]	273	13.28	19.80	25.40	2.00	5.30	8.00	8.00	8.00	16.00	16.00	16.00	24.00	36.00	64.00	192.00
Commercial Fish[2]	625	16.69	26.90	42.00	1.00	5.36	8.00	8.00	12.00	16.00	16.00	24.00	32.00	60.00	80.00	672.00
Recent Consumers of SF Bay Fish																
SF Bay Fish	501	16.55	28.08	39.63	2.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	36.00	56.00	108.00	324.00
All Sport Fish[3]	501	19.82	32.96	42.84	2.00	5.36	8.00	12.00	16.00	16.00	24.00	32.00	48.00	72.00	112.00	324.00
All Fish[4]	501	28.84	46.52	62.52	2.00	8.00	12.00	16.00	24.00	32.00	36.00	48.00	60.00	96.00	144.00	848.00
Fish Outside SF Bay[1]	119	14.11	20.52	22.65	2.00	5.28	8.00	8.00	10.72	16.00	16.00	18.00	24.00	40.00	64.00	144.00
All Sport Fish[1,3]	119	33.09	45.51	44.25	4.00	13.20	16.00	24.00	24.00	32.00	36.00	48.00	56.00	96.00	168.00	240.00
Commercial Fish[2]	256	16.05	26.54	51.37	2.00	5.33	8.00	8.00	13.33	16.00	16.00	24.00	32.00	48.00	80.00	672.00
All Fish[2,4]	256	39.95	56.93	71.27	5.33	16.00	24.00	24.00	32.00	40.00	48.00	56.00	72.00	120.00	156.00	848.00
Recent Consumers of Sport Fish[5]																
All Sport Fish[3]	694	17.99	29.92	40.02	2.00	5.36	8.00	8.00	16.00	16.00	24.00	32.00	40.00	64.00	108.00	324.00
All Fish[4]	694	27.99	45.31	58.98	2.00	8.00	12.00	16.00	24.00	32.00	36.00	48.00	60.00	96.00	144.00	848.00

1 Excludes anglers with no consumption of fish from outside SF Bay.
2 Excludes anglers with no consumption of commercial fish.
3 Fish from SF Bay and outside SF Bay.
4 Fish from SF Bay, outside SF Bay, and commercial fish.
5 Anglers with recent consumption of either SF Bay fish or fish from outside SF Bay.

Table K45b. Consumption Rates (g/d) for Fish from Other Sources (adjusted)

	N	Geom Mean	Arith Mean	SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
All Respondents																
Fish Outside SF Bay[1]	266	12.84	18.40	21.10	2.00	5.33	8.00	8.00	8.00	12.00	16.00	16.00	24.00	32.20	64.00	200.00
Commercial Fish[2]	608	16.20	26.50	47.10	1.00	5.33	8.00	8.00	12.00	16.00	16.00	24.00	32.00	56.00	80.00	672.00
Consumers of SF Bay Fish																
Fish Outside SF Bay[1]	234	12.18	17.00	19.60	2.00	5.30	8.00	8.00	8.00	12.00	16.00	16.00	24.00	32.00	48.00	192.00
Commercial Fish[2]	531	17.17	27.70	49.30	2.00	8.00	8.00	8.00	16.00	16.00	21.40	24.00	32.00	60.00	80.00	672.00
Recent Consumers of SF Bay Fish																
SF Bay Fish	465	13.97	23.02	32.05	2.00	4.00	8.00	8.00	8.00	16.00	16.00	16.00	32.00	48.00	80.00	324.00
All Sport Fish[3]	465	17.06	27.86	35.64	2.00	4.00	8.00	8.00	16.00	16.00	24.00	24.00	36.00	56.00	96.00	324.00
All Fish[4]	465	25.99	43.36	75.96	2.00	8.00	12.00	16.00	24.00	24.00	32.00	40.00	56.00	80.00	128.00	848.00
Fish Outside SF Bay[1]	113	13.54	18.80	20.30	2.00	5.36	8.00	8.00	12.00	16.00	16.00	16.00	24.00	32.00	48.00	144.00
All Sport Fish[1,3]	113	30.29	40.17	38.41	4.00	13.20	20.00	24.00	24.00	32.00	32.00	40.00	48.00	80.00	136.00	240.00
Commercial Fish[2]	234	15.77	28.66	73.62	2.00	5.36	8.00	8.00	12.00	16.00	16.00	24.00	32.00	48.00	60.00	672.00
All Fish[2,4]	234	36.24	55.75	95.31	5.33	12.00	20.00	24.00	28.00	32.16	40.00	54.00	64.00	104.00	144.00	848.00
Recent Consumers of Sport Fish[5]																
All Sport Fish[3]	620	15.33	24.47	31.67	2.00	5.28	8.00	8.00	12.00	16.00	16.00	24.00	32.00	48.00	74.67	324.00
All Fish[4]	620	25.02	40.65	65.24	2.00	8.00	12.00	16.00	22.00	24.00	32.00	40.00	52.00	80.00	128.00	848.00

1 Excludes anglers with no consumption of fish from outside SF Bay.
2 Excludes anglers with no consumption of commercial fish.
3 Fish from SF Bay and outside SF Bay.
4 Fish from SF Bay, outside SF Bay, and commercial fish.
5 Anglers with recent consumption of either SF Bay fish or fish from outside SF Bay.

Table K46. Recent Consumers of Shellfish Among Consumers of SF Bay Fish (unadjusted & adjusted)

Shellfish	Respondents			Consumers			Recent Consumers			Above Advisory Consumers[1]		
	N	%	adj%	N	%	adj%	N	%	adj%	N	%	adj%
N	1331			1152			537			164		
Crab	77	6	5	76	7	6	55	10	11	24	15	16
Mussels	13	1	1	13	1	1	11	2	2	5	3	<1
Clams	10	1	1	10	1	1	8	1	3	2	1	3
All Shellfish Combined	84	6	5	83	7	6	59	11	12	27	16	17

1 Consumption rates of SF Bay Fish above health advisory recommendations.

Table K47. Recent Consumption of Crab by Demographic Factors (unadjusted & adjusted)

Consumers of Bay Fish	N	Consumers of Crab N	%	adj%[1]
Total	1152	76	7	6
Mode				
Piers	583	54	9	8
Beach and Bank	81	5	6	7
Private Boats	390	10	3	2
Party Boats	98	7	7	9
Chi-Square p-value[2]		0.0014		
Ethnicity (major groups)				
African American	104	8	8	8
Latino	151	8	5	4
Caucasian	431	17	4	5
Asian	400	41	10	8
Other	27	1	4	0
Missing/Don't Know/Refuse	39	1	3	1
Chi-Square p-value[2]		0.0089		
Ethnicity (with Asian subgroups)				
African American	104	8	8	8
Latino	151	8	5	4
Caucasian	431	17	4	5
Chinese	63	3	5	2
Filipino	157	22	14	9
Vietnamese	96	10	10	13
Pacific Islander	26	2	8	6
Other Asian	58	4	7	3
Other	27	1	4	0
Missing/Don't Know/Refuse	39	1	3	1
Chi-Square p-value[2]		Not valid		
Income				
<$20,000	217	19	9	9
$20,000-$45,000	309	18	6	4
>$45,000	463	28	6	5
Missing/Don't Know/Refuse	163	11	7	6
Mantel-Haenszel Chi-Square p-value[2]		0.3210		
Education				
<12th Grade	163	12	7	9
HS or GED	356	22	6	5
Some College	339	23	7	6
>=4 yrs. College	219	15	7	5
Missing/Don't Know/Refuse	75	4	5	4
Chi-Square p-value[2]		0.9681		
Season Interviewed				
Winter	202	2	1	1
Spring	208	8	4	2
Summer	458	40	9	9
Fall	284	26	9	9
Mantel-Haenszel Chi-Square p-value[2]		0.0002		

1 Adjusted for avidity bias.
2 Missing/Don't Know/Declined not included in Chi-square statistic.
Chi-square statistic was calculated for unadjusted data only.

Table K48. Meal Frequency of Crab and Shellfish (unadjusted & adjusted)

	N	Arith Mean	Arith SD	Min	P10	P20	P30	P40	Med	P60	P70	P80	P90	P95	Max
Respondents															
Crab (unadjusted)	73	2.60	3.84	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	10.00	30.00
All Shellfish (unadjusted)	80	2.75	3.73	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	5.00	8.50	30.00
Crab (adjusted)	61	2.39	3.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	10.00	30.00
All Shellfish (adjusted)	67	2.46	3.46	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	5.00	10.00	30.00
Consumers															
Crab (unadjusted)	72	2.63	3.86	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	4.00	10.00	30.00
All Shellfish (unadjusted)	79	2.77	3.74	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	5.00	10.00	30.00
Crab (adjusted)	61	2.39	3.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	10.00	30.00
All Shellfish (adjusted)	67	2.46	3.46	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	5.00	10.00	30.00
Recent Consumers															
Crab (unadjusted)	52	2.79	4.31	1.00	1.00	1.00	1.00	1.00	1.50	2.00	3.00	4.00	4.00	10.00	30.00
All Shellfish (unadjusted)	56	3.05	4.19	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	4.00	5.00	10.00	30.00
Crab (adjusted)	46	2.24	3.79	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	4.00	30.00
All Shellfish (adjusted)	49	2.53	3.75	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	4.00	5.00	30.00

Table K49. Awareness of Health Advisory (unadjusted & adjusted)

A. Mode	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
Pier	695	392	56	58	583	324	56	58	112	68	61	58
Beach and Bank	99	54	55	53	81	44	54	51	18	10	56	61
Private Boats	433	276	64	65	390	248	64	65	43	28	65	72
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Chi-square p-value[2]		<0.0001				0.0002				0.1848		

B. Ethnicity (major groups)	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
Black/African American	117	81	69	74	96	67	70	73	21	14	67	80
Latino/Hispanic	165	87	53	51	144	73	51	50	21	14	67	55
Caucasian	452	305	67	67	368	254	69	68	84	51	61	61
Asian	420	219	52	53	384	197	51	53	36	22	61	57
Other	31	17	55	72	26	14	54	75	5	3	60	67
Missing/Don't Know/Declined	42	13	31	42	36	11	31	33	6	2	33	75
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Chi-square p-value[2]		<0.0001				<0.0001				0.9903		

C. Ethnicity (with Asian subgroups)	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
Black/African American	117	81	69	74	96	67	70	73	21	14	67	81
Latino/Hispanic	165	87	53	51	144	73	51	50	21	14	67	55
Caucasian	452	305	67	67	368	254	69	68	84	51	61	61
Chinese	69	41	59	58	59	36	61	58	10	5	50	56
Filipino	157	76	48	46	149	73	49	47	8	3	38	38
Vietnamese	98	44	45	52	96	42	44	52	2	2	100	100
Pacific Islander	29	21	72	77	25	17	68	72	4	4	100	100
Other Asian	67	37	55	56	55	29	53	57	12	8	67	56
Other	31	17	55	72	26	14	54	75	5	3	60	67
Missing/Don't Know/Declined	42	13	31	42	36	11	31	33	6	2	33	75
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Chi-square p-value[2]		<0.0001				<0.0001				Not Valid		

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K49 (cont.). Awareness of Health Advisory (unadjusted & adjusted)

D. Income	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
< $20,000/year	240	120	50	53	214	104	49	51	26	16	62	72
$20,000 - $45,000/year	328	190	58	56	289	167	58	56	39	23	59	60
> $45,000/year	480	339	71	73	400	281	70	73	80	58	73	72
Missing/Don't Know/Declined	179	73	41	40	151	64	42	43	28	9	32	27
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Mantel-Haenszel Chi-square p-value[2]		<0.0001				<0.0001				0.5026		

E. Education	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
< 12th Grade	174	90	52	50	161	83	52	49	13	7	54	63
Completed HS or GED	392	233	59	63	332	196	59	65	60	37	62	55
Some college/trade school	351	225	64	64	309	197	64	63	42	28	67	65
>= 4 years college	230	152	66	69	182	120	66	68	48	32	67	75
Missing/Don't Know/Declined	80	22	28	32	70	20	29	32	10	2	20	32
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Mantel-Haenszel Chi-square p-value[2]		0.0027				0.0032				0.6990		

F. Years Fishing in SF Bay	Respondents				Consumers				Non-Consumers			
	Total[1]	Responded Yes			Total[1]	Responded Yes			Total[1]	Responded Yes		
	n	n	%	adj%	n	n	%	adj%	n	n	%	adj%
< 1 year	120	52	43	42	119	51	43	41	1	1	100	100
1-5 years	307	164	5	53	307	164	53	53	0	0	0	0
6-10 years	137	78	57	55	135	76	56	55	2	2	100	100
11-20 years	167	104	62	62	166	103	62	62	1	1	100	100
21-30 years	97	70	72	68	97	70	72	68	0	0	0	0
31+ years	156	122	78	77	154	120	78	76	2	2	100	100
Missing/Don't Know/Declined	243	132	54	66	76	32	42	86	167	100	60	61
Total	1227	722	59	61	1054	616	58	60	173	106	61	62
Mantel-Haenszel Chi-square p-value[2]		<0.0001				<0.0001				Not Valid		

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K50. Comprehension of Health Advisory by Mode (unadjusted & adjusted)

A. Respondents

Mode	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
Pier	177	46	52	205	54	48	382
Beach and Bank	27	51	50	26	49	50	53
Private Boats	101	37	36	170	63	64	271
Total	305	43	45	401	57	55	706
Chi square p-value[2]							0.0349

16 Respondents are missing health advisory details.

B. Consumers

Mode	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
Pier	151	48	56	166	52	44	317
Beach and Bank	20	47	39	23	53	61	43
Private Boats	89	37	35	154	63	65	243
Total	260	43	45	343	57	55	603
Chi square p-value[2]							0.0300

13 Consumers are missing health advisory details.

C. Recent Consumers

Mode	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
Pier	72	46	54	84	54	46	156
Beach and Bank	10	45	35	12	55	65	22
Private Boats	37	32	23	80	68	77	117
Total	119	40	38	176	60	62	295
Chi square p-value[2]							0.0468

4 Recent Consumers are missing health advisory details.

D. Non-Consumers

Mode	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
Pier	26	40	36	39	60	64	65
Beach and Bank	7	70	89	3	30	11	10
Private Boats	12	43	48	16	57	52	28
Total	45	44	45	58	56	55	103
Chi square p-value[2]							0.2038

3 Non-Consumers are missing health advisory details.

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic was calculated for unadjusted data only.

Table K51. Comprehension of Health Advisory by Ethnicity (unadjusted & adjusted)

A. Respondents

Ethnicity	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
African American	40	51	58	39	49	42	79
Latino/Hispanic	41	48	49	45	52	51	86
Caucasian	109	37	39	186	63	61	295
Asian	102	47	49	114	53	51	216
Other	8	47	53	9	53	47	17
Missing/Don't Know/Declined	5	38	34	8	62	66	13
Total	305	43	45	401	57	55	706
Chi square p-value[2]							0.0691

African American	40	51	58	39	49	42	79
Latino/Hispanic	41	48	49	45	52	51	86
Caucasian	109	37	39	186	63	61	295
Chinese	17	43	35	23	58	65	40
Filipino	45	60	65	30	40	35	75
Vietnamese	18	42	49	25	58	51	43
Pacific Islander	10	48	45	11	52	55	21
Other Asian	12	32	34	25	68	66	37
Other	8	47	53	9	53	47	17
Missing/Don't Know/Declined	5	38	34	8	62	66	13
Total	305	43	45	401	57	55	706
Chi square p-value[2]							0.0224

16 Respondents are missing health advisory details.

B. Consumers

Ethnicity	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
African American	31	48	55	34	52	45	65
Latino/Hispanic	37	51	55	35	49	45	72
Caucasian	88	36	35	159	64	65	247
Asian	92	47	50	102	53	50	194
Other	7	50	70	7	50	30	14
Missing/Don't Know/Declined	5	45	54	6	55	46	11
Total	260	43	45	343	57	55	603
Chi square p-value[2]							0.0413

African American	31	48	55	34	52	45	65
Latino/Hispanic	37	51	55	35	49	45	72
Caucasian	88	36	35	159	64	65	247
Chinese	15	43	35	20	57	65	35
Filipino	44	61	64	28	39	36	72
Vietnamese	16	39	49	25	61	51	41
Pacific Islander	9	53	55	8	47	45	17
Other Asian	8	28	34	21	72	66	29
Other	7	50	70	7	50	30	14
Missing/Don't Know/Declined	5	45	54	6	55	46	11
Total	260	43	45	343	57	55	603
Chi square p-value[2]							0.0053

13 Consumers are missing health advisory details.

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/DK/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K51 (cont.). Comprehension of Health Advisory by Ethnicity (unadjusted & adjusted)

C. Recent Consumers

Ethnicity	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
African American	13	41	45	19	59	55	32
Latino/Hispanic	15	54	58	13	46	42	28
Caucasian	32	32	22	69	68	78	101
Asian	54	45	46	67	55	54	121
Other	2	33	53	4	67	47	6
Missing/Don't Know/Declined	3	43	52	4	57	48	7
Total	119	40	38	176	60	62	295
Chi square p-value[2]							0.1825

African American	13	41	45	19	59	55	32
Latino/Hispanic	15	54	58	13	46	42	28
Caucasian	32	32	22	69	68	78	101
Chinese	10	50	49	10	50	51	20
Filipino	25	57	58	19	43	42	44
Vietnamese	10	34	46	19	66	54	29
Pacific Islander	5	50	38	5	50	62	10
Other Asian	4	22	24	14	78	76	18
Other	2	33	53	4	67	47	6
Missing/Don't Know/Declined	3	43	52	4	57	48	7
Total	119	40	38	176	60	62	295
Chi square p-value[2]							0.0741

4 Recent Consumers are missing health advisory details.

D. Non-Consumers

Ethnicity	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
African American	9	64	70	5	36	30	14
Latino/Hispanic	4	29	11	10	71	89	14
Caucasian	21	44	54	27	56	46	48
Asian	10	45	39	12	55	61	22
Other	1	33	0	2	67	100	3
Missing/Don't Know/Declined	0	0	0	2	100	100	2
Total	45	44	45	58	56	55	103
Chi square p-value[2]							0.4300

African American	9	64	70	5	36	30	14
Latino/Hispanic	4	29	11	10	71	89	14
Caucasian	21	44	54	27	56	46	48
Chinese	2	40	49	3	60	51	5
Filipino	1	33	58	2	67	42	3
Vietnamese	2	100	46	0	0	54	2
Pacific Islander	1	25	38	3	75	62	4
Other Asian	4	50	24	4	50	76	8
Other	1	33	0	2	67	100	3
Missing/Don't Know/Declined	0	0	0	2	100	100	2
Total	45	44	45	58	56	55	103
Chi square p-value[2]							Not Valid

3 Non-Consumers are missing health advisory details.

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K52. Comprehension of Health Advisory by Income (unadjusted & adjusted)

A. Respondents

Income	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	58	49	50	60	51	50	118
$20,000-$45,000	82	44	51	105	56	49	187
>$45,000	126	38	39	204	62	61	330
Missing/Don't Know/Declined	39	55	57	32	45	43	71
Total	305	43	45	401	57	55	706
Mantel-Haenszel Chi square p-value[2]							0.0300

16 Respondents are missing health advisory details.

B. Consumers

Income	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	53	51	51	50	49	49	103
$20,000-$45,000	72	44	51	93	56	49	165
>$45,000	103	38	38	170	62	62	273
Missing/Don't Know/Declined	32	52	56	30	48	44	62
Total	260	43	45	343	57	55	603
Mantel-Haenszel Chi square p-value[2]							0.0148

13 Consumers are missing health advisory details.

C. Recent Consumers

Income	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	30	50	52	30	50	48	60
$20,000-$45,000	28	37	36	48	63	64	76
>$45,000	46	36	33	83	64	67	129
Missing/Don't Know/Declined	15	50	41	15	50	59	30
Total	119	40	38	176	60	62	295
Mantel-Haenszel Chi square p-value[2]							0.0833

4 Recent Consumers are missing health advisory details.

D. Non-Consumers

Income	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	5	33	37	10	67	63	15
$20,000-$45,000	10	45	47	12	55	53	22
>$45,000	23	40	43	34	60	57	57
Missing/Don't Know/Declined	7	78	66	2	22	34	9
Total	45	44	45	58	56	55	103
Mantel-Haenszel Chi square p-value[2]							0.7766

3 Non-Consumers are missing health advisory details.

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K53. Comprehension of Health Advisory by Education (unadjusted & adjusted)

A. Respondents

Education	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	49	55	57	40	45	43	89
HS/GED	96	42	44	132	58	56	228
Some college	93	42	47	126	58	53	219
>= 4 years college	54	36	32	96	64	68	150
Missing/Don't Know/Declined	13	65	75	7	35	25	20
Total	305	43	45	401	57	55	706
Mantel-Haenszel Chi square p-value[2]							0.0131

16 Respondents are missing health advisory details.

B. Consumers

Education	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	46	55	59	37	45	41	83
HS/GED	81	42	44	110	58	56	191
Some college	82	42	46	111	58	54	193
>= 4 years college	40	34	30	78	66	70	118
Missing/Don't Know/Declined	11	61	71	7	39	29	18
Total	260	43	45	343	57	55	603
Mantel-Haenszel Chi square p-value[2]							0.0067

13 Consumers are missing health advisory details.

C. Recent Consumers

Education	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	22	48	45	24	52	55	46
HS/GED	39	43	45	51	57	55	90
Some college	34	38	35	55	62	65	89
>= 4 years college	20	32	27	42	68	73	62
Missing/Don't Know/Declined	4	50	46	4	50	54	8
Total	119	40	38	176	60	62	295
Mantel-Haenszel Chi square p-value[2]							0.0723

4 Recent Consumers are missing health advisory details.

D. Non-Consumers

Education	Vague Knowledge			Specific Knowledge			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	3	50	30	3	50	70	6
HS/GED	15	41	42	22	59	58	37
Some college	11	42	52	15	58	48	26
>= 4 years college	14	44	39	18	56	61	32
Missing/Don't Know/Declined	2	100	100	0	0	0	2
Total	45	44	45	58	56	55	103
Mantel-Haenszel Chi square p-value[2]							Not Valid

3 Non-Consumers are missing health advisory details.

1 Party boat anglers were excluded because they were not asked any health advisory questions.
2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K54. Consumers With Consumption Above and Below the Health Advisory (unadjusted & adjusted)

	Above Advisory			Below Advisory		
	n	%	adj%	n	%	adj%
Total[1]	139	14	8	832	86	92
Not Aware of Health Advisory	54	39	40	332	40	37
Vague Knowledge	42	30	34	212	25	28
Specific Knowledge	43	31	26	288	35	35

1 Party boat anglers were excluded because they were not asked any health advisory questions.
Missing health advisory data for 50 Consumers.

Table K55. How Anglers Have and Have Not Changed Fish Eating Habits (unadjusted & adjusted)

A. Consumers

Have Changed Fish Eating Habits:			
	n	%	adj%
Engaged in protective measures	164	77	71
Stopped eating Bay fish	23	11	16
Eat only uncontaminated fish	9	4	5
Missing	16	8	8
Total	212	100	100
Have Not Changed Fish Eating Habits:			
	n	%	adj%
Consumed below limit before aware of advisory	205	55	60
Believes contamination is not a problem	67	18	15
General no; Did not change behavior	44	12	12
Response not specific to advisory	3	1	1
Missing	55	15	12
Total	374	100	100

30 Consumers are missing habit data.

B. Non-Consumers

Have Changed Fish Eating Habits:			
	n	%	adj%
Engaged in protective measures	6	20	18
Stopped eating Bay fish	22	73	74
Eat only uncontaminated fish	1	3	3
Missing	1	3	5
Total	30	100	100
Have Not Changed Fish Eating Habits:			
	n	%	adj%
Consumed below limit before aware of advisory	48	68	59
Believes contamination is not a problem	1	1	1
General no; Did not change behavior	3	4	8
Response not specific to advisory	1	1	1
Missing	18	25	31
Total	71	100	100

5 Non-Consumers are missing habit data.

C. Respondents

Have Changed Fish Eating Habits:			
	n	%	adj%
Engaged in protective measures	170	70	61
Stopped eating Bay fish	45	19	26
Eat only uncontaminated fish	10	4	5
Missing	17	7	8
Total	242	100	100
Have Not Changed Fish Eating Habits:			
	n	%	adj%
Consumed below limit before aware of advisory	253	57	59
Believes contamination is not a problem	68	15	13
General no; Did not change behavior	47	11	12
Response not specific to advisory	4	1	1
Missing	73	16	15
Total	445	100	100

35 Respondents are missing habit data.

Table K56. Consumers Who Changed Fish Eating Habits (unadjusted & adjusted)

A. Mode	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
Pier	116	38	39	191	62	61	307
Beach and Bank	16	38	39	26	62	61	42
Private Boats	80	34	34	157	66	66	237
Total	212	36	37	374	64	63	586
Chi square p-value[2]							0.6027

B. Ethnicity (major groups)	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
African American	25	38	43	40	62	57	65
Latino/Hispanic	32	48	52	35	52	48	67
Caucasian	70	28	29	176	72	71	246
Asian	77	42	43	107	58	57	184
Other	4	29	19	10	71	81	14
Missing/Don't Know/Declined	4	40	46	6	60	54	10
Total	212	36	37	374	64	63	586
Chi square p-value[2]							0.0098

C. Ethnicity (with Asian subgroups)	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
African American	25	38	43	40	62	57	65
Latino/Hispanic	32	48	52	35	52	48	67
Caucasian	70	28	29	176	72	71	246
Chinese	11	33	43	22	67	57	33
Filipino	25	36	42	44	64	58	69
Vietnamese	21	51	41	20	49	59	41
Pacific Islander	8	50	56	8	50	44	16
Other Asian	12	48	40	13	52	60	25
Other	4	29	19	10	71	81	14
Missing/Don't Know/Declined	4	40	46	6	60	54	10
Total	212	36	37	374	64	63	586
Chi square p-value[2]							0.0234

D. Income	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	39	39	45	60	61	55	99
$20,000-$45,000	59	36	33	105	64	67	164
>$45,000	97	37	38	165	63	62	262
Missing/Don't Know/Declined	17	28	23	44	72	77	61
Total	212	36	37	374	64	63	586
Mantel-Haenszel Chi square p-value[2]							0.7654

E. Education	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	25	32	33	52	68	67	77
HS/GED	71	37	39	120	63	61	191
Some college	65	35	34	119	65	66	184
>= 4 years college	46	40	42	69	60	58	115
Missing/Don't Know/Declined	5	26	24	14	74	76	19
Total	212	36	37	374	64	63	586
Mantel-Haenszel Chi square p-value[2]							0.4147

F. Season Interviewed	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
Winter	37	30	31	85	70	69	122
Spring	43	34	32	83	66	68	126
Summer	83	37	40	139	63	60	222
Fall	49	42	46	67	58	54	116
Total	212	36	37	374	64	63	586
Chi square p-value[2]							0.2587

1 Party boat anglers were excluded because they were not asked any health advisory questions. Health advisory behavior details are missing for 30 Consumers.

2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K57. Non-Consumers Who Changed Fish Eating Habits (unadjusted & adjusted)

A. Mode	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
Pier	15	23	30	51	77	70	66
Beach and Bank	3	33	56	6	67	44	9
Private Boats	12	46	58	14	54	42	26
Total	30	30	40	71	70	60	101
Chi square p-value[2]							0.0835

B. Ethnicity (major groups)	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
African American	6	43	60	8	57	40	14
Latino/Hispanic	2	14	24	12	86	76	14
Caucasian	15	32	41	32	68	59	47
Asian	5	24	25	16	76	75	21
Other	0	0	2	3	100	100	3
Missing/Don't Know/Declined	2	100	100	0	0	0	2
Total	30	30	40	71	70	60	101
Chi square p-value[2]							Not Valid

C. Ethnicity (with Asian subgroups)	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
African American	6	43	60	8	57	40	14
Latino/Hispanic	2	14	24	12	86	76	14
Caucasian	15	32	41	32	68	59	47
Chinese	1	25	45	3	75	55	4
Filipino	0	0	0	3	100	100	3
Vietnamese	0	0	0	2	100	100	2
Pacific Islander	2	50	23	2	50	77	4
Other Asian	2	25	22	6	75	78	8
Other	0	0	0	3	100	100	3
Missing/Don't Know/Declined	2	100	100	0	0	0	2
Total	30	30	40	71	70	60	101
Chi square p-value[2]							Not Valid

D. Income	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
<$20,000	3	19	22	13	81	78	16
$20,000-$45,000	7	32	55	15	68	78	22
>$45,000	17	30	41	39	70	45	56
Missing/Don't Know/Declined	3	43	22	4	57	59	7
Total	30	30	40	71	70	60	101
Mantel-Haenszel Chi square p-value[2]							0.4567

E. Education	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
<12th grade	1	14	33	6	86	67	7
HS/GED	7	19	28	30	81	72	37
Some college	12	46	58	14	54	42	26
>= 4 years college	10	32	41	21	68	59	31
Missing/Don't Know/Declined	0	0	0	0	0	0	0
Total	30	30	40	71	70	60	101
Mantel-Haenszel Chi square p-value[2]							Not Valid

F. Season Interviewed	Changed Habits			Didn't Change Habits			Total[1]
	n	%	adj%	n	%	adj%	
Winter	7	33	39	14	67	61	21
Spring	9	41	53	13	59	47	22
Summer	7	18	30	32	82	70	39
Fall	7	37	58	12	63	42	19
Total	30	30	40	71	70	60	101
Chi square p-value[2]							0.2123

1 Party boat anglers were excluded because they were not asked any health advisory questions. Health advisory behavior details are missing for 30 Consumers.

2 Chi-square statistic does not include Missing/Don't Know/Declined responses. Chi-square statistic was calculated for unadjusted data only.

Table K58. How Respondents Prefer to Receive Information About Fish (unadjusted)

A. Mode

Method	Piers		Shore		Private Boats		Total[1]	
	n	%	n	%	n	%	n	%
Newspapers	235	34	35	35	163	38	433	35
Television	240	35	36	36	135	31	411	34
Sign	176	25	25	25	70	16	271	22
Friend/Family	140	20	17	17	48	11	205	17
Fishing Regulations	92	13	9	9	69	16	170	14
Radio	87	13	12	12	49	11	148	12
Bait/Sport Shops	77	11	16	16	40	9	133	11
Other/Misc.	44	6	7	7	13	3	64	5
Contact with Educator	29	4	7	7	18	4	54	4
Internet	20	3	4	4	15	3	39	3
Fish and Game Warden	17	2	4	4	17	4	38	3
Don't Know	23	3	5	5	9	2	37	3
Direct Mailing	4	1	0	0	4	1	8	1
All Respondents	695	57	99	8	433	35	1227	100

B. Ethnicity

Method	African American		Latino/Hispanic		Caucasian		Asian		Other		Missing		Total[1]	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Newspapers	40	34	48	29	192	42	133	32	13	42	7	17	433	35
Television	45	38	71	43	120	27	151	36	13	42	11	26	411	34
Sign	35	30	47	28	82	18	100	24	4	13	3	7	271	22
Friend/Family	24	21	34	21	56	12	85	20	3	10	3	7	205	17
Fishing Regulations	16	14	27	16	72	16	47	11	4	13	4	10	170	14
Radio	17	15	30	18	48	11	47	11	2	6	4	10	148	12
Bait/Sport Shops	22	19	15	9	52	12	37	9	3	10	4	10	133	11
Other/Misc.	6	5	10	6	30	7	15	4	3	10	0	0	64	5
Contact with Educator	7	6	5	3	24	5	16	4	2	6	0	0	54	4
Internet	1	1	2	1	23	5	13	3	0	0	0	0	39	3
Fish and Game Warden	2	2	2	1	19	4	13	3	2	6	0	0	38	3
Don't Know	2	2	0	0	6	1	27	6	1	3	1	2	37	3
Direct Mailing	0	0	1	1	3	1	1	1	2	6	1	2	8	1
All Respondents	117	10	165	13	452	37	420	34	31	3	42	3	1227	100

1 Party boat anglers were excluded because they were not asked any health advisory questions.

Table K59. How Consumers Prefer to Receive Information About Fish by Mode (unadjusted)

Method	Piers		Shore		Private Boats		Total[1]	
	n	%	n	%	n	%	n	%
Newspapers	193	33	27	33	151	39	371	35
Television	210	36	32	40	124	32	366	35
Sign	147	25	21	26	64	16	232	22
Friend/Family	126	22	13	16	45	12	184	18
Fishing Regulations	83	14	9	11	63	16	155	15
Radio	77	13	10	12	45	12	132	13
Bait/Sport Shops	61	10	13	16	36	9	110	10
Other/Misc.	38	7	6	7	11	3	55	5
Contact with Educator	24	4	6	7	17	4	47	4
Fish and Game Warden	11	2	4	5	17	4	32	3
Don't Know	19	3	3	4	8	2	30	3
Internet	14	2	3	4	12	3	29	3
Direct Mailing	4	1	0	0	3	1	7	1
All Consumers	583	55	81	8	390	37	1054	100

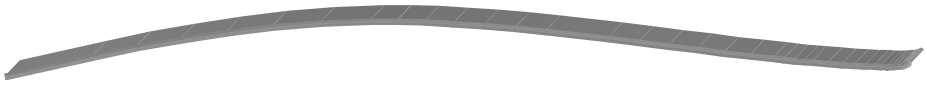
Method	African American		Latino/Hispanic		Caucasian		Asian		Other		Missing		Total[1]	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Newspapers	34	35	41	28	159	43	122	32	9	35	6	17	371	35
Television	37	39	65	45	102	28	141	37	10	38	11	31	366	35
Sign	29	30	41	28	64	17	92	24	4	15	2	6	232	22
Friend/Family	22	23	30	21	46	13	80	21	3	12	3	8	184	18
Fishing Regulations	15	16	24	17	62	17	47	12	4	15	3	8	155	15
Radio	15	16	25	17	42	11	44	11	2	8	4	11	132	13
Bait/Sport Shops	18	19	12	8	43	12	30	8	3	12	4	11	110	10
Other/Misc.	5	5	10	7	25	7	12	3	3	12	0	0	55	5
Contact with Educator	6	6	5	3	20	5	14	4	2	8	0	0	47	4
Fish and Game Warden	2	2	2	1	17	5	9	2	2	8	0	0	32	3
Don't Know	0	0	0	0	2	1	26	7	1	4	1	3	30	3
Internet	1	1	2	1	18	5	8	2	0	0	0	0	29	3
Direct Mailing	0	0	1	1	2	1	1	0	2	8	1	3	7	1
All Consumers	96	9	144	14	368	35	384	36	26	2	36	3	1054	100

1 Party boat anglers were exlcuded because they were not asked any health advisory questions.

Appendix L

Health Advisory Discussion Groups

San Francisco Bay Seafood Consumption Study



Appendix L - Health Advisory Discussion Groups

The California Department of Health Services (CDHS) conducted four discussion groups with anglers in order to better assess anglers' actual awareness of the advisory, the effectiveness of the advisory language, and the best messages and modes of delivery for reaching anglers with information. We originally planned to conduct four discussion groups, each consisting of 8-12 participants. Participants would attend a two and one half-hour discussion facilitated by a community relations coordinator.

Discussion group participants were recruited from the survey population. At the conclusion of the interview, respondents were asked for their name, address, and telephone number for the purposes of quality control and follow-up. Of the 1331 respondents, 581 (44%) provided contact information. After reviewing preliminary study results, the project staff identified four target groups to participate in discussion groups. The four groups were categorized as: (1) Filipino anglers, who made up the largest group of Asian anglers; (2) anglers who were unaware of the advisory; (3) anglers who were aware of the advisory but had not changed their consumption habits; and (4) boat anglers. Out of the 581 anglers who provided contact information, 216 were eligible to participate in the discussions because they met the criteria for at least one of the four groups. The field coordinator attempted to contact all eligible participants. She explained the purpose of the focus groups and provided them with several scheduling options by which they could participate, including weekday evenings and weekend mornings. Those who indicated a willingness, received a confirmation letter with the date, time, and place of the discussion, and directions to the site. They also received a reminder call 24 hours before the meeting.

Out of 216 of eligible participants, 35 agreed to participate in the groups, and 17 actually participated. In response to the low attendance of the early meetings, we increased the compensation from $50 to $75, and offered meeting times during the workday as well as weekend and evening. We also re-contacted anglers who either declined to participate or failed to show, and offered them the increased compensation and meeting options. Participation by shore-based anglers, however, did not improve. We conducted all four of the proposed groups, and an additional group consisting of anglers from all three of the shore groups (aware, unaware, and Filipino anglers) in order to maximize participation. Information on discussion group contact and participation is presented in Table L1.

Table L1. Discussion Group Dates, Location, Contacts and Participants

Date Location	Target Group	Number Contacted	Number Confirmed	Number Participated
9/21/99 San Francisco	Filipino Consumers	21	5	2
9/23/99 Oakland	Filipino Consumers	55	5	2
10/30/99 Oakland	Unaware of Advisory	117	7	0
11/15/99 Oakland	Unaware of Advisory	117	5	3
11/20/99 Oakland	Unaware, Aware but haven't changed habits	117	5	3*
12/8/99 Martinez	Boat anglers	23	8	7

*One of these anglers was also Filipino.

One group was held in San Francisco, three were held in Oakland, and one was held in the Martinez Yacht Club (boat anglers). The group participants consisted of five Filipino anglers, three anglers who were unaware of the advisory, three anglers who were aware of the advisory but had not changed their behaviors, and seven boat anglers. One Filipino angler was also unaware of the advisory. For the purpose of discussion, we categorized respondents as either boat or shore-based anglers. Among participants, the length of time fishing ranged from 2 to 20 years.

To enhance objectivity in the interpretation of the discussion, three CDHS facilitators were present at each meeting. The groups were led by Ian Walker, Community Relations Coordinator, along with Gloria Cordona, and Diana Lee or Alyce Ujihara. Group participants were guided through a discussion outline (Attachment L-1) which contained specific questions. Responses were qualitative in nature, and recorded both on audio tape and by a note-taker.

Due to the small number of anglers who participated in the discussion groups, generalization to the overall fishing population was not possible. However, discussion group participants raised pertinent questions and concerns regarding the advisory messages and educational strategies. They also provided some insight into the efficacy of the language used in the advisory.

A. Discussion of Health Advisory

Even though anglers in the discussion groups had been read a summary and were offered written materials about the advisory during their field interview, their knowledge of the SF Bay advisory ranged from none whatsoever to two boat anglers who had a firm understanding of all the major recommendations. In general, the majority of participants

had fragmented or incorrect information regarding the health advisory. Anglers often had awareness of one element of the advisory (such as fish in different locations, limit size of fish, or eat less fish) but they were not knowledgeable about more than one aspect of the advisory. Overall, the boat anglers had the most accurate knowledge. Six out of seven expressed an awareness of the advisory and were able to correctly recite some element of it.

Anglers were then shown the health advisory for SF Bay fish (Appendix A). After reading the advisory, overall, the participants indicated that the information was important. Boat anglers and participants who were aware of the advisory but had not changed their habits, attached the least importance to the advisory.

B. **Discussion of Terms used in the Health Advisory**

In the discussion groups, we tried to assess whether anglers understood the term "sport fish." In the health advisory, "sport fish" refers to all species of fish from the Bay that an angler may catch and eat. All of the participants claimed to know what the term sport fish meant; however, none of the groups were able to agree on its definition. Despite some awareness of the advisory guidelines, no one from the three shore-based groups believed the term applied to all fish from the Bay. The most common assertion was that it applied to fish one did not eat (e.g. caught and released). Two anglers felt the term referred to fish one could not sell. Some believed it applied to specific kinds of fish, such as bass and shark, or fish from the ocean, that were caught for recreation and not for food. Boat anglers were closest to describing the health advisory's definition of "sport fish." Two anglers initially felt that it applied to all fish from the Bay; however this definition was not supported in the discussion, which continued to propose alternate definitions. Some of the boat anglers felt that white croaker, shark, string ray, and other fish were definitely <u>not</u> "sport fish"; two people in this group felt that subsistence fishing was different than sport fishing, and that anglers who needed the fish for food were not catching "sport" fish.

Overall, anglers appeared at a loss for a better term to describe all fish that they may catch and eat. Some anglers felt the term "fish" didn't need to be qualified if used on a waterfront sign. Others felt that "Bay fish" was a better term, or that a definition (such as "fish caught from the SF Bay") would help clarify text in which sport fish was used. A couple of anglers felt that the current wording suggested that all fish, including river and ocean fish, were implicated in the advisory. They felt it was important that the wording state very clearly that the advisory was for SF Bay fish only.

In general, terms referring to the fish itself, like fillet, and juices were well understood by the participants. In referring to amounts of fish that can be safely eaten, most anglers felt that indicating "grams" was not helpful. While the majority of participants understood "ounces," they also felt that people do not think in those terms.

Almost all of the shore-based anglers preferred "pounds" as the best way to express amount. They felt it took into consideration different meal sizes, and gave them more

freedom of choice. In contrast, almost everyone in the boat anglers group preferred that the amounts be expressed as "two meals." They felt it was simple and sufficient. However, several anglers in this group clearly stated that they would not be following any advice to limit their consumption.

Filipino anglers who participated in the groups felt strongly that they did not think in terms of meal or portion sizes. They indicated that rather than an individual "meal" or portion on a plate, fish is generally put on the table whole, and family members then take what they want throughout the meal.

During the discussions, we noted that the Filipino anglers (4) all reported eating the skin and parts other than the fillet (e.g. head, cheeks). Boat anglers, on the other hand, indicated that they almost always ate only the skinned fillet. Other anglers varied in their response to eating the skin.

C. Discussion of Methods to Conduct Educational Outreach

We asked participants who they thought would be the most believable agency for conveying information about fish. Given a choice between the state health department or a federal health agency, almost everyone from shore-based and boat groups believed that the state was a more believable messenger for advisory information. The majority of people also preferred the state to city or county health departments. On whether the state was a more believable messenger than non-governmental environmental agencies such as Save San Francisco Bay, the response was divided. While the majority of participants felt that the state should be responsible for this type of information, and would be less biased, several participants believed that non-governmental agencies would be more protective and more believable messengers. Many of the anglers felt that the Department of Fish and Game was a very credible messenger; however, a couple of participants felt that they were more interested in enforcing regulations, and considered their presence threatening.

We asked participants whom they would go to if they had a question regarding their health. Everyone stated their doctor as the first person they would ask about their health. Most of the doctors were identified as being connected to a health maintenance organization. Other people mentioned relatives and one individual mentioned his wife. We also asked if there were leaders in their communities who would be effective messengers for fish-related concerns. No one could identify a "leader" in their community. If the question was specifically about fish, other anglers were frequently mentioned as sources of information. Several individuals said they had already spoken to fishing friends about participating in this discussion group, and that they would be sharing with them information from this group.

Almost unanimously people did not participate in community centers, cultural centers, or other cultural/community activities. The local bar was the only "place" identified as a center for shore-based anglers. Boat anglers also indicated the yacht club as a social center for themselves.

Although we did not ask questions about in which languages fish messages should be provided, all four of the Filipino anglers who participated in the discussion group indicated that written materials in Tagalog were unnecessary. These anglers shared that given the many dialects of Tagalog, written communication is difficult, and the majority of individuals who could read Tagalog could also read English. Considering the small number of Filipino anglers who particpated in the discussion groups, clarification of this issue is merited.

D. **Sign Building Activity and Discussion**

We asked participants to assist us in the development of a fish health advisory sign, using their knowledge from our discussion. As a group, participants were shown three fish images, and asked which image they were most drawn to. The images were designed to be prototypes that could be simplified for logos, or elaborated upon for brochures and other educational materials. Each image contained two fish to visually support the advisory of two meals, or two half-pound portions, a month. Each of the three images were presented in three different color choices, making a total of nine possible images to choose from. After selecting their first choice, participants were asked to select a second choice. The most common choice for an image was of two colored fish on a line. The same image in black and white was the second most frequent choice with other images being mentioned with less frequency.

We then asked participants to assist us in the development of an advisory sign to be posted on fishing piers. Each of the signs were to contain three elements: a title, the general advisory consumption guidelines, and a the choice of additional health recommendations or information on how to obtain these recommendations. Participants in the two smallest discussion groups were allowed to create individual signs; the three larger groups developed signs as a group. A total of five signs were created. Participants were asked to choose between two word choices for the title of the sign: "Caution" or "Eat Bay Fish Safely." Three signs chose "CAUTION" as their title, two signs "EAT BAY FISH SAFELY."

Next we asked participants to choose between two grids showing consumption guidelines. The first presented the guidelines for the general population and pregnant women with size of fish; the second presented the guidelines with different consumption rates based upon individual species for men and pregnant women with size of fish. Four signs chose the simpler consumption rate, one chose the more complex.

Finally we asked participants to choose between providing information on where to write for additional recommendations and information, and one that provided information on how to prepare fish in healthier ways. Four signs chose additional information on where to write, one chose information on how to prepare fish.

The participant's choices regarding wording and content often appeared contrary to the views expressed during the earlier discussions. Individuals who had expressed

skepticism regarding the advisory sometimes chose the stronger (Caution) title for their sign. Likewise, people who wanted more information and greater freedom of choice sometimes selected the simpler consumption chart. The importance of access to more information may well have been a result of the lengthy discussion we were able to have with participants, which may have underscored the complexity of the issue.

Despite the small number of anglers who participated in the discussion groups, there were several notable observation:

- Almost none of the anglers who participated in our focus groups understood the term "sport fish."
- Use of "pounds" to indicate meal size is more acceptable than "ounces" or "grams".
- Anglers want to maintain some control over how they implement the advisory guidelines.
- None of the participants identified a "community leader" or local social or health center that could be utilized as a vehicle for delivering education.
- No single choice of words or content was preferred by the anglers in our discussion groups.

Attachment L-1

DISCUSSION GROUP -QUESTION GUIDELINES

Introductions **15 minutes**

Who we are	Presentation
Why we're having the group / **goals** / **Agenda**	Presentation
Confidentiality & recording the session	Presentation
Importance of individual answers (it's okay to disagree)	Presentation
Questions and Concerns	Q&A

Ice Breaker **10 Minutes**

Who's been out fishing in the last week?
In your opinion, has the water in the bay gotten worse? Better? Same?

Recognition / Meaning of the term "Sport Fish" **15 Minutes**

1. Have you ever heard of the term "Sport Fish" before? Show of Hands
2. What does it mean? Group Discussion
3. Where have you heard this term? Group Discussion
4. If you were to refer to <u>all</u> fish from the bay, what term would you use? Group Discussion
   - 4a. Would the term: "Fish from the Bay" be better?
   - 4b. Would the term: "Fish you catch yourself?"

Health Advisory Knowledge **20 Minutes**

1. Have you heard of a health advisory for the SF Bay? Show of Hands
2. What does it say? Discussion
3. How many fish does it say one can safely eat? Discussion
4. What types of fish does the advisory include? Discussion
5. How important do you feel this advisory is? Discussion

Understanding Lack of Behavior Change **20 Minutes**

(these questions will only be asked of the group which has indicated an awareness of the advisory, yet hasn't changed its behavior)

1. Have you changed how much you eat since hearing the advisory? Discussion
2. Do you feel the following statements are true? Show of Hands
   - 2a: The advisory isn't correct
   - 2b: The advice will change in a few years
   - 2c: I don't eat enough to hurt my health
   - 2d: I eat only healthy fish from the Bay
   - 2e: I don't plan to eat the fish forever
3. Why do you feel this/these statements are true? Group Discussion

The best way to deliver info **20 Minutes**

1. Who would you go to, trust, for advice on your health? Group Discussion
2. Who do you see as leaders, people you trust? Group Discussion
3. What groups, or agencies, do you regularly visit? Group Discussion
    3a. Where do you receive health care? Group Discussion
4. What is the best way to get this type of information to fishers? Discussion

BREAK **10 Minutes**

Educational Materials Evaluation **30 Minutes**

1. Which card would you pick up first? Group Activity
    1a. Which card would you pick up second?
2. (After reading the card) What did the card say? Group Discussion
3. Do you believe the info on this card? Group Discussion
    3a. Do think it comes from a reliable source?
    3b. What sources would be more reliable?
    3c. What would make the card/info more believable?
4. Should "one meal" be phrased in grams, pounds, or as "a meal" Group Discussion
5. What is meant by cooking juices Group Discussion
6. What part of the fish is the fillet or muscle? Group Discussion
7. How may types of fish/consumption rates can be included? Group Discussion

Build your own Sign Activity **15 Minutes**

Thanks/Closing **5 Minutes**

California Tribes Fish-Use

Final Report

California tribes have used fish for ceremony, diet, and as a part of culture for far longer than California has existed. Because of concern expressed by members of California tribes, the State Water Resources Control Board and the US Environmental Protection Agency supported the collection of information about the current and traditional use of fish by members of tribes across the state, to inform draft water regulations. We found that tribes use fish in similar patterns (fish types and source-waters) as they did traditionally, but not in terms of amounts. Tribes used 29 freshwater/anadromous fin-fish species, 23 marine fin-fish species, and 18 other invertebrate, and plant species and groups of species. Current 95th percentile rates of consumption of caught-fish varied by tribe and ranged between 30 g/day (Chumash) and 240 g/day (Pit River). The rate of fish use (frequency and consumption rate) was suppressed for many tribes, compared to traditional rates, which most tribes attributed primarily to water quantity and quality issues. This report describes the surveying approach and findings about tribes' use of fish.

July, 2014

California Tribes Fish-Use: Final Report

A Report for the State Water Resources Control Board and the US Environmental Protection Agency

Agreement # 11-146-250 between SWRCB and UC Davis

By
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July, 2014

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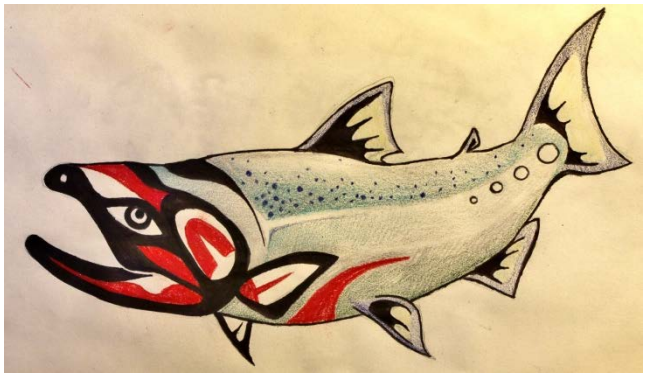

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Summary

Tribes have been concerned that water quality and other water-related decisions tend to lack consideration of tribes' use of water and fish. The State Water Resources Control Board and the USEPA provided funding to collaborate with tribes in discovering what the patterns of fish use were historically and are currently. UC Davis researchers worked with partner tribes to establish an appropriate approach to interviewing tribe members about fish use. Members of 40 CA tribes and tribe groups were surveyed directly at 24 locations and staff from 10 tribes were surveyed online using standard questionnaires. Traditional uses of fish were assessed using literature review and surveying of tribe members and staff. Contemporary uses were assessed using tribe member interviews. We found that tribes use fish in similar patterns (fish types and source-waters) as they did traditionally, but not in terms of amounts. Tribes used 26 freshwater/anadromous fin-fish species, 23 marine fin-fish species, and 18 other invertebrate, and plant species and groups of species. The single most commonly caught and/or eaten fish species group among all tribes was "salmon", which could include chinook or coho salmon. 95th percentile rates of consumption of caught-fish varied by tribe and ranged between 30 g/day (Chumash) and 240 g/day (Pit River). The rate of fish use (frequency and consumption rate) was suppressed for many tribes, compared to traditional rates, which most tribes attributed primarily to water quantity and quality issues.

Background

California Tribes have been fishing and eating fish for far longer than California has existed. Although practices, fishing areas, fished species, and amounts of fish eaten may have changed over time, the cultural and dietary importance of fish has not. Anglo-American anthropologists have estimated that for certain California tribes, fish consumption was at least one pound per day, which for certain coastal tribes may have been mostly salmon (Hewes, 1973; Hewes, 1942 and Hewes 1947, cited in Swezey and Heizer, 1977). This rate is similar to other reported rates in Northern California, for example, Harper and Harris (2008) report that a review of the literature reveals that Columbia River Tribes consumed about a pound of fish per day (620 gpd) before contact with Europeans led to suppression of fish populations and fish consumption.

The Karuk tribe and academic collaborators have studied their own fish use practices and health consequences of fish use (Karuk Tribe, 2004; Reed and Norgaard, 2005). They have demonstrated that the loss of salmon led to a decline in fish consumption by tribe members, and this was linked to health declines, including an increase in an incidence in diabetes, heart disease and hypertension. Because of the direct linkage between dam construction blocking salmon runs, which led to cultural, diet, and health problems for the Karuk, a case could be established that the dams should be removed.

Suppression of fish use and consumption is an important concept in the regulation of water management and problems related to development and extraction activities. Because many of these activities are permitted by state and federal agencies, there is an opportunity to reverse

the harm being caused to a use of aquatic systems, once it has been identified. Harper and Harris (2008) make the case that although fish consumption by Columbia River Tribes has been suppressed, a subset of the Tribes' members still practice original subsistence rates and that the subsistence practice should form the basis for regulatory and other means of protecting a recovered use of fish.

Aquatic organism use by California Tribes has been previously studied primarily by analyzing shell and bone fragments in middens associated with traditionally-settled areas, both before and after European colonization. Studies by Gobalet et al. (1990a, 1990b, 1992, 2004) demonstrated that tribes used at least 76 species and groups of species of marine and freshwater fish throughout California. Since colonization and displacement of tribes from most of their traditionally-fished areas, the pattern (fish targeted), geographic distribution, and rate of fish use may have changed.

Policy Framework

Water and aquatic ecosystems are protected by a number of different state and federal laws, such as the state and federal Clean Water Acts. Fish populations are further protected from endangerment and extinction by the state and federal Endangered Species Acts. Fish use by members of the public is protected as a beneficial use (when applicable) under the Clean Water Act, as a recreational use by the Fish and Game code and administratively protected on most public lands. Fish use by tribes is further protected for certain tribes with treaty rights, but not for most tribes. There is an increasingly-recognized gap between the traditional practices of many tribes to use fish for various reasons and the protection of these practices in state and federal law.

Previous studies of fish use by specific California tribes (e.g., Reed and Norgaard, 2005) and the current study suggest that new, or reformation of existing policies are needed that protect the various ways that fish use is important to tribes. These ways include health, sovereignty, culture, environment, economy, and moral/legal. Responsive policies from state and federal agencies will explicitly take these ways of use into account. Being responsive could mean developing new policies, such as SWRCB's proposed beneficial use designation for cultural and traditional use. It could also mean articulating the various ways that fish use is important in new state and federal statutes. Finally, it could mean identifying and protecting these uses in re-negotiated or new treaties between the US and tribes, or in new agreements between California and tribes.

A key component of water policy in California is the development of water quality criteria based upon standard fish consumption rates. These criteria are usually related to fish contamination (e.g., by mercury) and vary inversely with fish consumption rates. The USEPA recommends using a 90th percentile rate of consumption to protect the general population and a 99th percentile rate to protect anglers who consume their catch (USEPA, 2000). In California, both the San Francisco Bay Regional Water Quality Control Board (SFRWQCB, 2006) and the Central Valley Water Quality Control Board (CVRWQCB, 2010) have used the 95th percentile rate of consumption from regional studies to protect fish consumers. Subsistence fishing was considered in one alternative (Alternative 5) of the Delta methylmercury TMDL (CVRWQCB, 2010) as follows: "*Some people are subsistence consumers; because of tradition or need, these people have high consumption rates of locally caught fish, represented by a rate of 142.4 g/day (four to five fish meals per week). This rate is the 99th percentile consumption rate identified in a national food intake survey and recommended by USEPA for subsistence anglers and their families… Therefore, Alternative 5 is protective of (a) people who eat a very high amount of TL4 fish species*." (CVRWQCB, 2010). These various sources of guidance and policy findings support the use of a 95th or 99th percentile rate of consumption by tribes as the basis for local and regional water quality criteria, fish tissue criteria, and other water policies promulgated by the state to protect tribes' use of fish.

Methods

The sections below describe how partnerships were developed with tribes, how interviews were conducted, literature retrieval and analysis, and methods of statistical analysis.

Project Locations and Times

There were two primary types of locations where interviews were conducted: 1) tribal offices and 2) tribal or inter-tribal events. The tribes and event locations were distributed widely across California (Figure 1). Interviews were conducted between 1 and 3 times for each tribe between May/2013 and June/2014 (Table 1).

Figure 1. **Tribe and interview locations in California.**

Table 1 **Tribe locations and identities (in parentheses) and month when interviewing was carried out.**

Partner Tribes/Locations	Interview Months
Upper Lake Rancheria (Habematolel Band Pomo)	5,7/2013
North Coast Campout (Inter-Tribal)	6/2013
Bridgeport Indian Colony (Paiute)	6/2013
Big Valley Rancheria (Big Valley Band Pomo)	7/2013
Sugar Bowl Rancheria (Scotts Valley Band Pomo)	7,11,12/2013
Stewarts Point Rancheria (Kashia Band Pomo)	8/2013
Buena Vista Rancheria (Me-Wuk)	8/2013

Blue Lake Rancheria (Wiyot & Yurok)	8/2013
Round Valley Rancheria (Yuki, Pit, Pomo, Nomlacki, Concow, Wailaki)	9/2013
Bear River Rancheria (Mattole & Wiyot)	9/2013
Fort Bidwell Reservation (Northern Paiute)	9/2013
Big Pine Indian Reservation (Paiute)	10/2013
Wiyot Tribe Reservation (Wiyot)	11/2013
Bishop Reservation (Paiute)	12/2013
Death Valley (Timbisha Shoshone)	12/2013
Mechoopda Indian Tribe of Chico Rancheria (Maidu)	3/2014
North Fork Rancheria (Mono)	4/2014
Big Sandy Rancheria (Mono/Monache)	4/2014
Grindstone Indian Rancheria (Wintun-Wailaki)	4/2014
Manchester/Pt. Arena (Pomo)	4/2014
Santa Ynez Rancheria (Chumash)	5/2014
Chemehuevi Reservation (Chemehuevi)	5/2014
Fort Mojave (Mohave)	5/2014
Pit River (Achomawi & Atsugewi)	6/2014

Collaboration with Tribes

The project was inspired by tribes expressing the need for the state and federal agencies to use information about tribes' use of fish in setting water quality standards and thresholds. Tribes were also consulted about appropriate techniques to use to approach tribes and individual tribe members, appropriate questions to ask individuals, and the types of information that would be important to collect. This consultation led to the development and refinement of the questionnaires and the methods used in the field. Tribes suggested collecting information about historical uses of fish, traditional and customary uses of fish, contemporary uses of fish, and threats and causes of fish use reduction (if any).

Contact with Tribes

All 146 federally-recognized and state-recognized tribes and one tribe that has neither recognition (Winnemem-Wintu) were contacted twice by email and letter-mail to solicit their participation in the project. About two-dozen tribes responded by email, phone, or in-person at meetings that they would be interested in further discussion and possible participation. Of these, 12 participated and the remainder changed their position about participating. After

learning about the project in various ways (e.g., word-of-mouth), another 12 tribes wanted to participate.

Various reasons were given for not wanting to participate in the project. One major concern was that the federal and state governments and the University of California had all violated trust in various ways in the past and that regulatory, trust, and land management agencies were inconsistent in their consideration of tribes' needs, interests, and indigenous rights and uses of land and water. It is important to consider non-participation in this project NOT as lack of interest in fish use, but rather some combination of lack of time/resources to participate, political resistance to governmental intrusion, and knowledge of past failure of government to act to protect tribal interests.

Interview instruments

Two questionnaires were used to interview tribe members in the field, one focused on traditional uses and threats to uses (Appendix 1) and the other focused on contemporary uses and threats to use (Appendix 2). The traditional use questionnaire included questions about tribe's traditional fishing dependence, fishing areas, and traditionally-used fish. The questionnaire also included questions about past rates of consumption of traditionally-used fish and whether and why current fish use might have been impaired compared to traditional patterns. The contemporary use questionnaire included questions based on 30-day recall about the frequency of fishing and consumption of particular locally-caught and store-bought fish species. It also included questions about reasons that fish use may be less than desired or anticipated, as well as basic household and demographic information.

Tribes were also surveyed using an online instrument focused on tribes' traditional and customary use of fish (Appendix 3). The questionnaire contained questions focused on whether tribes used and still use fish, the types of fish used, the frequency tribes traditionally ate fish, and the barriers to fish use. Tribe staff were contacted via email and provided a link to the survey. This online questionnaire was used to reach additional tribes that were not involved in the two field surveys.

Field interviews

Field interviews were carried out in two primary ways: 1) working with tribes to organize tribe members on certain days when UC Davis staff could come and interview them and 2) working with tribes to find out how to engage in specific tribe events where interviewing tribe members was feasible. This approach is different from the method that an epidemiological study might use of randomly sampling a population, based on tribe rolls, and conducting in-person or phone interviews. The demographic mix (income, age, and gender) that resulted from our approach led us to believe that we had incidentally interviewed a random subset of each tribe. To encourage tribe members to come on certain days to be interviewed, staff would announce to the tribe members via email list-serves, newsletter announcements, and posted fliers (on notice boards) that interviews were going to take place. All tribe members were invited and no attempt was made to target anglers and users of fish specifically. Tribe cultural and community events were assumed to attract a cross-section of each tribe. People were approached opportunistically at these events, or sometimes people approached the interviewers at the UC Davis project booth.

Literature review

Available literature about tribes' fish use was searched from tribal and academic library resources. Several kinds of information were retrieved from these sources: 1) narrative descriptions of traditionally-fished areas, 2) narrative or quantitative description of rates of fish use and consumption, 3) narrative description of fish species used, and 4) descriptions of and threats to and changes in fish use. This information was important in understanding what fish tribes had traditionally relied upon and is important context for reports of current fish use.

Data management

Data from the questionnaires were entered into Excel spreadsheets by the field interview staff and the project lead. Photocopies of the questionnaires were kept by the field staff until safe delivery of the originals to UC Davis, then destroyed. Original questionnaire forms were kept in a locked file cabinet inside a locked office at UC Davis. Data entered into Excel spreadsheets were kept in password-protected computers. Incomplete questionnaire responses were retained as blanks in the spreadsheet. Any questions about individual responses were resolved

by discussions between the field staff and the project lead. All tribes were informed that they had the right to refuse sharing of the data after it had been collected. No tribe used this right.

Coding of interview responses

Narrative responses to questions were recorded as either one of the existing possible answers to questions, or as a new type of answer to the question. One of the questions referred to why a certain fish that had been eaten in the past was not consumed in the last 30 days. Answers were grouped by type of response, for example many respondents to this example questions said that they had not been fishing for the fish, or it was out of season. These types of answers were grouped as response types. If too few people responded with particular answer-types, then these more individual responses were retained, but not coded and therefore lumped together.

Mapping waterways for fishing

Tribe members were asked to list waterways where they had traditionally/historically caught fish and waterways where fish originated that they had consumed in the last 30 days. This list of waterway names was used to select hydrologic unit code-10 (HUC-10) watersheds from a standard USGS HUC map using ArcGIS 10. The HUC-10 scale was chosen because it was the smallest HUC scale that captured full waterways, such as specific creeks. For each tribe, 2 maps were created: 1) core traditionally-fished watersheds (identified by 2 or more respondents), and 3) watersheds where currently-consumed fish were obtained.

Statistical Analyses

State regulatory processes typically use the 95th percentile rate of fish consumption to calculate target contaminant concentrations that will protect most users (CVRWQCB, 2008). In order to represent as many native fish-users as possible, we calculated 95th and 99th percentile fish use rates. The mean use rate was not calculated or reported, because it has no meaning in policies intended to be protective of most or all users. The measures examined included frequency of fish consumption, fish portion sizes and fish consumption rates.

Frequency of traditional fish consumption was reported in one of 6 categories (>1 meal/day, 1/day, 2-3/week, 1/week, 1/month, <1/month). Frequency of contemporary consumption was reported as # meals in last 30 days and for comparison with traditional frequencies was converted to the frequency categories used for the traditional interviews. Traditional and contemporary frequency distributions among all tribe respondents were tested for significant differences using a Chi-test R (a statistical package; R Core Team, 2013) for two independent sample frequency distributions.

Traditional fish consumption rates were calculated by multiplying individually-reported frequencies of consumption by an estimated portion size of fin-fish. Meal portion sizes were estimated using the average and 95^{th} % portion size from the contemporary survey. The assumption of a similar portion size in the past and current consumption could be questionable, it was a conservative approach considering the lack of data on fish meal portion size from the past. The average consumption rate obtained was then multiplied by the traditional frequency numbers to get estimates of traditional consumption rates (grams per day).The comparison of traditional and contemporary fish consumption rates was carried out using the Wilcoxon-Mann-Whitney test, which is a suitable non-parametric test for two independent samples for which the dependent variable is not normally-distributed.

Fish consumption rate comparisons were also tested at more specific levels: at the tribe level and the regional level. For tribe comparisons, only those with samples sizes of 10 or more respondents were used. The regional level comparisons have been based on the Water Board region classification for California.

Results

Traditionally Fished Watersheds

Tribes traditionally used most or all streams in their national territories. This traditional use has been reduced in most cases to a set of streams and watersheds that are still used, or were used by recent generations (Figure 3). When present, ancillary areas were often at least as large as the core areas. In some cases, nearby tribes fished the same watersheds.

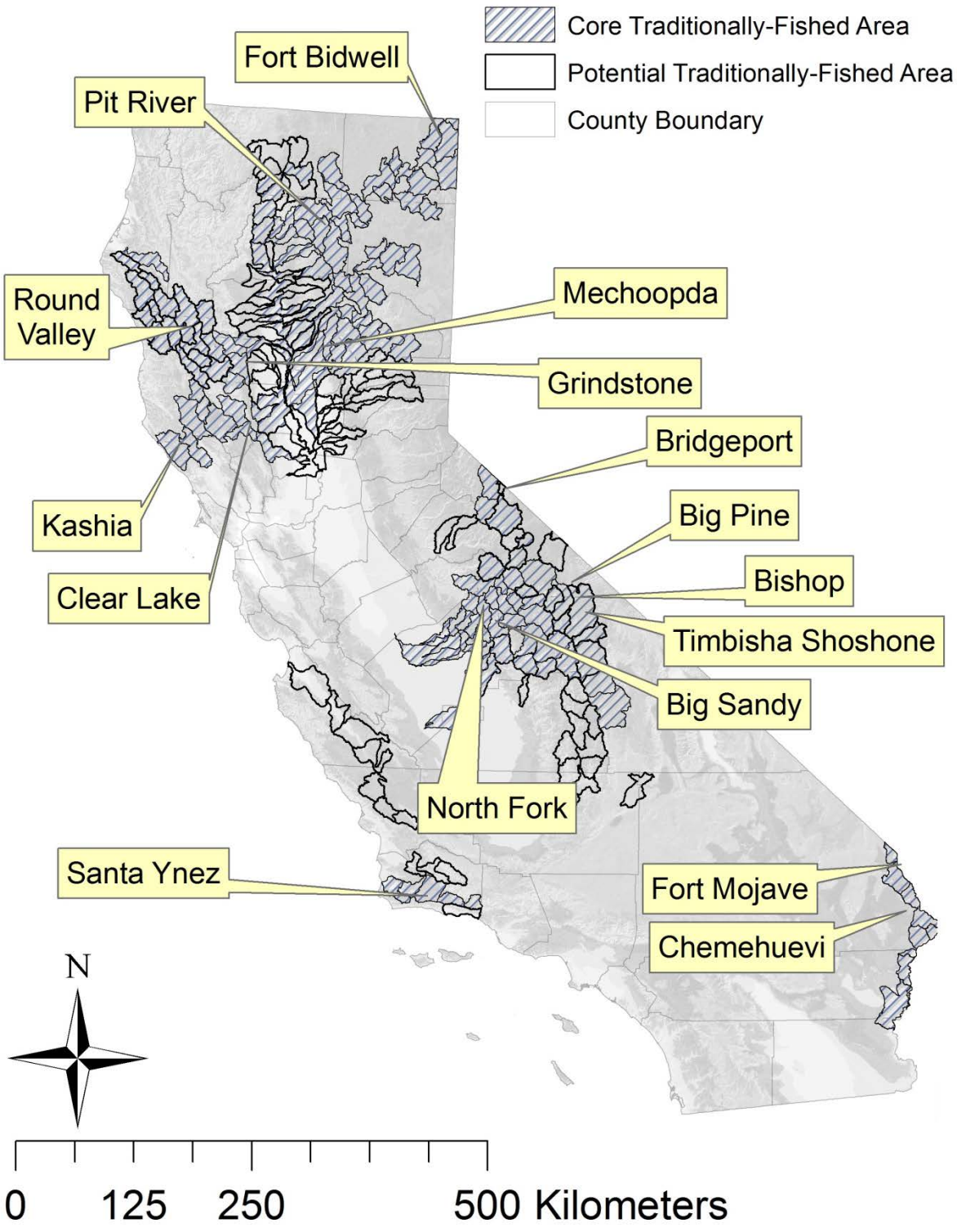

Figure 3. Traditionally-fished watersheds (hydrologic unit code HUC-10). Areas with darker color represent areas where fishing areas of more than one tribe overlapped.

Traditional Reliance of California Tribes on marine, estuarine, and freshwater aquatic organisms

California tribes have longed relied on bony and cartilaginous (e.g., sharks) fish. Much of this reliance has been recorded by the tribes by themselves and by archaeologists who have investigated midden piles at pre- and post-contact village sites (Table 2).

Table 2. Fish species relied upon historically/traditionally by California tribes.

Region	Tribe(s)	Marine, estuarine, freshwater	Fish Species/Groups	Top 5 (Marine, estuarine, freshwater)
North Coast (Karuk Tribe, 2009)	Karuk	All	Salmon, steelhead, sturgeon, trout, lamprey, suckers	*(list not prioritized) Salmon, steelhead, lamprey, sturgeon, trout, suckers
San Pablo Bay (Gobalet, 1990a)	Ohlone	Marine	Shark, rays, skates, herring, sardine, anchovy, midshipman, smelt, white seabass, surfperch, shiner perch, seaperch, pile perch, monkeyface prickleback, rockfish, sanddab	Sturgeon, sardine/herring, salmon, bat ray, topsmelt/jacksmelt
		Estuarine	Sturgeon, threadfin shad, salmon, striped bass, surfperch, gobies, longjaw mudsucker, sculpin, flounder	
		Freshwater	Minnows, splittail, hitch, hardhead, Sacramento sucker	
Delta, Cache Ck (Gobalet, 1990b)	Ohlone, Pomo, Patwin	Estuarine	Sturgeon, salmon, delta smelt,	
		Freshwater	Carp/minnow, thicktail chub, hitch, California roach, hardhead, Sacramento blackfish, splittail, Sacramento pikeminnow, speckled dace, Sacramento sucker, threespine stickleback, prickly sculpin, perch	Carp/minnow, perch, Sacramento sucker, salmon/steelhead, thicktail chub
South Bay, Central Coast (Gobalet, 1992)	Coastanoan	Marine	Shark, ray, longjaw mudsucker, anchovy, rockfish, pile perch, cabezon, rock prickleback, silverside, topsmelt, jacksmelt, herring/shad/sardine	Silverside, carp/minnow, Sacramento perch, Sacramento sucker, sturgeon
		Estuarine	Sturgeon, steelhead, salmon	

		Freshwater	Sacramento perch, Sacramento sucker, carp/minnow, thicktail chub, hitch, hardhead, Sacramento blackfish, splittail, Sacramento pike minnow	
	Chumash	Marine	Shark, ray, skate, herring/sardine, anchovy, jacksmelt, white sea bass, white croaker, corbina, black croaker, drum/hardheads, senorita, sheephead, kelp bass, sea bass/grouper, skipjack tuna, bonito, mackerel, albacore, yellowtail, barracuda, shiner perch, rubberlip seaperch, pile perch, surfperch, opaleye, lingcod, rockfish, halibut, flatfish	herring/sardine, shark, anchovy, ray, senorita
		Estuarine	Steelhead	
		Freshwater	Arroyo chub	
Sacramento Valley watershed (Gobalet et al., 2004)	Maidu, Wintu, Nomlacki, Wailaki, Pomo, Me-Wuk		Sturgeon, thicktail chub, hitch, California roach, hardhead, Sacramento blackfish, splittail, Sacramento pike minnow, speckled dace, Sacramento sucker, steelhead, chinook salmon, delta smelt, longfin smelt, threespine stickleback, sculpin, Sacramento perch, tule perch	Sacramento perch, Sacramento sucker, thicktail chub, Oncorynchus spp., Sacamento blackfish
San Joaquin Valley watershed	Mono, Yokuts	Freshwater	Sturgeon, thicktail chub, hitch, hardhead, Sacramento blackfish, splittail, Sacramento pikeminnow, Sacramento sucker, Chinook salmon, Sacramento perch, tule perch	Sacramento perch, Sacramento sucker, Sacramento blackfish, hitch, tule perch
		Marine	Shark, ray, yellowtail, barracuda	
Central Coast (near SB)	Chumash	Marine	Shark, smoothhound, skate, guitarfish, ray, herring/shad/sardine, anchovy, midshipmen, northern clingfish, silverside, rockfish, lingcod, sculpin, sea bass, yellowtail, jack mackerel, drum/croaker/hardhead, white sea bass, white croaker, queenfish, opaleye, shiner perch, perches, pile perch, barracuda, senorita, sheephead, kelpfish, longjaw mudsucker, bonito, chub mackerel, swordfish, flatfish, ocean sunfish	
		Freshwater	Steelhead, threespine stickleback	

Fish Historically Present in Traditionally-Fished Watersheds

Freshwater fish historically present in waterways fished traditionally by tribes were derived from the PISCES database (http://pisces.ucdavis.edu). According to this database, the number of species historically available in traditionally-fished areas varied between 2 (Fort Bidwell Paiute) and 12 (Mechoopda) species. This range is likely a function of the size of the area, the fish species diversity of the bioregion within which the tribe fishes, and the thoroughness of surveys of fish presence.

Tribe/Region	Fish Species
Bishop Paiute	Owens sucker, Owens speckled dace, Long Valley speckled dace, Kern River rainbow trout, Central California roach, Sacramento pikeminnow,
Bridgeport Paiute	Mountain sucker, Lahontan redside, Lahontan speckled dace, Lahontan cutthroat trout, mountain whitefish
Big Pine Paiute	Owens sucker, Owens speckled dace, Long Valley speckled dace
North Fork	Central California roach, hardhead, Sacramento pikeminnow, Sacramento hitch, Sacramento perch, Sacramento tule perch
Grindstone	Sacramento hitch, hardhead, Sacramento pikeminnow, Pacific lamprey, Chinook salmon, Central California roach, Central Coast coho salmon
Mechoopda	Hardhead, Sacramento pikeminnow, Pacific lamprey, Chinook salmon, Central California roach, Sacramento perch, Sacramento tule perch, Sacramento hitch, riffle sculpin, Lahontan redside, Lahontan speckled dace, mountain sucker
Fort Bidwell Paiute	Pacific lamprey, Northern (Pit) roach,
Clear Lake Pomo	Sacramento perch, Sacramento hitch, hardhead, Sacramento pikeminnow, Sacramento tule perch, Pacific lamprey, Chinook salmon, Central California roach, Central Coast coho salmon, coastal cutthroat trout
Kashia Pomo	Pacific lamprey, coastal cutthroat trout, Central Coast coho salmon, Sacramento pikeminnow, hardhead

Traditional Pattern of Fish Use

Traditional fish use among tribes varies geographically, based on a combination of local fish availability and trade with other tribes. We found that tribes used a wide range of aquatic species and organism types (Table 3). Salmon was reported as traditionally-used by all tribes except Timbisha Shoshone (Table 3). There was a tendency for the number of types of aquatic organism to increase based on the number of people interviewed (Figure 2), suggesting that it would be useful in the future to interview at least 20 to 30 people per tribe about traditionally-used organisms.

Table 3. Aquatic species and species groups historically used by tribe-members interviewed.

Tribe	Aquatic spp. (#)	Aquatic species (types)
Me-Wuk (1)	5	Striped bass, catfish, clams, mussels, salmon
Nomlacki (12)	20	Catfish, sucker, pike, salmon, steelhead, Sacramento pike minnow, hitch, surf-fish, black bass, trout, perch, carp, bluegill, crayfish, mussels, clams, abalone, seaweed, kelp, tule
Maidu (10)	17	Bluegill, bass, carp, catfish, trout, eel, salmon, perch, rainbow trout, pike, sturgeon, steelhead, crayfish, clams, mussels, tule, seaweed
Paiute (35)	17	Tui chub, speckled dace, sucker, pupfish, rainbow trout, salmon, catfish, Lahontan cutthroat, brook trout, brown trout, perch, brine fly larvae, freshwater clams, snails, watercress, tule
Timbisha Shoshone (9)	8	Brook trout, golden trout, rainbow trout, brown trout, carp, bass, catfish, pupfish
Mojave (4)	14	Trout, striped bass, catfish, humpback catfish, carp, bullhead, steelhead, rainbow trout, bluegill, sturgeon, black bass, bonytail chub, minnows, crayfish
Washoe (2)	3	Trout, salmon, catfish
Mono (13)	16	Rainbow trout, brown trout, salmon, steelhead, black bass, perch, sucker, bluegill, eel, carp, minnows, crayfish, mussels, clams, water cress, cattails
Chemehuevi (24)	15	Black bass, catfish, striped bass, bonytail chub, razorback sucker, humpback chub, bluegill, red-ear sunfish, Colorado humpback chub, Sacramento pike minnow, trout, carp, crappie, crayfish, clams
Pit River (13)	17	Salmon, trout, sucker, red-band trout, steelhead, catfish, sturgeon, eel, black bass, bluegill, perch, crab, crayfish, mussels, clams, water cress, water lily
Wiyot (1)	2	Salmon, sturgeon
Wailaki (2)	6	Salmon, trout, surf fish, crab, mussel, seaweed
Pomo (56)	27	Catfish, carp, bluegill, crappie, blackfish, perch, sucker, cod, shark, tuna, surf fish, salmon, trout, cabezon, rockfish, bullhead, crab, crayfish, barnacles, mussels, abalone, snails, sea urchins, sea anemone, kelp, seaweed, tule

Pomo/Wailaki (5)	16	Catfish, surf fish, salmon, blackfish, night fish, cod, abalone, hitch, bass, carp, bluegill, perch, eel, crab, mussels, seaweed
Chumash (7)	30	Salmon, trout, black bass, catfish, rockfish, steelhead, swordfish, sailfish, shark, sardine, tuna, halibut, perch, sea bass, surf-fish, mackerel, smelt, eel, crayfish, lobster/crab, abalone, snails, oyster, mussels, clams, urchin, cattails, seaweed, kelp

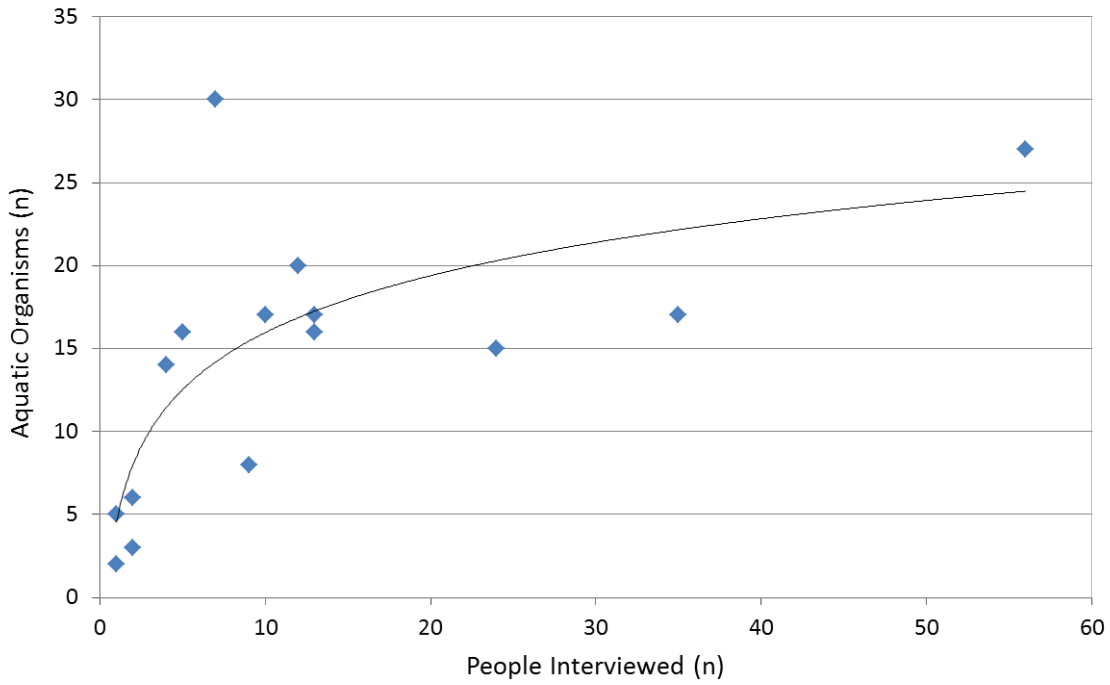

Figure 2. Comparison of number of aquatic organisms reported used by a tribe and the number of people interviewed. The log curve fit better than a linear regression (based on R).

The patterns of traditional fish use by tribes in different regions varied considerably (Table 4). Fish species used in certain regions were not used in others, most likely because of lack of availability. For commonly-used species and species groups (e.g., trout and black bass), the proportions varied among regions. The overall effect was that patterns varied among tribes and among regions.

Table 4. Fish species and groups historically used by tribe-members within each Region. Black bass includes both largemouth and smallmouth bass.

	Water Board Region				
Species	**Central Coast**	**Central Valley**	**Lahontan**	**North Coast**	**Total**
Black bass	11.1	8.3	6.7	7.9	6.4
Black crappie	0.0	3.1	0.5	0.0	1.9
Blackfish	0.0	0.3	0.0	0.0	0.2
Bluegill	0.0	6.7	4.6	1.6	5.4
Brook trout	0.0	0.3	3.1	0.0	1.1
Brown trout	0.0	0.6	10.3	0.0	3.5
Bullhead	0.0	0.3	0.0	6.4	0.8
Carp	0.0	5.3	6.2	1.6	5.1
Catfish	11.1	16.1	15.9	9.5	15.3
Chi/Hitch	0.0	8.0	0.0	6.4	5.3
Chub	0.0	0.0	4.1	0.0	1.3
Cutthroat trout	0.0	0.0	4.1	0.0	1.3
Golden trout	0.0	0.0	3.1	0.0	1.0
Lahontan dace	0.0	0.0	0.5	0.0	0.2
Minnow	0.0	0.3	0.5	0.0	0.3
Native trout	0.0	0.6	0.0	0.0	0.3
Perch	0.0	9.1	0.5	3.2	5.7
Pike	0.0	1.9	0.0	0.0	1.1
Pupfish	0.0	0.0	5.1	0.0	1.6
Quiee	0.0	0.0	0.5	0.0	0.2
Rainbow trout	0.0	1.7	11.8	0.0	4.6
Salmon	33.3	12.7	4.1	31.8	12.3
Shad	0.0	0.3	0.0	0.0	0.2
Shapal	0.0	0.3	0.0	0.0	0.2
Speckled dace	0.0	0.0	1.5	0.0	0.5
Sacramento pike minnow	0.0	0.3	2.1	0.0	0.8
Steelhead	11.1	4.2	0.5	12.7	4.0
Sturgeon	0.0	2.2	0.5	3.2	1.8
Sucker	0.0	6.7	4.1	0.0	5.1
Trout	33.3	11.1	9.7	15.9	11.5

Traditional Rates of Fish Use

Most respondents to traditional-practices surveying (64%) reported eating fish every day, or more than once a day when they were young (Figure 4). About 90% of respondents ate fish more frequently than once per week.

Rates of fish consumption (of any fish species) were calculated for each respondent to the traditional survey (rate = meal size X frequency). For an average meal size of 7.9 oz, 95th % rates were up to 222.9 g/day for Maidu, Paiute, Pomo, Wailaki, and Yurok tribe members. For a 95th % meal size of 17.5 oz, rates were up to 496.1 g/day for Maidu, Paiute, Pomo, Wailaki, and Yurok tribe members.

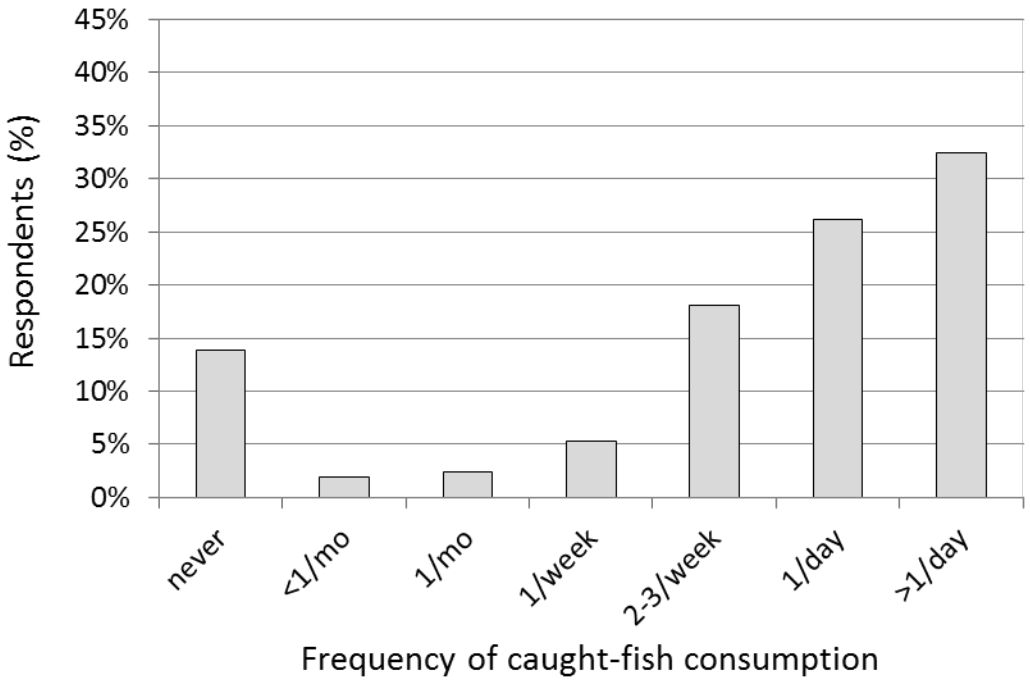

Figure 4. **Traditional frequencies of fish consumption.**

The vast majority of respondents reported that fishing and eating fish was culturally and traditionally important to tribes and an important part of tribe members' diet (Figure 5). Conversely, the majority reported that these traditional practices were not maintained now.

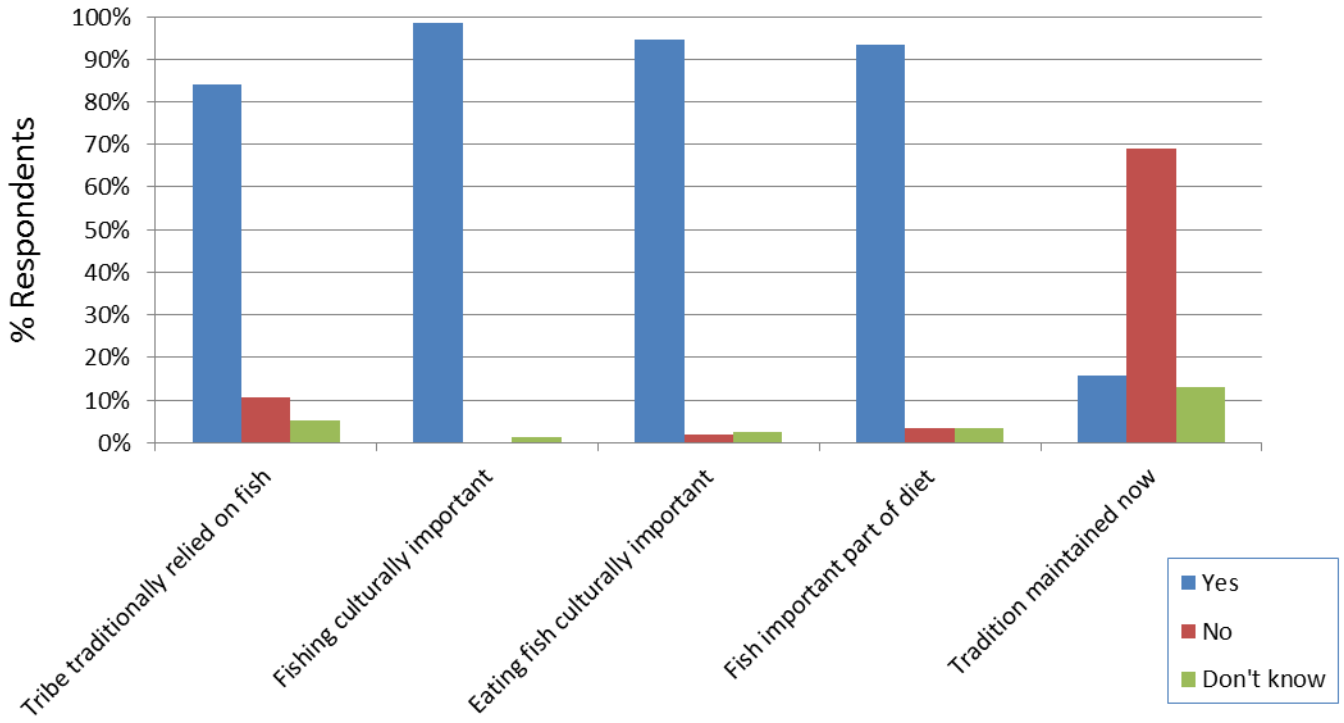

Figure 5. Fish use traditions and maintenance of traditions today.

Contemporary Places for Catching Fish

Where there were sufficient respondents, watersheds were identified from which tribe members had obtained fish in the last 30 days (Figure 6). In most cases, fished areas were adjacent to the tribes' Rancherias or Reservations. Most tribes had received salmon from the lower Klamath River watershed and many had caught fish from the ocean and coastal areas.

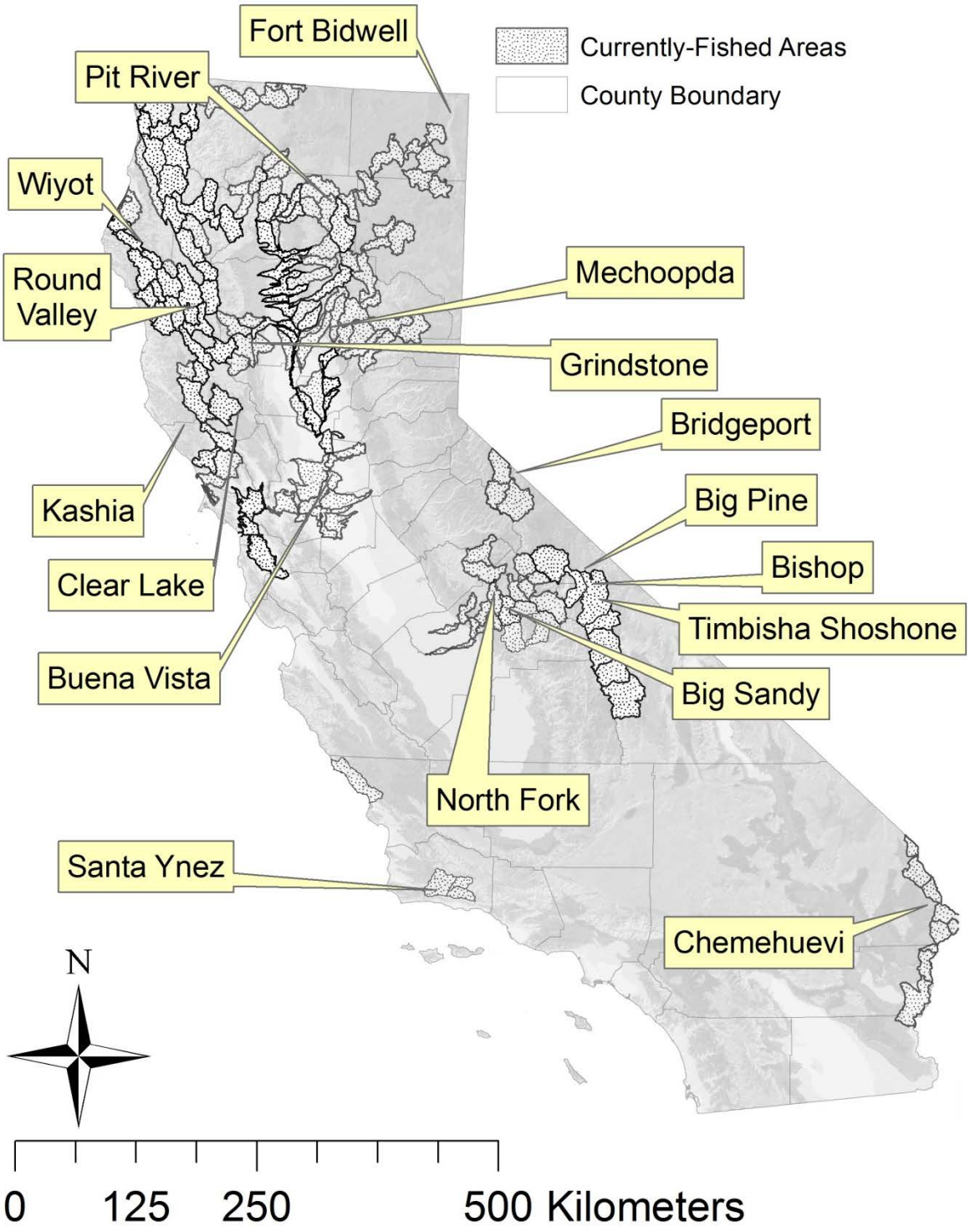

Figure 6. Currently-fished watersheds (hydrologic unit code HUC-10). Areas with darker color outlines represent areas where fishing areas of more than one tribe overlapped.

As was the case with the use of different types of aquatic organism, the number of places reported as being sources of fish increased based on the number of people interviewed (Figure 7), suggesting that it would be useful in the future to interview at least 30 people per tribe about places fished.

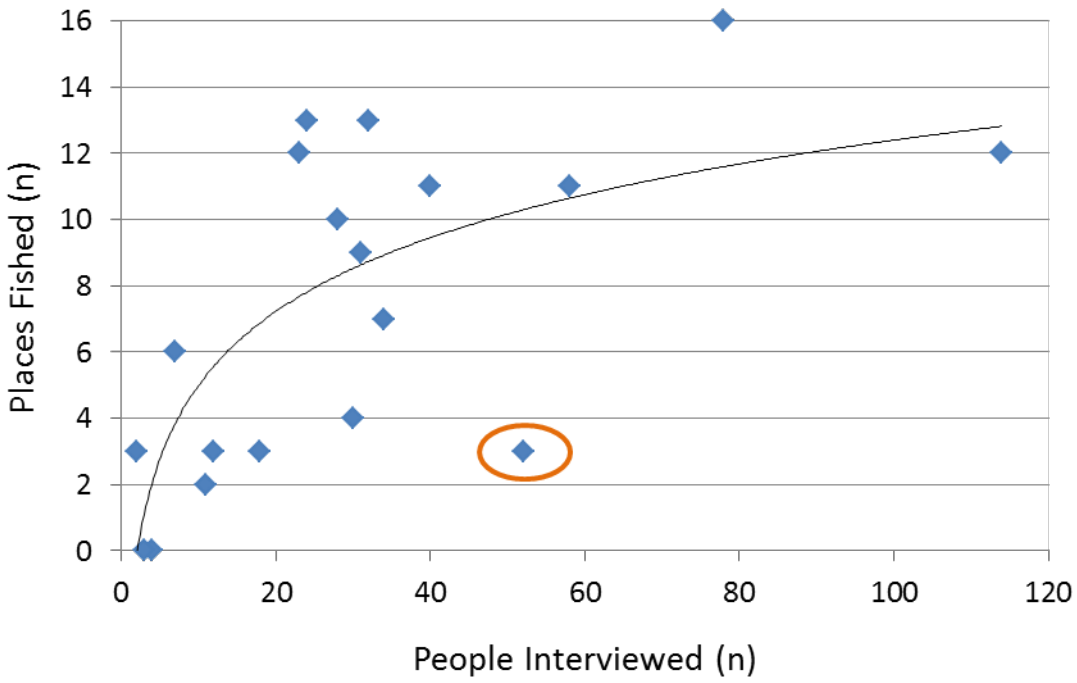

Figure 7. Relationship between # of people interviewed and number of places from which fish was caught and eaten. The log curve fit better than a linear regression (based on R). The circled point represents a desert tribe where 3 large places were cited as sources of fish.

Contemporary Pattern of Fish Use

Contemporary fish use among tribes varies geographically, based upon local native and non-native fish availability. We found that tribes used a wide range of aquatic species and organism types (Table 5). Salmon was reported as currently-used by all tribes and for most tribes was among the top 3 fish species/groups used (Table 5). For most tribes, current fish use was similar to historical use by the same tribe, where similarity was indicated by dividing the number of fish that are currently used that were used historically, divided by the total number historically used. As was the case with traditional use, there was a tendency for the number of types of

aquatic organism to increase based on the number of people interviewed (Figure 8), suggesting that it would be useful in the future to interview at least 30 people per tribe about currently-used organisms.

Table 5. Aquatic species and species groups used by each tribe interviewed. The number of people from each tribe is indicated in parentheses following the tribe name. Similarity was calculated as the number of currently-fished species/groups divided by the number traditionally-fished (underlined, cf. Table 3).

Tribe/Location	Aquatic species /species groups	Similarity (%)
Me-Wuk (37)	Salmon, trout, sturgeon, catfish, striped bass, bivalves, lobster/crab, crayfish, halibut, abalone, carp, sunfish/bluegill, perch, largemouth bass, snapper, cod, rockfish, lamprey/ eel, crappie, smelt, shrimp, squid, steelhead, American shad	100
Nomlacki (31)	Catfish, salmon, trout, abalone, lobster/crab, seaweed, bivalves, striped bass, largemouth bass, shrimp, sunfish/bluegill, carp, surf-fish, perch, sturgeon, kelp, Sacramento pikeminnow, lamprey/ eel, shark, sucker, crappie, hitch, steelhead, halibut, squid	80
Mono (6)	Salmon, trout, striped bass, largemouth bass, catfish, bivalves, smallmouth bass, sunfish/bluegill, sucker, lobster/crab, watercress	47
Maidu (32)	Salmon, trout, catfish, lobster/crab, largemouth bass, striped bass, crayfish, abalone, shrimp, bivalves, seaweed, sunfish/bluegill, sturgeon, carp, halibut, cod, tuna, perch, lamprey/ eel, rockfish, Sacramento pikeminnow, crappie, surf-fish, smallmouth bass, hitch, snapper, lingcod, tilapia, seabass, shark	47
Paiute (Bishop, 17)	Trout, salmon, catfish, crayfish, bivalves, largemouth bass, water cress, sunfish/bluegill, lobster/crab, brine fly larvae, carp, tule, striped bass, codfish, abalone, tuna, rockfish, perch, frog, sturgeon, lingcod, tilapia, haddock, algae, cattails	50
Paiute (Big Pine, 24)	Salmon, trout, crayfish, catfish, lobster/crab, bivalves, shrimp, largemouth bass, carp, sunfish/bluegill, striped bass, triggerfish, swordfish, mahi mahi,	29
Paiute (Bridgeport, 18)	Salmon, trout, catfish, crayfish, striped bass, largemouth bass, sunfish/bluegill, cui cui, tui chub, bivalves, sturgeon, smallmouth bass, perch, carp, pupfish, mountain whitefish, sucker, lobster/crab, abalone	57
Northern Paiute (Fort Bidwell, 11)	Salmon, trout, catfish, crayfish, lobster/crab, bivalves, abalone, largemouth bass, sturgeon, shrimp, cutthroat trout, striped bass, walleye, snapper, squid, scallop	36
Timbisha	Trout, catfish, salmon, crayfish, largemouth bass, lobster/crab, bivalves,	80

Shoshone (14)	sunfish/bluegill, striped bass, carp, watercress, shrimp, tuna, halibut, squid, shark, perch, crappie, rooster fish, cod, abalone, brine shrimp larvae, snail	
Washoe (6)	Salmon, trout, catfish, smelt, abalone, striped bass, largemouth bass, smallmouth bass, perch, sunfish/bluegill, sturgeon, steelhead, bivalves, crayfish	100
Chemehuevi (46)	Striped bass, catfish, largemouth bass, salmon, trout, sunfish/bluegill, crayfish, bivalves, lobster/crab, carp, abalone, tuna, smallmouth bass, sturgeon, shark, swordfish, tilapia, perch, halibut, sea bass, cod, orange roughy, squid, seaweed	60
Mojave (5)	Catfish, trout, striped bass, largemouth bass, salmon, crayfish, smallmouth bass, sunfish/bluegill, sturgeon, carp, steelhead, tuna, tilapia, bivalves, lobster/crab	64
Pit River (27)	Salmon, trout, catfish, bivalves, lobster/crab, sturgeon, largemouth bass, crayfish, abalone, striped bass, squid, seaweed, sunfish/bluegill, sucker, lamprey/ eel, smallmouth bass, shrimp, carp, tule, watercress, perch, cabezon, cod, split-tail, Sacramento pike minnow, halibut, lingcod, snapper, tuna, surf-fish, rockfish	88
Wiyot (32)	Salmon, lobster/crab, trout, bivalves, sturgeon, lamprey/eel, abalone, surf perch, smelt, cod, catfish, rockfish, largemouth bass, halibut, sunfish/bluegill, steelhead, striped bass, night fish, perch, cabezon, snapper, crayfish, carp, tuna, sand dabs,	100
Hoopa (Blue Lake/Bear River 4)	Salmon, sturgeon, trout, steelhead, lamprey/eel, lobster/crab, bivalves, abalone, crayfish	ND
Karuk (Bear River, 3)	Salmon, sturgeon, trout, lamprey/eel, snapper, ling-cod, halibut, lobster/crab, bivalves, abalone, crayfish, seaweed, catfish, striped bass, largemouth bass, perch, steelhead, smelt, rockfish, surf fish, cod, tuna, flounder, ray, squid, snail	ND
Pomo (Clear Lake, 164)	Salmon, catfish, trout, abalone, lobster/crab, bivalves, largemouth bass, hitch, crayfish, striped bass, carp, seaweed, sturgeon, perch, surf-fish, smelt, crappie, lamprey/eel, halibut, shrimp, squid, tilapia, tuna, snapper, kelp, snail, blackfish, sea slug, rockfish, American shad	63
Pomo (Kashia, 23)	Salmon, abalone, bivalves, trout, seaweed, lobster/crab, striped bass, largemouth bass, surf-fish, crayfish, sunfish/bluegill, catfish, bullhead, snail, tilapia, carp, sturgeon, split tail, perch, cabezon, kelp, rock cod, rock fish	63
Pomo-Wailaki (12)	Split-tail, carp, lobster/crab, seaweed, striped bass, salmon, kelp, largemouth bass, smallmouth bass, trout, Sacramento pike minnow, abalone, cod, catfish, sunfish/bluegill, blackfish, bivalves, crayfish, smelt, sea anemone	69
Wailaki (16)	Salmon, trout, catfish, abalone, lobster/crab, striped bass, smelt, carp, crayfish, largemouth bass, split-tail, sturgeon, bivalves, seaweed, sunfish/bluegill, steelhead, cabezon, cod, halibut, shrimp, kelp	83
Round Valley (35)	Salmon, trout, abalone, smelt, striped bass, catfish, lobster/crab, steelhead, sturgeon, bivalves, crayfish, largemouth bass, sunfish/bluegill,	ND

	lamprey/eel, cod, snapper, carp, seaweed, tuna, hitch, nightfish, rockfish, surf-fish, crappie, halibut, squid	
Yurok (15)	Salmon, sturgeon, trout, lobster/crab, cod, steelhead, lamprey/eel, bivalves, surf-fish, abalone, halibut, striped bass, largemouth bass, catfish, sunfish/bluegill, rockfish, crayfish, perch, carp, smelt, tuna, crappie, Sacramento pike minnow, nightfish, walleye, snapper, seaweed	ND
Chumash (12)	Trout, salmon, catfish, crayfish, largemouth bass, lobster/crab, halibut, bivalves, sunfish/bluegill, sturgeon, striped bass, abalone, shrimp, snapper, perch, carp, smelt, rockfish, cabezon, tuna, flounder, lingcod, snail	71

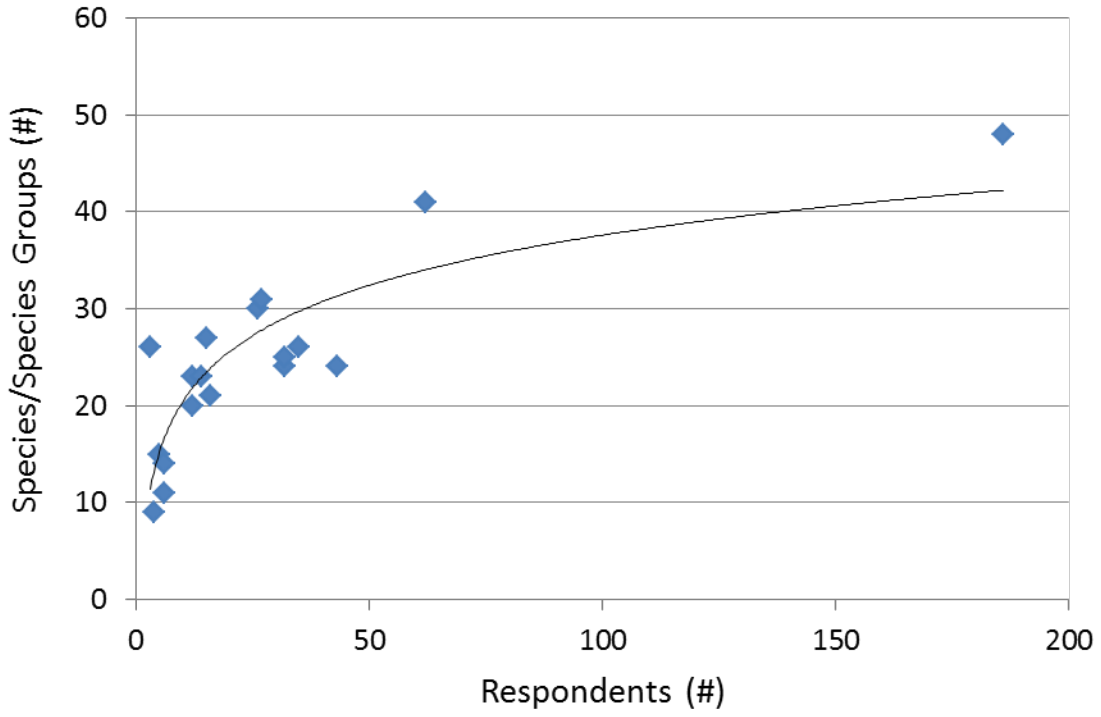

Figure 8. Relationship between # of people interviewed and number of aquatic organisms species and species groups caught and eaten. The log curve fit better than a linear regression (based on R).

Tribe and Region Standard Rates of Fish Consumption

Where there was sufficient information, the contemporary frequency of fish use was compared to the frequency of traditional fish use. For all tribes as a group, there was a significant difference ($P<0.001$) between contemporary and traditional frequencies of using fish. This is

reflected in the distributions of frequencies (Figure 9), with contemporary frequencies of eating fish skewed toward low frequencies (never to once per month) and traditional frequencies skewed toward high frequencies (once per day).

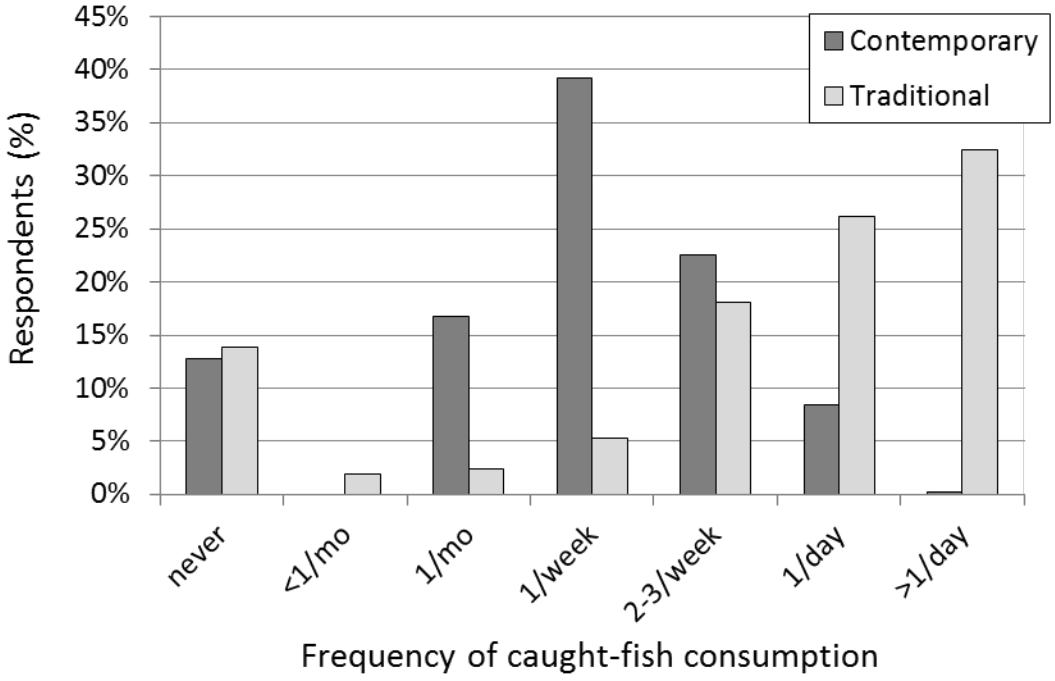

Figure 9. Comparison of contemporary and traditional frequencies of fish use

Tribe-specific rates of fish use were calculated for individual species, groups of species, for all caught finfish, and for all aquatic organism use. Of particular interest for state water policy formulation is the rate of use of caught-fish (all finfish retrieved from state waters). The 95th percentile rate of contemporary caught-fish consumption for all tribes as a group was 141.8 g/day (Table 6). This rate was significantly different from the traditional rate, which was estimated as frequency per individual times average portion size from contemporary consumption. The estimated 95th percentile traditional consumption rate was at least 222.9 g/day (one 7.88 oz average portion size per day) for all tribes interviewed.

Table 6. Contemporary rates of fish and other aquatic organism consumption for all interviewed tribe members.

Component	Min (g/day)	Max (g/day)	95th % (g/day)	99th % (g/day)
Salmon	0	382.7	72.6	179.9
All caught fish	0	623.7	141.8	240.2
Bought fish	0	255.1	60.8	152.1

Other aquatic organisms	0	402.6	27.7	96.8
Total fish	0	623.7	181.9	333.2
Total aquatic organisms	0	708.7	200.0	400.0

Importance of Salmon

Salmon was reported as being currently consumed by almost every tribe member interviewed, regardless of tribe and was the most common single type of fish consumed by tribes individually and collectively (Tables 6 & 7). North Coast tribes generally consumed more salmon and a larger proportion of caught fish as salmon than interior tribes (Central Valley, mountains, and desert). This pattern held when tribes' fish uses were grouped by Water Board Region: Lahontan, Central Valley, North Coast, and Central Coast (Table 8).

Table 7. Proportion of consumed caught-fish composed of salmon for each tribe.

Tribe Name (n)	Salmon (95th % g/day)	Caught fish (95th % g/day)	Total fish (95th % g/day)	% Caught = Salmon
Me-Wuk (32)	22.4	57.2	99.7	39
Maidu (26)	69.1	133.6	183	52
Pit River (17)	196.2	240.4	277.3	82
Paiute (52)	28.3	59.5	81.5	48
Northern Paiute (11)	37.6	63.1	99.9	60
Timbisha Shoshone (14)	39.8	104	257.8	38
Mono (6)	29.8	42.2	52.1	70
Chemehuevi (43)	0	110.3	178.6	0
Pomo (183)	28.3	59.2	101.8	48
Pomo-Wailaki (12)	28.9	34.8	59.2	83
Wailaki (16)	19.8	81.5	85.8	24
Round Valley Tribes (35)	57.8	70.3	81.6	74
Wiyot (30)	132.5	139.1	144.2	95
Yurok (15)	115.1	170.2	170.2	68
Chumash (12)	8.2	29.8	55.4	28
Total	72.6	141.8	181.9	51

Table 8. Proportion of caught fish composed of salmon within each region.

Water Board Region (n)	Salmon (95th % g/day)	Caught fish (95th % g/day), (99th% g/day)	Total fish (95th % g/day) , (99th% g/day)	% Caught = Salmon
Central Valley (288)	42.5	83.1, 203.8	125.1, 264.3	51
Lahontan (135)	20.4	71.9, 126.1	122.6, 206.8	28
North Coast (107)	119.1	162.2, 374.1	180.3, 374.8	74
Central Coast (12)	8.2	29.8, 47.9	55.4, 56.8	27

Barriers to Traditional Fish Use

Tribe members were asked why traditional fishing and fish use practices were not maintained. Responses ranged widely, but centered around two main themes – aquatic ecosystem conditions and being able to fish. Degraded stream/water conditions and the loss of fish populations were the most commonly cited barriers to traditional fish use, followed by regulatory and access restrictions (Table 9).

Table 9. Reasons traditional and contemporary fish use practices were not maintained for all tribes as a group (traditional, n=152 respondents; contemporary, n=394 respondents).

Reasons Traditions Not Maintained	% Traditional Respondents	% Contemporary Respondents
Aquatic ecosystem condition		
Fish declines	45%	24%
Concerns about water/fish quality	42%	11%
Streams dried up	37%	16%
Fish locally extinct	16%	ND
Land/water development	10%	ND
Ability to fish		
Regulation/limits/restrictions	18%	18%

Access to traditional fishing areas	15%	15%
License not affordable	10%	5%
Racism/hostility toward tribe members	2%	0.3%

Relationship Between Fish Use and Income

Like all populations of people, there is variation in income within California tribes. The largest income class among respondents (36% of respondents) had an individual annual income in the range $18,000 to $50,000. This is similar to the distribution of income in 2012 among people in the US, where 25% of people interviewed by the US Census Bureau reported an individual annual income between $17,500 and $50,000 (Source: U.S. Census Bureau, Current Population Survey, 2013 Annual Social and Economic Supplement. http://www.census.gov/hhes/www/income/data/incpovhlth/2012/dtables.html, accessed 7/18/2014). Amounts of salmon, caught fish, bought fish, and total fish varied among income classes. For most income classes, caught fish dominated the fish diet, while for the >$100,000 income class, caught and bought fish were eaten in similar proportions. In the >$100,000 income class, the vast majority of fish consumed was salmon, whereas for other income classes, was closer to half of total caught fish consumed. One explanation for the zig-zag pattern in consumption across income classes is that there may be multiple patterns occurring simultaneously. One possibility is that very low income people have less ability to afford fishing equipment, transportation to fishing sites, and time to go fishing, resulting in less fishing. There may be a threshold when more fish can be acquired through fishing (i.e., >$18,000) and higher thresholds where fish can be bought more readily, possibly replacing caught fish. Finally, greater income may also affect peoples' ability to travel to catch salmon, which are only available in a few places in the state.

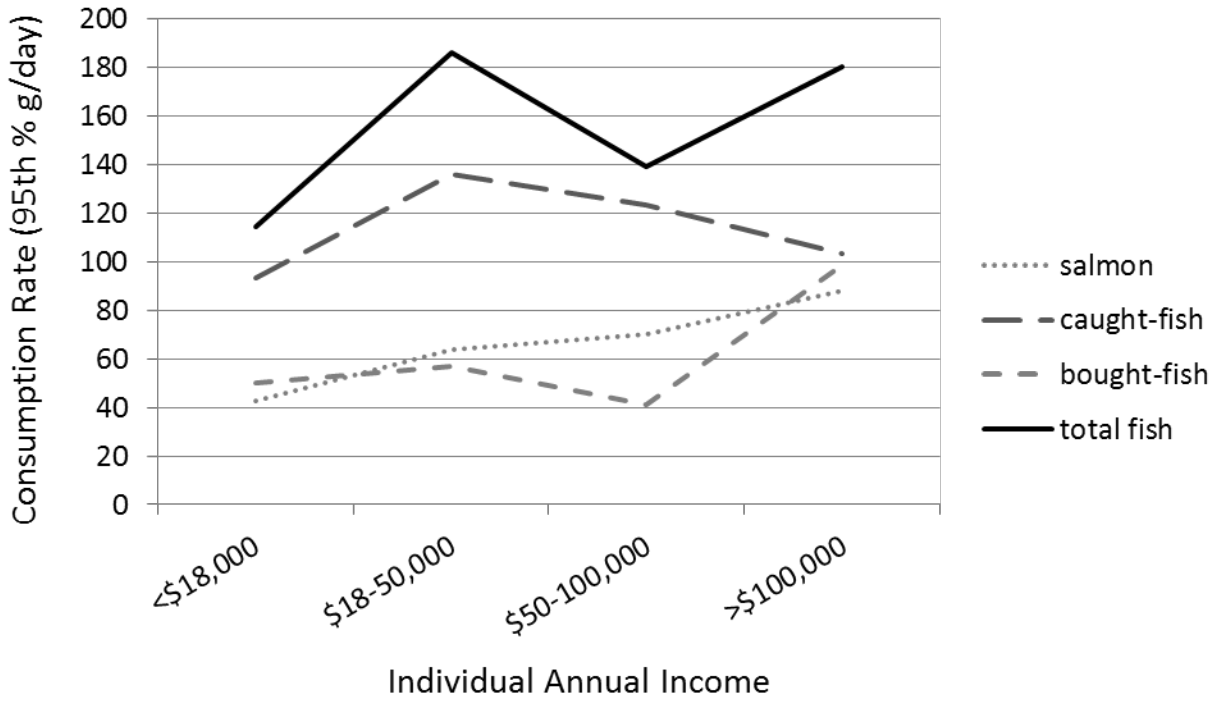

Figure 9. Comparison of patterns of fish-use and individual annual income.

Maintenance of Traditional Practices

Three standards were used for maintenance of traditional fish use by tribes: 1) maintenance of fishing locations, 2) maintenance of fish species range, and 3) maintenance of fish consumption. Comparison of currently-fished areas with traditionally-fished areas revealed that traditional fishing is maintained in most places (Figure 9). Although access was described as a problem (Table 8), tribe members reported that they were able to fish most historically-fished waterways. Similarly, although certain fish species and species groups may have gone locally-extinct or endangered, most tribes reported currently using most species/groups that they traditionally-used (Table 5).

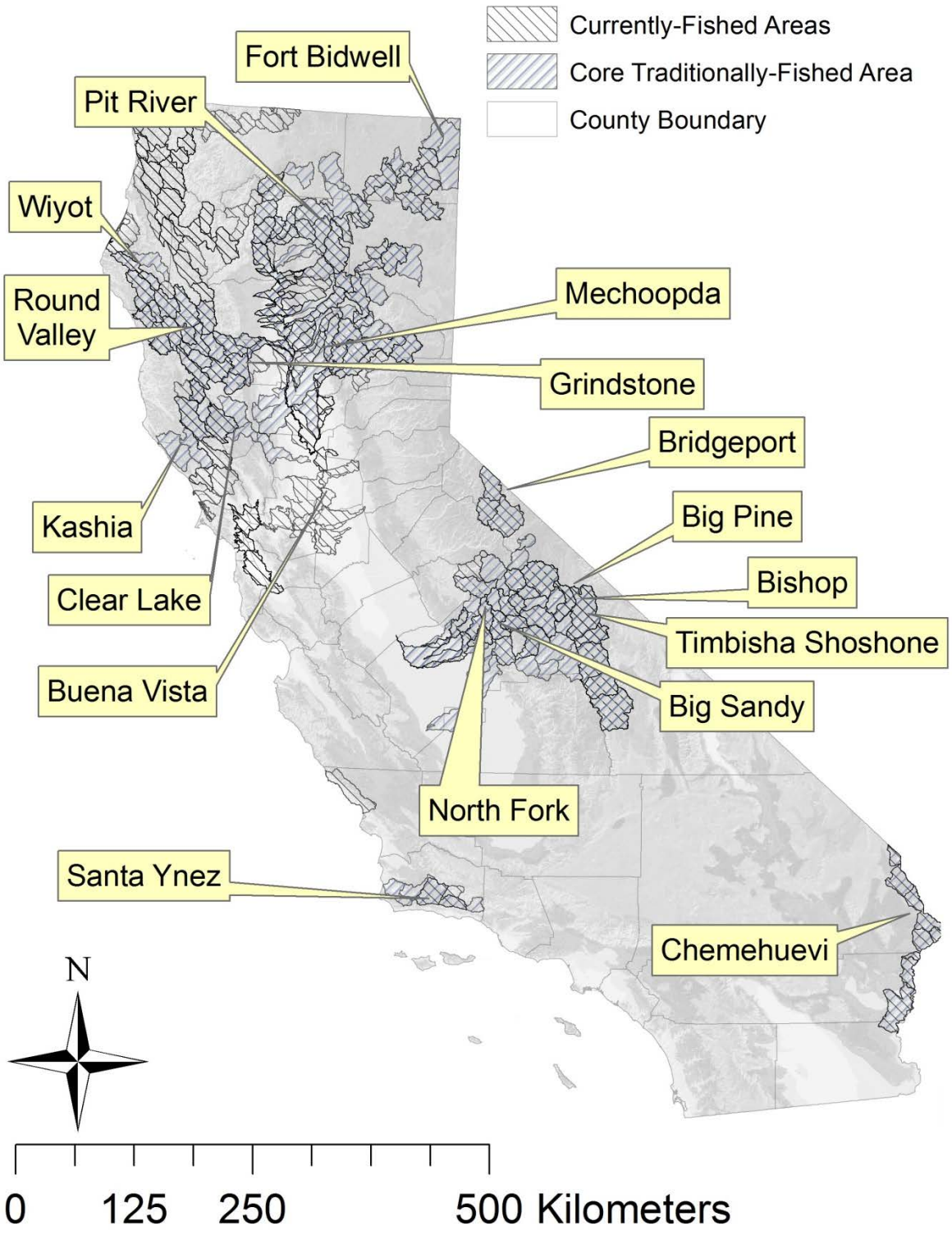

Figure 9. Comparison of currently-fished and traditionally-fished areas (HUC-10 watersheds). Doubly-hatched ("criss-cross" pattern) watersheds were both historically fished and were recently-fished.

Tribe Staff Perspective

Tribe staff were contacted by email and asked various questions about traditional and contemporary fish use. In general their responses were similar to the responses of individual tribe members (see Appendix 4 for more detail). The vast majority of tribe staff responses were consistent with these statements and ideas: fish use was and still is important to tribes for cultural, subsistence, and other reasons; tribe members historically ate fish once per day or more often; aquatic ecosystem conditions and ability to fish (e.g., regulations and access) are barriers to fish use; and tribe members do not eat as much fish as they used to. Tribe staff also expressed the opinion that future projects of this type that rely on interviews of tribe members be conducted and/or led by tribes themselves.

Discussion and Conclusion

Members of California Tribes use fish in similar patterns compared to traditional and historical uses, but sometimes at suppressed rates. The rates of fish consumptions for tribe members are among the highest recorded in California and for many regions are likely to be the highest and therefore the most policy-relevant. Although there are many exogenous barriers to fish use, such as reduced flows from excessive water withdrawals and water quality issues, tribes still practice the main patterns of fish use in terms of broad use of aquatic organisms and wide geographic spread of waterways used. Protection of tribes' use of fish will require target fish tissue concentrations of contaminants to be near background, recovery of fish populations through recovery of aquatic systems/flows, and recognition of accessibility issues that tribes face.

Widespread and Broad Tribe Use of Aquatic Ecosystems and Organisms

The watershed area fished by individual tribes increased with the number of tribe members interviewed and for all regions represented a significant proportion of the total watershed area. Based on the area included after interviewing members of only 10 tribes about historically fished areas and members of 24 tribes about currently fished areas, it is likely that if all tribes were interviewed, the majority of California's waterways and watersheds could be considered traditionally and culturally used by tribes.

Tribe members reported traditional and contemporary use 26 freshwater/anadromous fin-fish species, 23 marine fin-fish species, and 18 other invertebrate, and plant species and groups of species. The more people interviewed per tribe, the longer the list of organisms reported as being used, suggesting that the lists are incomplete. Even with potentially incomplete reporting, about half of the fin-fish reported as being used were fish that had been found during archaeological investigations of middens. The other half of fish reported used was primarily composed of non-native fish that had been introduced since the mid-1800s (e.g., catfish in 1874; Dill and Cordone, 1997).

Importance of Salmon Within and Among Regions

Yoshiyama (1999) provides one of the most exhaustive reviews of the use of salmon by California tribes, particularly in the Central Valley. By his estimate, based on citations, there may have been ~160,000 indigenous people living in the Central Valley and foothills (Cook, 1978; in Yoshiyama, 1999), equaling a density of ~3 people per square mile. Hewes (1947, 1978; in Yoshiyama, 1999) estimated that the per capita consumption rate of salmon among tribes was up to 1 pound (453 g) per day. This rate was likely just part of overall fish consumption, as suggested by archeological investigation suggesting tribes' use of a broad range of fish species (e.g., Gobalet et al., 2004).

Within the primary salmon-bearing areas of the Klamath, Sacramento and San Joaquin Rivers and tributaries, access to salmon runs was the object of some conflict, negotiated fishing rights, and trade of the resulting fish products (reviewed in Yoshiyama, 1999). Tribes from the desert east of the Sierra Nevada may have traditionally crossed the range to catch salmon in the Spring (Jackson and Spence, 1970; in Yoshiyama, 1999), suggesting that salmon was important historically to California desert tribes in the same way that tribes report its importance today.

Because so many salmon runs are listed as threatened or endangered or at risk of becoming so, it is challenging for most native people to practice using what may have been the most important fish to them collectively. The reasons that salmon populations are reduced in California rivers varies among regions, ranging from water quality issues (all rivers), to physical barriers (dams, most rivers), to insufficient flows due to withdrawal for agricultural and urban uses (most rivers). The cause of salmon declines is one of the most well-studied of the ecological impacts of Euro-American settlement of the West. Although the reasons vary for salmon declines, the regulatory (for agencies) and statutory (for the legislature) authority exists to solve most of the problems salmon, and by extension tribes, face for recovery to healthy populations that could support restored traditional use. The current problem with salmon

recovery is usually not lack of knowledge, but rather lack of political will to act to protect salmon and their traditional use.

Tribe and Region Standard Rates of Fish Consumption

The USEPA (USEPA, 2000), San Francisco Bay Regional Water Quality Control Board (SFBWQCB, 2006), and Central Valley Water Quality Control Board (CVRWQCB, 2010) have all supported the use of the 95th or 99th percentile rates of fish consumption to develop water quality criteria and fish tissue criteria that are protective of people catching and eating fish from local waterbodies. These recommendations and actual use of these standards were made without conditioning based on the impact these criteria might have on those responsible for implementing or meeting these criteria, which is consistent with the use of the Clean Water Act as protective of beneficial uses and users without condition.

The standard rates are reported here as 95th percentile rates for individual tribes and for regions. The tribe specific rates presented here are useful in setting water quality criteria and fish tissue criteria at both the local waterbody scale and the region scale. Because tribes reported the waterbodies/HUC-10 watersheds that they had traditionally fished and the waterbodies/HUC-10 watersheds from which they had derived fish in the last 30 days, these criteria can be used at the HUC-10 or more general scale. In order to develop criteria useful at the regional scale, tribes' collective use of fish can be used for all waterbodies in a region, unless absence of use by tribes can be demonstrated.

Suppression, Maintenance and Recovery of Traditional Fish Use

Compared to estimates from archaeological investigations and recall of elder tribe members, use of fish has been suppressed compared to historical rates. The daily use of fish reported by elders for only a couple of generations ago suggests that the suppression has been most severe in recent years. Elder and younger tribe members observed that fish availability, flows, and water quality may all be barriers to catching and eating fish at historical rates. The preponderance of evidence points toward regulated and restorable environmental conditions as being the primary barriers to recovery of traditional uses by tribes. For most tribes, there are individual and groups of tribe members who consume fish at rates similar to historical rates of fish use. This maintenance of traditional fish use points to the possibility that fish use could be

recovered for the majority of tribe members, as has been described for Columbia River tribes (Harper and Harris, 2008).

Recoverable rates of fish use should be established based on tribe or regional standards, based on quantification of "traditional, cultural and subsistence use" of fish based on tribe members' reporting of historical activities. This has been done here for several tribes, but could be expanded to include more tribes who potentially made greater use of fish than those who were interviewed.

Barriers to Traditional and Contemporary Fish Use by California Tribes

Almost half of tribe members interviewed reported declines in fish populations as the primary barrier to maintenance or recovery of traditional rates of fish use. Approximately a third of tribe members reported water flows and quality as critical issues, which is highly correlated with fish declines. Lower proportions reported logistical problems with fish access, ranging from physical access to traditional fishing locations to state regulations and limits and cost of fishing.

Similar patterns were seen for barriers to contemporary fish use. Approximately ¼ of respondents reported declines in fish populations as the primary barrier to being able to use fish. Fewer, but sizable proportions of respondents reported water flows, water quality, regulations/limits, access to fishing sites, and costs as barriers.

The state policy nexus with these barriers to both traditional and contemporary fish use includes many state regulatory frameworks and permitting systems for water use and discharge of pollutants. If tribal traditional, customary, and subsistence use is regarded as a "beneficial use" under the Clean Water Act, then restoration of the use will require recovery of the flows and water quality that will permit healthy and less-contaminated fish populations to return and be used by tribes.

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Appendix 1. Traditional Fish Use Questionnaire

Survey #	Card #

California Tribes, Traditional Fishing and Fish Use Survey

Date: _____ Interviewer name: _____ Time start: _____:_____ am pm
end: _____:_____ am pm

Location of Interview:
Tribe:

Hello. My name is _____. Because of concerns expressed by California tribes about fish and fishing, I am conducting a survey for the University of California Davis. We want to learn about the fishing practices and uses of fish by people in your tribe. This will help the tribe and the state set water quality standards to protect your ability to safely eat fish. At the same time, we want to protect your privacy, so I will not be asking your name or collecting personal information. This survey will take about 15 minutes and we are giving this gift to people who participate. Do you agree to let me interview you about your tribe's traditional fishing practices and use of fish?

1a. ☐ **Y agree, proceed**
☐ N (do not proceed)

1b. [IF INDIVIDUAL DOES NOT WANT TO BE SURVEYED] Please note any known reason that they declined:

☐ No time
☐ Language barrier
☐ Appeared threatened/uncooperative ☐ Other:_____
☐ Unknown

1c. [IF NO] Record observed gender:

☐ Male ☐ Female

2. Have you ever been interviewed before about fishing or eating fish
☐ Y (fishing __ eating fish ___) Who?
☐ N (proceed)

3. Did your tribe traditionally rely on fish as a source of food in the past?
☐ Y
☐ N
☐ Don't know/refused

4. Were subsistence practices such as fishing protected under treaties signed by the tribe?
☐ Y
☐ N
☐ Don't know/refused

5. What major creeks, rivers, lakes, or other water-bodies were traditionally fished by your tribe (possibly use map as aid)?

6. What kinds of fish did you traditionally catch and eat?
[List fish by common name, clarify and/or use visual aid if uncertain]

_____

_____

_____

7. How much of each kind of fish did you traditionally eat?

_____

_____

_____

_____

_____

1	> one meal a day
2	1 meal per day
3	2-3 meal per week
4	1 meal per week
5	1 meal per month
6	less often than 1/month

8. Was fishing a culturally important activity in the past?
- ☐ Y
- ☐ N
- ☐ Don't know/refused

9. Was eating fish an important part of culture in the past?
- ☐ Y
- ☐ N
- ☐ Don't know/refused

10. Was eating fish an important part of the diet in the past?
- ☐ Y
- ☐ N
- ☐ Don't know/refused

11. Is this tradition maintained now?
- ☐ Y
- ☐ N
- ☐ Don't know/refused

12. If not, why not?

☐ Fish declines ☐ Fish locally extinct ☐ Streams dried up
☐ Concern about water/fish quality ☐ Don't know/refused

☐ Other: _____

Appendix 2. Contemporary Fish Use Questionnaire

Survey #	Card #

California Tribes, Contemporary Fishing and Fish Use Survey

Date: _____ Interviewer name: _____ Time start: _____:_____ am pm
end: _____:_____ am pm

Location of Interview:

Hello. My name is _____. Because of concerns of California Tribes about fish, I am conducting a survey for the University of California Davis. We want to learn about the fishing practices and uses of fish by people in your tribe. This will help the tribe and the state set water quality standards to protect your ability to safely eat fish. At the same time, we want to protect your privacy, so I will not be asking your name or collecting personal information. We are not concerned with licenses or size limits. This survey will take about 15 minutes and we are giving this gift to people who participate. Do you agree to let me interview you about fishing and using fish?

1a. ☐ **Y agree, proceed**
☐ N (do not proceed)

1b. [IF INDIVIDUAL DOES NOT WANT TO BE SURVEYED] Please note any known reason that they declined:

☐ No time
☐ Language barrier
☐ Appeared threatened/uncooperative
☐ Other:_____
☐ Unknown

1c. [IF NO] Record observed gender:

☐ Male ☐ Female

2. Have you ever been interviewed before about fishing or eating fish
☐ Y (fishing __ eating fish ___) Who?
☐ N (proceed)

3. Do you fish? ☐ Yes ☐ No

If interviewed while fishing

4. What are you trying to catch today?_____

4b. Are you going to eat the fish you catch today?

☐ Yes
☐ No
☐ Don't know/Not Sure
☐ Refused

[If yes] Are you going to feed it to your family? ☐ Yes ☐ No

If interviewed in office/home

4c. [IF NO] What do you usually do with the fish you catch?
☐ Eat it myself
☐ Give it to others to eat
☐ Catch and release it
☐ Other: _____
☐ Refused

4d. [IF NO] Do you ever eat fish that you or someone you know catches?

☐ Yes
☐ No [IF NO, SKIP TO **Q7a**]
☐ Don't know/Not Sure [SKIP TO **Q7a**]
☐ Refused [SKIP TO **Q7a**]

5. About how many times did you go fishing in the last 30 days?

_____[ENTER NUMBER] per

☐ week ☐ Don't know
☐ month ☐ Refused
☐ other_____

6a. Do you eat [*NAME OF FISH]* that you or someone you know catches? *Ask about specific fish listed below, as well as any others not named. Fresh, smoked, canned, etc.* *Do this question first down the column, then come back and do fish by fish for b-d.*	**6b. How many times did you eat *[NAME OF FISH]* in the LAST 30 DAYS?** **>once per day possible** *If zero, skip to next row.*	**6c. If check box in 6a and** **6b = 0, ask why have not eaten in last 30 days**	**6d. How much *[NAME OF FISH]* did you eat in one meal?** *SHOW PICTURE OF FISH PIECES. Circle letter and write number of UNCOOKED models per meal.* *Only ask for types eaten in the **last 30 days.*** **A – Small** **C – Medium** **E – Large**	**6e. Where was the *[NAME OF FISH]* caught?** *Only ask for types eaten in the **last 30 days.*** *WRITE RESPONSE AND ENTER CODE* 1= Local river 2= Local reservoirs, ponds, or lakes 3 = Coastline, beach 4= Oceans or seas 5= Other (write response) 6= Location of survey
☐ Catfish			A B C D E (Circle) ____ # of pieces/meal	
☐ Striped Bass			A B C D E (Circle) ____ # of pieces/meal	
☐ Largemouth bass			A B C D E (Circle) ____ # of pieces/meal	
☐ Sunfish/bluegill			A B C D E (Circle) ____ # of pieces/meal	
☐ Salmon			A B C D E (Circle) ____ # of pieces/meal	
☐ Carp			A B C D E (Circle) ____ # of pieces/meal l	
☐ Sturgeon			A B C D E (Circle) ____ # of pieces/meal	
☐ Trout/Rainbow			A B C D E (Circle) ____ # of pieces/meal	
☐ Other_____			A B C D E (Circle) ____ # of pieces/meal	
☐ Other_____			A B C D E (Circle) ____ # of pieces/meal	
☐ Other_____			A B C D E (Circle) ____ # of pieces/meal	
☐ Other_____			A B C D E (Circle) ____ # of pieces/meal	

	Do you eat [*NAME OF SHELLFISH]* that you or someone you know catches?			
☐ Clams/mussels/ oysters			____ # /meal	
☐ Crawdads/crayfish			____ # of crayfish/meal	
☐ Abalone			____# or amount/meal	
☐ Crab			____ # or amount/meal	
☐ Other			____ # or amount/meal	

7a. In the last 30 days, have you eaten fish that came from stores, markets, restaurants, or cafeterias? (examples, tuna, fish sticks)

☐ Yes
☐ No
☐ Don't know/ Not Sure
☐ Refused

[GO TO Q8a]

7b. In the last 30 days, how many times did you eat fish that comes from stores, markets, restaurants, or cafeterias?

[SHOW PICTURES]. Circle letter and write number of pieces per meal]

A B C D E (Circle)

_____ times in last 30 days

____ #of pieces/meal

What kind of fish was it? _____

8. Are you able to eat as much fish now as in the past?
☐ Yes
☐ No
☐ Don't know/ Not Sure
☐ Refused

9. What are the main things that affect how much fish you can catch?

_____

_____

10. Are there times of year when you eat more fish? When is that and what kinds of fish

_____

11. What are the main things that affect how much fish you can eat?

_____

_____

HOUSEHOLD & DEMOGRAPHIC INFORMATION

12. In the past year, have any children under 18 in your household eaten fish that you or someone you know caught?

☐ Yes
☐ No
☐ Don't know/ Not Sure
☐ Refused

13. In the past year, have any women between ages 18 and 49 in your household eaten fish that you or someone you know caught?

☐ Yes
☐ No
☐ Don't know/ Not Sure
☐ Refused

14. In the past year, have any women expecting a child or who have a baby in your household eaten fish that you or someone you know caught?

☐ Yes
☐ No
☐ Don't know/ Not Sure
☐ Refused

15. If you don't mind, could you tell me how best to describe your tribal affiliation and ethnicity:

16. If you don't mind me asking, what is your age: [READ CHOICES. CHECK APPROPRIATE BOX.]
1 ☐ Under 18?
2 ☐ between 18 and 34?
3 ☐ between 35 and 49?
4 ☐ over 49?
5 ☐ Refused

17. What city, town or zip code do you live in? _____

18. [RECORD APPARENT GENDER]
☐ male
☐ female

19. I am going to show you a list with some income levels on it, please pick the category that best describes your annual household income from all sources.

☐ Less than $18,000
☐ $18,000 to less than $50,000
☐ $50,000 to less than $100,000
☐ $100,000 or more
☐ Don't know / Not sure
☐ Refused

Appendix 3. Online Surveying Questionnaire

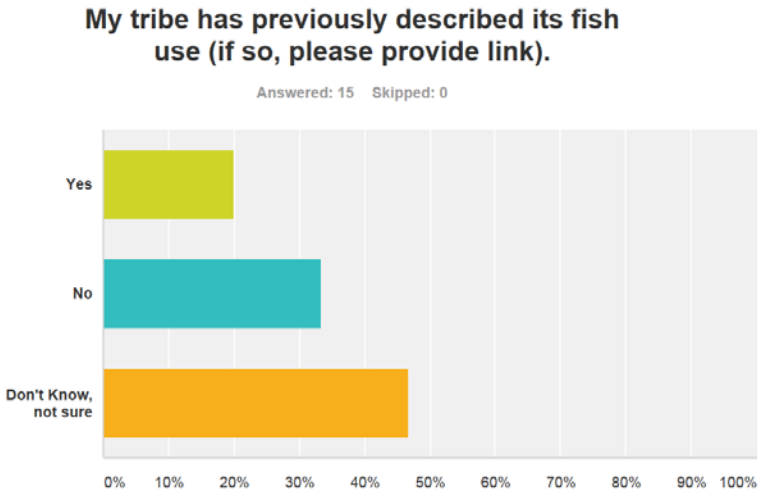
Online Surveying Questionnaire

1. What is your tribe?
2. My tribe has previously described its fish use (if so, please provide link).
3. Would you consider fish important to your tribe for cultural, subsistence, or other reasons?
4. Historically, were fish important to your tribe for cultural, subsistence, or other reasons?
5. What types of fish did your tribe rely on in the past? (Please write in order of importance)
6. What types of fish does your tribe rely on now? (Please write in order of importance)
7. How often did tribe members eat fish in the past?
8. What are the primary impacts or barriers to your tribe's fish use?
9. Do tribe members eat as much fish as they would traditionally?
10. In the future, studies of tribes' fish use should be conducted by...?

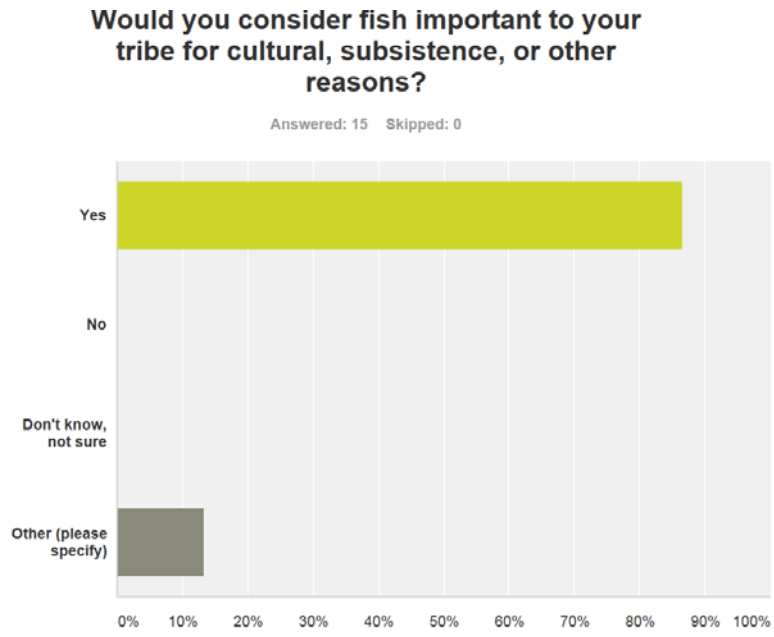
Appendix 4. Tribe Staff Responses to Survey

Question 1. Tribe staff responding: Wilton Rancheria, Karuk, Wintu, Round Valley Tribes, Big Valley Band of Pomo, Noyo River, Bear River Band of Rohnerville Rancheria, North Fork Rancheria of Mono Indians, Pala Band of Mission Indians, Mechoopda Indian Tribe

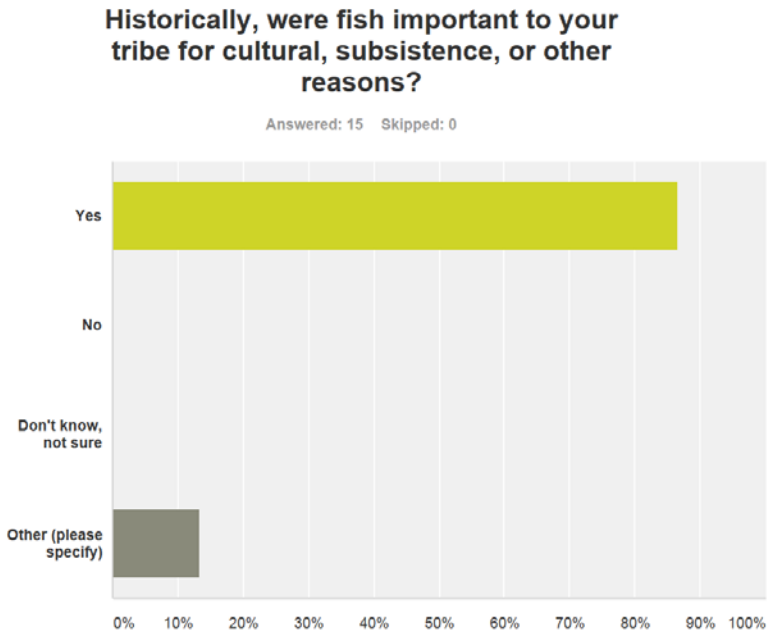
Question 2.



Question 3.



Question 4.

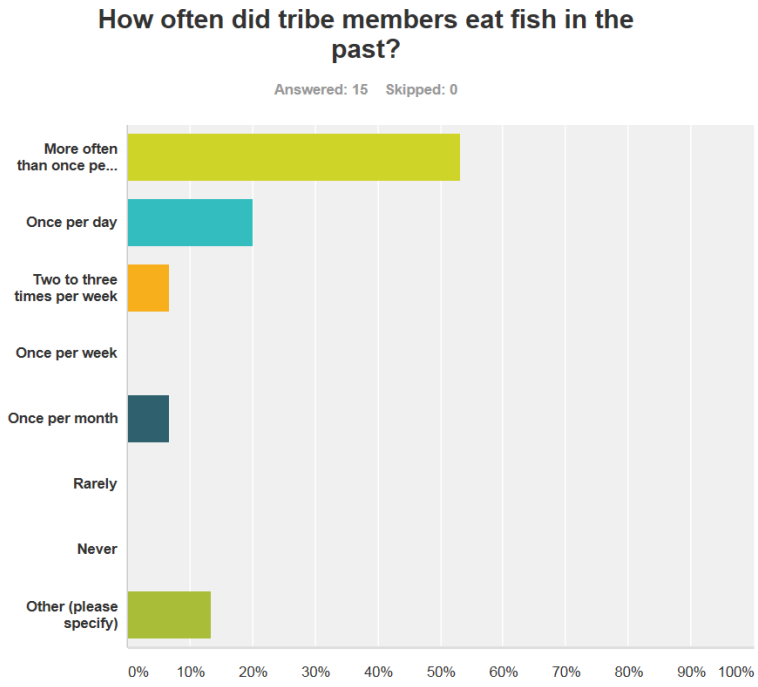


Questions 5 & 6.

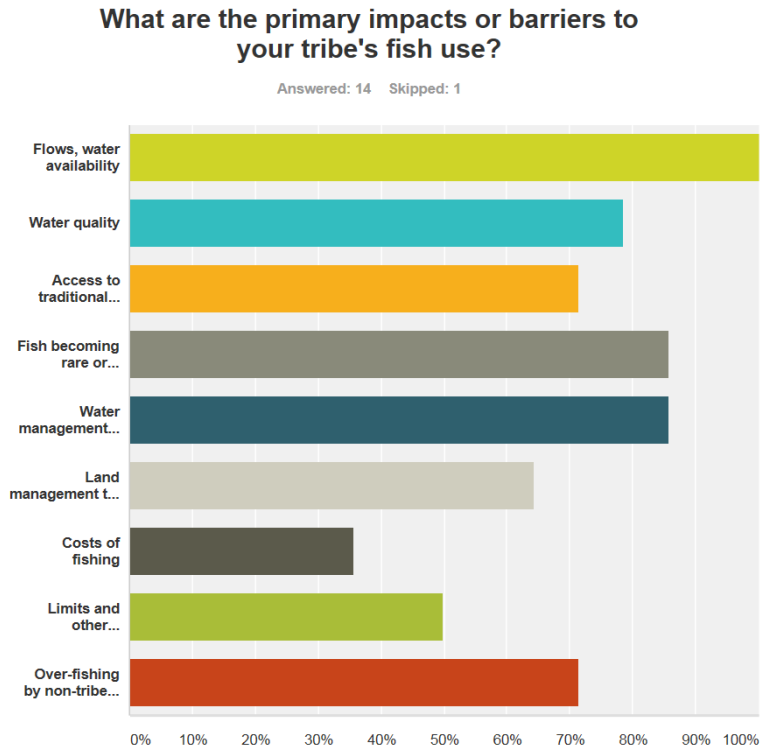
What types of fish did your tribe rely on in the past? (Please write in order of importance) What types of fish does your tribe rely on now? (Please write in order of importance)

Tribe	Past Fish Species/Groups	Current Fish Species/Groups
Wilton Rancheria (Me-Wuk)	Chinook salmon, sturgeon, fresh water eel	Chinook salmon
Karuk (2)	Chinook and coho salmon, sturgeon, eel	Chinook, eel
Wintu	Salmon, trout, sturgeon, eel	Salmon
Round Valley Indian Tribes (5)	Salmon, steelhead, trout, eel	Salmon, steelhead, trout
Big Valley Band of Pomo Indians	Sha (blackfish), hitch, ah-ah-sha (yellow catfish), sha-pal (sim. steelhead), dee-tah (sim. crappie), sun perch, bluegill, trout, black bass, catfish, clams	Store-bought fish, catfish and crappie from lake, clams and crayfish from lake, hitch from creeks, gifted salmon
Noyo River	Salmon, perch, surf fish & all other types of fish from the ocean	Salmon, surf fish, cod, cabazon, & anything else we can catch
Bear River Band of Rohnerville Rancheria	Salmon, lamprey/eel, steelhead, trout	Salmon, lamprey/eel
North Fork Rancheria of Mono Indians	Salmon	Trout
Pala Band of Mission Indians	Trout, bass, ocean shore fish	none
Mechoopda Indian Tribe	“Its not the type of fish, but what is in season and what is needed.”	“It is up to the Tribe and the season of fish that are available.”

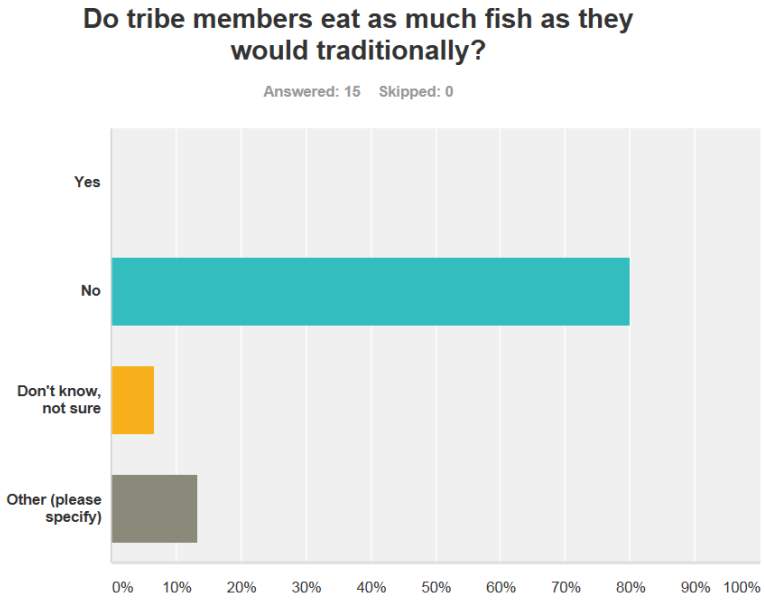
Question 7.



Question 8.



Question 9.



Question 10. In the future, studies of tribes' fish use should be conducted by...?

Type of Entity	Percent of responses
Tribes	40%
State agencies	0
Federal agencies	0
Academia	0
Non-governmental organizations	6.7%
Private consultants	0
Combination of above	53%

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Epidemiologic confirmation that fruit consumption influences mercury exposure in riparian communities in the Brazilian Amazon

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Abstract

Since deforestation has recently been associated with increased mercury load in the Amazon, the problem of mercury exposure is now much more widespread than initially thought. A previous exploratory study suggested that fruit consumption may reduce mercury exposure. The objectives of the study were to determine the effects of fruit consumption on the relation between fish consumption and bioindicators of mercury (Hg) exposure in Amazonian fish-eating communities. A cross-sectional dietary survey based on a 7-day recall of fish and fruit consumption frequency was conducted within 13 riparian communities from the Tapajós River, Brazilian Amazon. Hair samples were collected from 449 persons, and blood samples were collected from a subset of 225, for total and inorganic mercury determination by atomic absorption spectrometry. On average, participants consumed 6.6 fish meals/week and ate 11 fruits/week. The average blood Hg (BHg) was 57.1 ± 36.3 μg/L (median: 55.1 μg/L), and the average hair-Hg (HHg) was 16.8 ± 10.3 μg/g (median: 15.7 μg/g). There was a positive relation between fish consumption and BHg ($r = 0.48$; $P < 0.0001$), as well as HHg ($r = 0.34$; $P < 0.0001$). Both fish and fruit consumption entered significantly in multivariate models explaining BHg (fish: $\beta = 5.6$, $P < 0.0001$; fruit: $\beta = -0.5$, $P = 0.0011$; adjusted model $R^2 = 36.0\%$) and HHg levels (fish: $\beta = 1.2$, $P < 0.0001$; fruit: $\beta = -0.2$, $P = 0.0002$; adjusted model $R^2 = 21.0\%$). ANCOVA models showed that for the same number of fish meals, persons consuming fruits more frequently had significantly lower blood and HHg concentrations. For low fruit consumers, each fish meal contributed 9.8 μg/L Hg increase in blood compared to only 3.3 μg/L Hg increase for the high fruit consumers. In conclusion, fruit consumption may provide a protective effect for Hg exposure in Amazonian riparians. Prevention strategies that seek to maintain fish consumption while reducing Hg exposure in fish-eating communities should be pursued.

Keywords: Fish consumption; Fruit consumption; Mercury exposure; Amazon; Brazil

1. Introduction

Over the last decades, the presence of mercury (Hg) in the Amazon and its potential human health risks has given rise to much concern. During the 1970s, intense gold-mining activities were undertaken, with the arrival of thousands of gold miners coming from other regions of Brazil (Cleary, 1990; Santos et al., 1992). Although elevated Hg levels found in the Amazonian environment were initially attributed to these gold-mining activities (Hylander, 1994; Malm et al., 1990; Nriagu et al., 1992), more recent studies have shown high Hg concentrations both in fish and human tissues in regions where there has been no gold-mining (Guimarães et al., 1999; Silva-Forsberg et al., 1999; Dórea et al., 2003). Indeed, Amazonian soils constitute important reservoirs of Hg

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(Roulet et al., 1998, 1999, 2000; Fadini and Jardim, 2001), and a significant part of Hg contamination of the aquatic ecosystems is caused by erosion of such soils following deforestation for agriculture and/or cattle (Almeida et al., 2005; Farella et al., 2001, 2006; Roulet et al., 1999). Thus in the Amazonian environment, Hg from different sources is available for methylation processes contaminating the fish resources, which constitute a dietary mainstay for the large population living along the riverbanks (Dolbec et al., 2001; Guimarães, 2001; Lebel et al., 1997). Epidemiologic studies of riparian populations have shown dose-related associations between fish consumption, methyl mercury (MeHg) exposure, and early adverse health effects. Deficits in neurological and neuropsychological functions, as well as cytogenetic changes have been reported among adults and/or children from this area (Amorim et al., 2000; Cordier et al., 2002; Dolbec et al., 2000; Grandjean et al., 1999; Harada et al., 2001; Lebel et al., 1998, 1996; Yokoo et al., 2003). Additionally, recent exploratory studies in the Tapajós region suggest that Hg exposure may be associated with both increased blood pressure (Fillion et al., 2006) and autoimmune dysfunction (Silva et al., 2004).

There is a large variation in Hg levels in fish from the Tapajós region. A recent report indicated Hg concentrations above the recommended value of 0.5 μg/g in 31% of predatory fish species (Silva et al., 2006). Another study presented high mean Hg levels for carnivorous species such as Dourada (*Brachyplatystoma flavicans*: 0.8 μg/g), Surubim (*Pseudoplatystoma* sp.: 0.8 μg/g), Pescada (*Plagisocion squamosissimus:* 0.6 μg/g), and Sarda (*Pelona* sp.: 0.7 μg/g), whereas low levels of Hg have been reported in herbivorous fish such as Aracu (*Leporinus* sp.: 0.07 μg/g), Pacu (*Mylossoma* sp.: 0.05 μg/g), and Tambaqui (*Colossoma macropomum*: 0.08 μg/g) (Santos et al., 2000). In the Tapajós region, fish appear to be the only food source for Hg. A recent study evaluating mercury pollution in cultivated and wild plant parts from the Tapajós region concluded that the translocation of Hg from soils throughout roots to aboveground is not significant (Egler et al., 2006). This is supported by European studies examining Hg levels in agricultural products of Hg-containing soils, which concluded that Hg intake through vegetables and fruits does not represent a health hazard for consumers (Ursinyová et al., 1997; Barghigiani and Ristori, 1994).

Since fish is a central and highly nutritious element in the Amazonian diet, some authors have minimized the importance of Hg exposure, suggesting that changes in fish consumption practices would necessarily have strong negative consequences for human health (Dórea, 2004; Dórea et al., 2005). An alternative public health approach would be to identify elements in the traditional diet that might influence Hg absorption and/or toxicity, thereby providing a way for this population to continue eating fish, while reducing Hg exposure. Despite the recognition that diet and nutrition can influence a population's vulnerability to the effects of MeHg (NRC, 2000), dietary information has not been systematically collected in most epidemiologic studies examining the effects of MeHg exposure (Chapman and Chan, 2000). Although a number of controlled experiments have estimated the effects of specific nutrients on Hg absorption and/or toxicity (Calabrese, 1978; Levander and Cheng, 1980; Imura and Naganuma, 1985; Whanger, 1992; Peraza et al., 1998; Lapina et al., 2000; Rao et al., 2001; Rao and Sharma, 2001; Usuki et al., 2001; Afonne et al., 2002), studies examining the role of diet in determining Hg concentrations in free-living populations are still scarce.

In a hypothesis-generating study of 26 adult women from a riparian village in the Brazilian Amazon, we examined the influence of the consumption of traditional foods on the relationship between fish consumption and Hg exposure (Passos et al., 2003). In that study, the women kept extensive food consumption frequency diaries, which included all food and beverages, for 12 months. The results of this food consumption survey revealed that the strong relationship between fish consumption and Hg exposure was significantly modified by fruit consumption.

The objective of the present study was to determine, in a large riparian population in the Brazilian Amazon, the effects of fruit consumption on the relation between fish consumption and bioindicators of Hg exposure, using an epidemiologic design. It is part of the CARUSO Project, a large interdisciplinary, ecosystemic study on Hg contamination and exposure in the region (CARUSO, 2007).

2. Methods

2.1. Study design and population

A cross-sectional dietary survey was undertaken among 13 riparian communities situated on the banks of the Tapajós River, a major tributary of the Amazon (Fig. 1). These communities were chosen in order to represent the diversity created throughout the colonization process, as some of them were established after colonization began in the early 1960s, whereas others were established up to 100 years before. Because of the difficulties in applying a random sampling strategy in this setting, a convenience sample was used. Age and sex distributions were then compared to the underlying population, which had previously been determined through a house-to-house survey, in each community (Table 1). During this survey, the study was explained at each household and persons were invited to participate. Additionally, community meetings were conducted in each village in order to further explain the study.

Approval was obtained from Ethics Committees of the Federal University of Rio de Janeiro (Brazil) and the University of Quebec in Montreal (Canada). The study was explained individually, and persons agreeing to participate signed an informed consent form that was read to them.

2.2. Assessment of fish and fruit consumption frequency

Because of important seasonal differences in the availability of fish species and types of fruit (Lebel et al., 1997; Dolbec et al., 2001; Passos et al., 2001), a 7-day dietary recall questionnaire (7-DDR) was used in order to determine recent fish and fruit consumption frequency. Development and validation studies of this instrument have shown that it is relatively easily administered and it constitutes a sensitive method to assess short-term food consumption (Hebert et al., 1997).

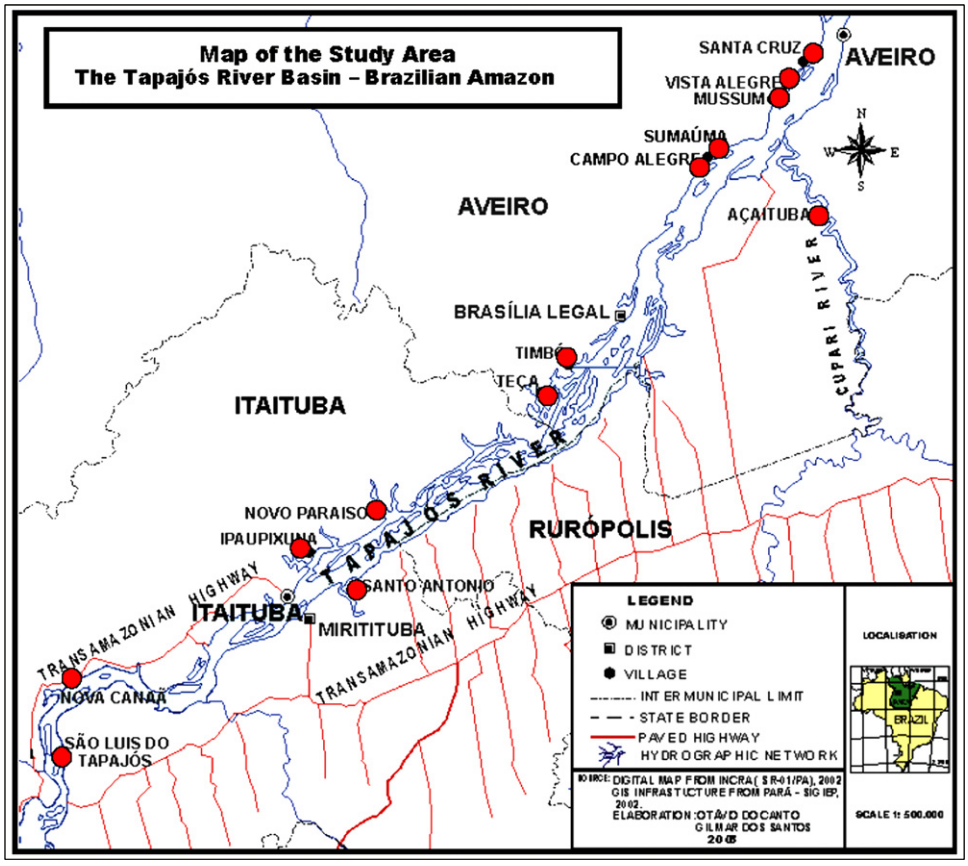

Fig. 1. Map of the study area. Participating communities are identified by a large red dot.

Table 1
Age distribution and rates of participation in the study population

Age category	Total adult population	Study population	% participation
15–24	427	112	26.2
25–34	260	102	39.2
35–44	218	97	44.5
45–54	161	54	33.5
55–64	116	50	43.1
⩾65	104	44	42.3
Total	1286	459	35.7

A list was prepared which included most of the fish and fruit species present in the region. In interviews performed over the months of June–August 2003, participants indicated the number of meals containing fish as well as the fish species that were consumed. As for fruits, the procedure was similar, but in this case, for each fruit species, the participant indicated the number of fruits that had been eaten each day over the preceding 7 days, whether during a meal or not. Fish and fruit species that were not in the initial list were also recorded.

2.3. Sampling and analyses of bioindicators

Hair samples were collected from 449 persons (211 men and 238 women) and blood samples were collected from a subset of 225 persons (114 men and 111 women). Hair strands from the occipital region were cut at the root and then placed in plastic bags, with the root end stapled. The samples were analyzed at the Laboratory of Radioisotopes of the Federal University of Rio de Janeiro (Brazil), by atomic absorption spectrometry with an AA 1475 Varian and a cold vapor generator accessory VGA-76 Varian. Mineralization of samples was done with mixtures of acids (HCl, HNO_3 and H_2SO_4) and oxidants ($KMnO_4$, $K_2S_20_7$ and H_2O_2), with techniques developed and adapted to the flow injection system vapor generator accessory (Malm et al., 1989). This laboratory participates regularly in inter-laboratory comparison programs for total and inorganic mercury analysis (Gill et al., 2002), and analytical quality control was ensured by the use of standard reference materials (Human Hair 085 and 086) provided by the International Atomic Energy Agency (IAEA).

Blood samples were collected by a nurse by venipuncture into 6 ml heparinized Becton Dickinson Vacutainer® (BD7863). All blood samples were kept frozen at -20° until analyzed. Total and inorganic mercury in blood were determined by atomic absorption spectrometry at the laboratory of the Quebec Toxicology Center of the Quebec Public Health Institute (CTQ-INSPQ), Canada, according to the method described by Ebbestadt et al. (1975). The detection limit for blood mercury (BHg) analysis was 0.2 μg/L and analytical quality control was ensured by the use of internal reference samples for blood analysis provided by the Inter-Laboratory Comparison Program conducted by the CTQ-INSPQ.

2.4. Statistical analysis

Descriptive statistics were used to describe the study population, Hg exposure as well as the results of fish and fruit consumption frequency. Correlation analyses were used to examine the relation between the frequency of consumption of specific fish species in relation to BHg and hair mercury (HHg) concentrations. Where appropriate, non-parametric techniques were used for comparisons.

The associations between fish and fruit consumption frequency with respect to BHg and HHg levels were assessed using simple and multiple linear regression models. BHg and HHg levels were the dependent variables in separate linear regression models, which tested for the influence of overall fish and fruit consumption; the latter were included as continuous independent variables.

All pregnant women were excluded from the analyses, and potential covariates such as alcohol consumption, gender, age, schooling, and cigarette smoking were included in the models. Analysis of covariance (ANCOVA) was used to test interactions. Results were defined as statistically significant for a value of $P \leqslant 0.05$. Analyses were performed using Statview for Windows Version 5.0.1 and JMP 5.0.1a (SAS Institute Inc.).

3. Results

Socio-demographic characteristics of the study population are shown in Table 2. Schooling varied between 0 and 12 years (mean 3.8 years $\pm$ 2.7), and the age range was 15–89 years (mean 38.6 years $\pm$ 17.2). Eighty-three percent (83%) of the participants were originally from the State of Pará, and 70% live on the Tapajós River banks, whereas 30% live on one of its tributaries. Fig. 2(A and B) presents the distribution of BHg and HHg levels, respectively. Overall, the average BHg was 57.1 $\pm$ 36.3 μg/L (median: 55.1 μg/L, ranging from 4.8 to 205.4 μg/L), and the average HHg was 16.8 $\pm$ 10.3 μg/g (median: 15.7 μg/g, ranging from 0.2 to 58.3 μg/g). The average percentage of MeHg was 86.8%, ranging from 75.2% to 94.3%. Men had significantly higher HHg levels (mean: 18.7 $\pm$ 11.2) than women (mean: 15.2 $\pm$ 9.1) (Mann–Whitney U, $P = 0.001$), but no significant difference was observed for BHg. There was a strong correlation between BHg and HHg concentrations ($r = 0.73$; $P < 0.0001$).

Table 2
Socio-demographic characteristics of the study population

Characteristics	Women		Men	
	n	%	*n*	%
Age				
15–24 years	61	25.1	51	23.6
25–34 years	58	23.9	45	20.8
35–44 years	51	21.0	47	21.8
45–54 years	27	11.1	25	11.6
55–64 years	23	9.5	27	12.5
⩾65 years	23	9.5	21	9.7
Alcohol consumption				
Drinks	79	32.6	125	58.1
No longer drinks	33	13.6	45	20.9
Never drank	130	53.7	45	20.9
Smoking habits				
Smoker	51	21.1	74	34.4
No longer smokes	49	20.2	59	27.4
Never smoked	142	58.7	82	38.1
Education				
No formal education	21	8.7	29	13.6
Elementary school (1–8 years)	206	85.5	175	81.8
High school and more (⩾9 years)	14	5.8	10	4.7
Born in Pará State	198	83.5	172	81.9
Location				
On the Tapajós River	172	70.8	144	66.7
On an tributary	71	33.3	72	33.2

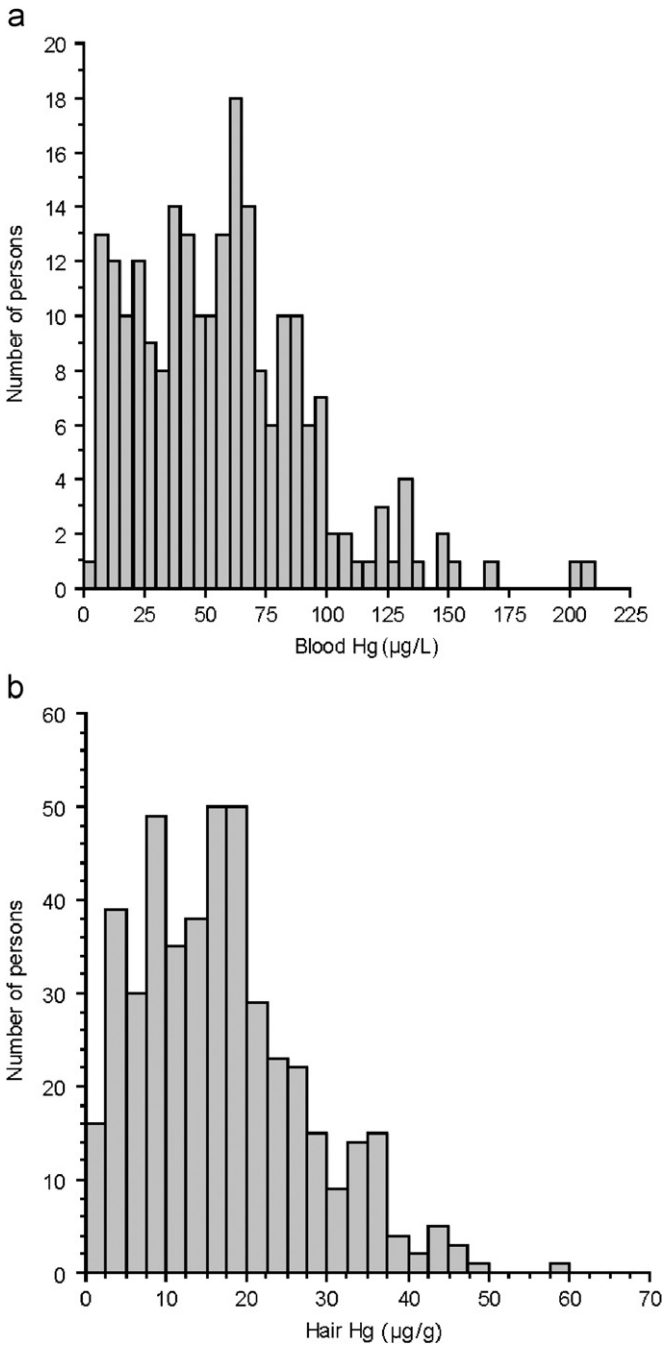

Fig. 2. Distribution of blood (A) and hair (B) total Hg concentrations for the study population.

In this survey, 457 persons consumed at least one meal with fish over the preceding seven days, making up 99.6% of the study population. Of these, 345 persons consumed at least one meal containing a carnivorous species (75.2%), whereas 393 persons ate at least one fish meal containing a non-carnivorous species (85.6%). In all, participants had consumed an average of 6.6 fish meals/week, ranging from

Table 3
Frequency of reports for fish most frequently eaten over the preceding 7 days

Fish species	Feeding habits[a]	Number of fish meals	%
Aracu (*Shizodon* sp.)	n-c	696	23.0
Pescada (*Plagioscion* sp.)	c	602	19.9
Caratinga (*Geophagus* sp.)	n-c	375	12.4
Tucunaré (*Cichla* sp.)	c	291	9.6
Jaraqui (*Semaprochilodus* sp.)	n-c	160	5.3
Pacu (*Myears lossoma* sp.)	n-c	155	5.1
Flexeira (*Hemiodus ocellatus*)	n-c	76	2.5
Branquinha (*Curimata amazonica*)	n-c	62	2.0
Piranha (*Sarrasalmus* sp.)	c	81	2.7
Others	—	529	17.5
Total	—	3027	100

[a]c, carnivorous; n-c, non-carnivorous.

0 to 19 meals/week. Table 3 shows the fish species most frequently eaten over the preceding 7-day period. Carnivorous fish made up an average of 43.5% of the fish diet, ranging from 0% to 100%. No associations were observed between total fish consumption and age, gender, schooling, cigarette smoking, and alcohol consumption. However, significant differences were observed between communities (Kruskal–Wallis, $P<0.0001$), as well as between persons originally from the Tapajós region and immigrants from northeast Brazil (Mann–Whitney U, $P<0.0001$). Those originally from the Tapajós region showed higher HHg levels (mean $= 17.9\,\mu g/g \pm 10.1$) compared to persons who had immigrated (mean $= 12\,\mu g/g \pm 9.9$).

Fig. 3(A and B) shows the relationships between weekly fish consumption (meals/week), BHg and HHg, respectively. Partial correlation analyses of fish consumption, categorized by feeding habits and Hg levels, show that the frequency of consumption of carnivorous fish is significantly correlated to both BHg and HHg ($r = 0.48$, $P<0.0001$ for BHg; $r = 0.34$, $P<0.0001$ for HHg), whereas the frequency of consumption of non-carnivorous fish is not related to BHg ($r = 0.01$, $P = 0.15$), and weakly correlated to HHg ($r = 0.14$, $P = 0.002$). This is reflected in individual species, with the highest correlations observed for large carnivorous fish such as *Pescada*, *Filhote* and *Piranha*. Despite its relatively high consumption, the carnivorous species *Tucunaré* was not significantly correlated to the bioindicators of Hg exposure, while *Aracu* and *Pacu* (non-carnivorous species) showed a weak correlation to HHg. These same relationships were observed when the fish were entered two-by-two into a multiple regression model.

A total of 40 fruit species were recorded during the survey, and 443 persons (96.5%) ate at least one of these fruits in the previous week. Three-hundred twenty-eight (328) persons (71.5%) reported eating bananas (*Musa* spp., Musaceae), the most consumed fruit, while 203 (44.2%) reported eating at least one orange (*Citrus* spp., Rutaceae).

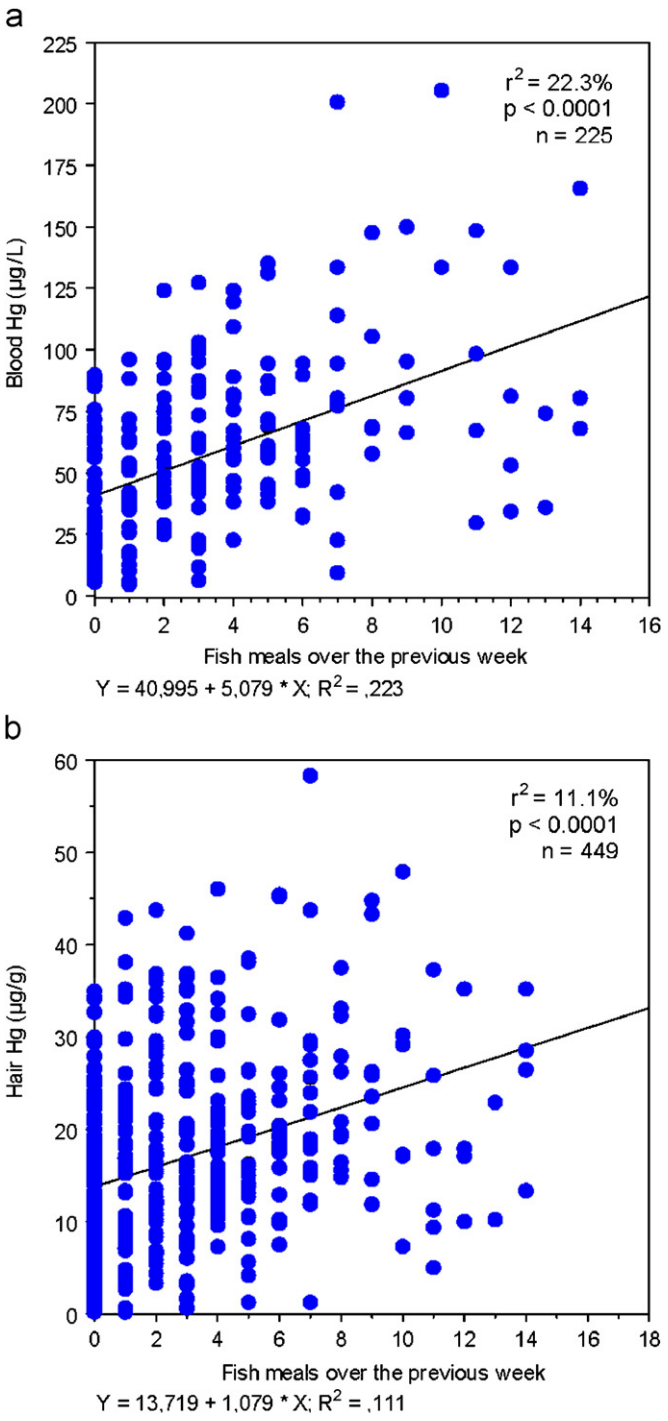

Fig. 3. The relationship between fish consumption (meals/week) and blood (A) and hair (B) total Hg concentrations.

Table 4 summarizes the distribution of persons with respect to fruit species consumption, as well as the frequency of reports for fruits most frequently eaten over the previous 7 days. Because of the important biodiversity in the Amazon, most fruits are consumed by only a small percentage of the participants, whereas only a few fruits are widely consumed by significant portions of the population.

On average, participants ate 11 fruits/week, ranging from 0 to 62 fruits/week. Although many types of fruit are

Table 4
Frequency of persons eating specific fruit and frequency of reports for fruit most frequently eaten over the previous 7 days

Fruit	Latin identification	Number of persons	Relative frequency (%)	Number of fruits	% total fruits
Bananas	*Musa paradisiaca*	328	71.5	1727	34.3
Oranges	*Citrus* sp.	203	44.2	973	19.3
Tucumã	*Astrocaryum aculeatum*	137	29.8	570	11.3
Guava	*Psidium guajava*	82	17.9	189	3.7
Passion fruit	*Passiflora* sp.	76	16.6	19	0.4
Jambo	*Eugenia* sp.	70	15.3	315	6.3
Avocado	*Persea Americana*	69	15.0	109	2.2
Ingá	*Inga* sp.	49	10.7	82	1.6
Brazil Nuts	*Bertholletia excelsa*	37	8.1	202	4.0
Others	—	300	65.4	845	16.8
Total	—	443	96.5	5031	100

Table 5
Results of multiple regression analyses for fish and fruit consumption in relation to BHg (μg/L) and HHg (μg/g) concentrations

Biological indicator	*n*	Regression estimates		Model R^2 (%)[a]
Blood total mercury (μg/L)		Carnivorous fish	Total fruit	
Women	111	4.8 ($P<0.0001$)	−0.7 ($P=0.0068$)	27.1
Men	114	6.8 ($P<0.0001$)	−0.4 ($P=0.0417$)	46.3
Total	225	5.6 ($P<0.0001$)	−0.5 ($P=0.0011$)	36.0
Hair total mercury (μg/g)				
Women	238	1.0 ($P<0.0001$)	−0.1 ($P=0.0276$)	16.1
Men	211	1.4 ($P<0.0001$)	−0.2 ($P=0.0058$)	21.6
Total	449	1.2 ($P<0.0001$)	−0.2 ($P=0.0002$)	21.0

[a]Adjusted factors in the regression equation: gender, cigarette smoking, non-carnivorous fish consumption.

seasonally available, the most frequently eaten are bananas and oranges. In this survey, we also observed a relatively high frequency of consumption of other regional fruits such as Tucumã (*Astrocaryum aculeatum*) and Jambo (*Eugenia* spp.), whereas Ingá (*Inga* spp., Leguminosae–Mimosoideae) was hardly consumed in this season. Total fruit consumption was weakly correlated with fish consumption ($r=0.1$; $P=0.003$), and inversely correlated with age ($r=-0.1$; $P=0.02$). It was also weakly correlated with schooling ($r=0.1$; $P=0.02$), but no relation was observed between fruit consumption and cigarette smoking or alcohol consumption. Similar to fish consumption, significant inter-village differences were observed (Kruskal–Wallis, $P=0.004$). Villagers living close to Itaituba City, the only urban center of the upper and middle Tapajós, reported lower fruit consumption as compared to villagers living in the proximity of Aveiro, a small town in the lower Tapajós.

Both fish and fruit entered significantly into the multivariate models explaining BHg and HHg; the regression estimates are presented in Table 5 for both women and men. The inverse relationship between fruit consumption and Hg levels remained significant, even when carnivorous and non-carnivorous fish were included separately. In addition to the overall effect of fruit consumption, multivariate models showed that some individual fruits presented enhanced negative regression estimates. Table 6 shows regression estimates for frequency of specific fruit consumption in multiple linear models with fish consumption and bioindicators of Hg exposure.

Fig. 4(A and B) illustrates the overall influence of these specific fruits (bananas, oranges, and jambos) on the relationship between fish consumption and Hg exposure. The regression lines are plotted for those with low fruit consumption ($\leqslant 3$ fruits/week; $n=64$), medium fruit consumption (>3 fruits/week $\leqslant 10$ fruits/week; $n=86$), and high fruit consumption (>10 fruits/week, $n=75$) in relation to BHg. For HHg, the low consumption group comprises 177 persons, the medium 169 persons, and the high consumers include 113 persons. Analysis of covariance showed that the intercepts of the three regression lines were similar, but their slopes were significantly different (Interaction term for BHg: $F=9.4$, $P=0.0001$; for HHg: $F=5.9$; $P=0.0029$). Thus, for low fruit consumers, each fish meal contributed 9.8 μg/L Hg increase in blood compared to only 3.3 μg/L Hg increase for the high fruit consumers. Similarly, each fish meal contributed approximately 1.7 μg/g Hg increase in hair of low fruit consumers as opposed to 0.5 μg/g increase in hair of high fruit consumers.

Most sociodemographic features such as age, schooling, cigarette smoking, and alcohol consumption were similar between low and high fruit consumers, while some slight differences were observed for a limited number of variables (Table 7). It is interesting to note that high fruit consumers ate more carnivorous fish.

Table 6
Regression estimates for frequency of specific fruit consumption (fruits/week) in multiple linear models with fish consumption (meals/week) as independent variable and bioindicators of Hg exposure

Biological indicator Fruits	Regression estimates		Model R^2 (%)[a]
Blood total mercury (μg/L)	Carnivorous fish	Fruit	
Oranges	5.3 ($P<0.0001$)	−1.6 ($P = 0.0006$)	36.2
Jambos	4.9 ($P<0.0001$)	−1.8 ($P = 0.0245$)	38.9
Hair total mercury (μg/g)			
Oranges	1.0 ($P<0.0001$)	−0.2 ($P = 0.0440$)	23.3
Bananas	1.0 ($P<0.0001$)	−0.2 ($P = 0.0246$)	23.0

[a]Adjusted factors in the regression equation: gender, cigarette smoking, non-carnivorous fish consumption, community.

4. Discussion

The results of the present study show a clear association between fruit consumption and lower Hg levels in this population, thus confirming the findings of our hypothesis-generating study conducted among 26 riparian women in the Amazon (Passos et al., 2003). This protective effect of fruit consumption against Hg exposure via dietary intake of fish is observed both for women and men; it is present in all categories of age and schooling, and occurs independently of other factors with a potential to influence Hg exposure, such as cigarette smoking and alcohol consumption.

A plausible explanation for the findings of this study is that the soluble dietary fiber content as well as other prebiotic nutrients of fruits could be interfering with absorption at the gastrointestinal tract. Indeed, demethylation of MeHg by microflora in the gut is a key and probably a rate-determining process in the removal of MeHg from the body, even though the microbes involved have not been identified nor have the biochemical mechanisms of cleavage of the carbon–mercury bond (Clarkson, 2002). A number of studies have suggested that the demethylation process in the intestine might well constitute an important site for interaction between diet and MeHg accumulation in the body (Chapman and Chan, 2000), the fiber content of the diet having already been shown to affect the excretion rate of MeHg (Rowland et al., 1986). Dietary elements have important effects on the metabolic activity of the intestinal flora (Gibson et al., 2004; Rowland, 1988), including a number of the carbohydrates present in significant amounts in several fruits and vegetables, which are able to stimulate the growth and/or activity of intestinal bacteria associated with health and well-being (Roberfroid, 2005). The effect of fruit consumption on these processes might explain, at least in part, why there is such a broad range of biologic half-times reported for adults exposed to MeHg.

The substantial inverse relation between Hg levels and consumption of oranges, which are known to present high levels of ascorbic acid (vitamin C), is particularly interesting since the role of this nutrient on MeHg exposure and toxicity has been controversial. Although Vitamin C has been implicated in the enhancement of MeHg toxicity (Murray and Hughes, 1976; cited in NRC, 2000), because of its strong reducing capacity, it is supposed to have potent detoxifying properties and has been used in cases of intoxication by heavy metals, including Hg. Sharma and colleagues (1982) demonstrated that ascorbic acid mediated a small but significant degradation of MeHg to inorganic mercury. Also, a more recent study concluded that ascorbic acid prevents mercury-induced genotoxicity in blood cultures due to its probable nucleophilic and detoxifying nature (Rao et al., 2001). In addition to ascorbic acid, oranges are also excellent sources of flavonoids and soluble dietary fiber.

Despite a positive relation between cigarette smoking and Hg levels observed in this population, the influence of fruit consumption remained unchanged. It is known that smokers have lower antioxidant status than non-smokers, but fruit consumption leads to a higher antioxidant status (Dietrich et al., 2003), which might explain the unchanged effect of fruit consumption. Indeed, one of the properties of several antioxidants particularly abundant in fruits is that they can form complexes with reactive metals, thus reducing their absorption (Bravo, 1998). Furthermore, the effect of fruit consumption also remained unchanged despite inter-village differences in terms of fruit consumption. Such regional differences probably reflect the fact that villagers near Itaituba City often buy fruit in the market, whereas those in more remote villages in lower Tapajós acquire fruit more often from their own home gardens.

Over these last years, diet of fish-eating communities has been the subject of much debate because of concerns about the potential health risks of MeHg exposure and, on the other hand, the public health implications of a diminished fish consumption (Arnold et al., 2005; Egeland and Middaugh, 1997; Myers et al., 2000; Weihg and Grandjean, 1998). Indeed, decreases in traditional food use has already been shown to affect diet quality and even to contribute to a number of diet-related health problems in indigenous peoples of Arctic Canada (Receveur et al., 1997). It is interesting that until recently the on-going birth cohort studies of heavy fish consumers of the Seychelles Islands in the Indian Ocean did not reveal adverse effects of MeHg, and some results even indicated beneficial outcomes

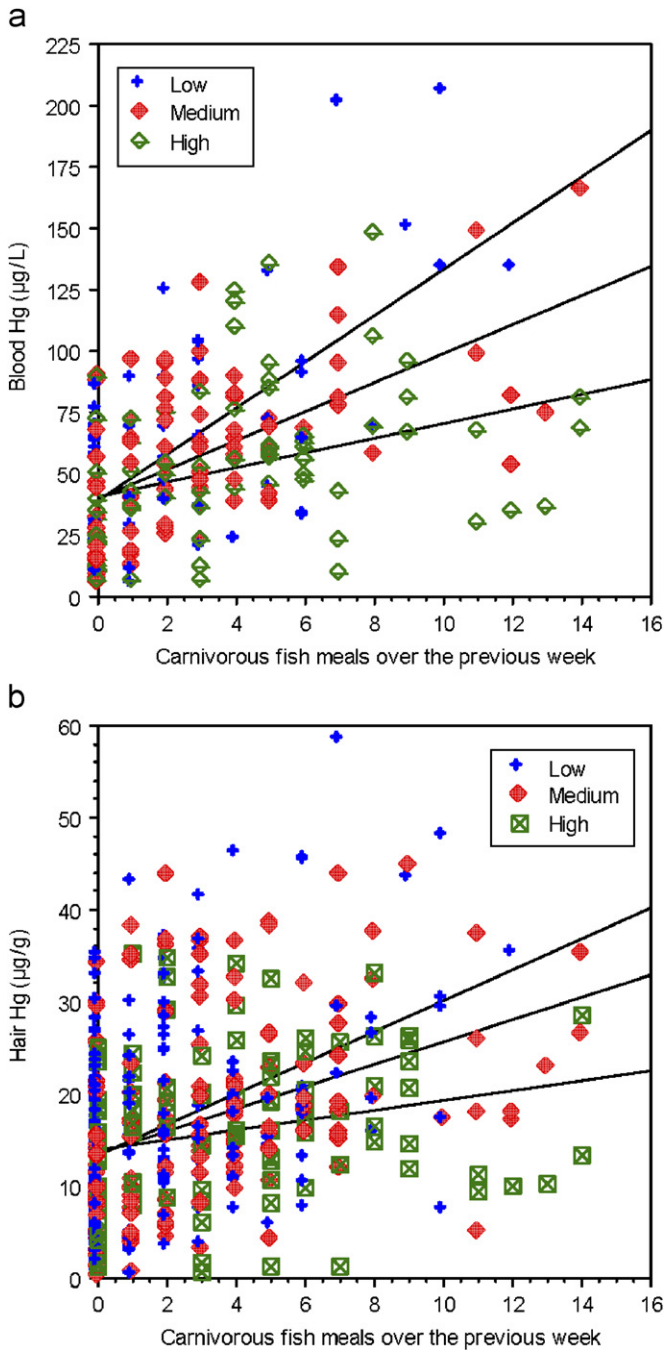

Fig. 4. The influence of fruit consumption on the relationship fish consumption (meals/week) and blood Hg levels (A), and HHg levels (B).

that correlate with Hg levels during pregnancy; the authors suggest a potential role of micronutrients in fish as a possible explanation for such findings (Clarkson and Strain, 2003). The importance of maintaining fish consumption when intervening to reduce Hg exposure in fish-eating populations was stressed by the Joint Expert Committee on Food Additives and Contaminants (JECFA) under the Food and Agriculture Organization (FAO) and the World Health Organization in their recent recommendations for tolerable daily maximum intake for Hg in pregnant/childbearing age women (WHO, 2003).

Table 7
Characteristics of fruit consumers according to their level of consumption

Characteristics	Low consumers[a] $n = 177$	Medium consumers[a] $n = 169$	High consumers[a] $n = 113$
Regional distribution			
Upriver (*Itaituba*)	97 (54.8)	78 (46.2)	38 (33.6)
Midriver (*Brasília Legal*)	37 (20.9)	18 (10.7)	6 (5.3)
Downriver (*Aveiro*)	43 (24.3)	73 (43.2)	69 (61.1)
Gender			
Women	98 (55.4)	97 (57.4)	47 (41.6)
Men	79 (44.6)	72 (42.6)	66 (58.4)
Fish consumption (meals/week)			
Carnivorous fish	2.1±2.7	3.2±3.2	3.8±3.6
Non-carnivorous fish	3.8±4.0	3.8±3.5	3.2±2.9
Hg levels			
Blood (µg/L)	61.7±44.6	57.9±33.1	52.3±31.5
Hair (µg/g)	17.0±11.2	17.4±10.4	15.8±8.4

[a]Data presented as mean±standard deviation or number of persons (percentage).

In the Amazon, recent reports have criticized any eventual suggestion to restrict fish consumption in traditional populations, which rely on fish as the main source of animal protein and other essential nutrients, suggesting that despite high concentrations of MeHg in fish, daily consumption of this food in large amounts poses no health hazards (Dórea, 2003, 2004). Although these reports rightfully point out the public health issues involved in diminished fish consumption, a more comprehensive approach, which takes into account the different sources of pollution as well as the socio-cultural and economic aspects of agriculture and diet, is needed in order to achieve viable risk management in this region. In particular, deforestation should be better controlled, thereby limiting Hg leaching from soils. It will also be necessary to better understand the dynamics involved in methylation in the areas of fish capture and to improve knowledge on the role of other foods able to influence Hg absorption and metabolism.

In this context, the challenge to maintain fish consumption while reducing Hg exposure remains. The encouraging results of a first intervention, which aimed at shifting towards consumption of less contaminated fish species and its impact in lowering exposure in a village on the Tapajós river have been presented elsewhere (Mertens et al., 2005; Bahia et al., 2004; Mergler et al., 2001). Indeed, through education based on posters showing the status of Hg contamination in relation to the fish species, the change in diet habits resulted in a reduction of close to 40% of HHg levels (Lucotte et al., 2004). The findings of the present study confirm a relevant avenue that deserves to be further explored as a potential additional intervention strategy

aimed at achieving the short-term challenge of maintaining fish consumption while reducing Hg exposure in this Amazonian setting.

In public health, it is well known that fruits contain a variety of compounds that may slow or prevent chronic diseases through several possible mechanisms. Components in fruits thought to be associated with the reduction of these conditions include soluble and insoluble dietary fiber, antioxidant nutrients (vitamins C, E, selenium, β-carotene), as well as other phytonutrients including polyphenols, flavonoids, anthocyanins and carotenoids (Feeney, 2004). Our findings indicate that fruit consumption may also be protective against the bioaccumulation of Hg in human populations exposed via dietary intake of fish.

Certain methodological issues of the present study need to be considered. First, there is always a tradeoff between the amount of data that can be collected and the size of the population. In the Passos et al. (2003) study, we opted for a large amount of chronological data collected through food diaries (written record of the foods as they are eaten, thus minimizing under- or over-reporting due to recall bias), and sequential HHg analyses from a small female population in order to identify the relevant food items that could then be used in a study with a much larger population (Passos et al., 2004). For the present study, we used a cross-sectional design on a convenience sample of men and women villagers from numerous riparian communities, assessing fish and fruit consumption frequency through a 7-DDR, and measuring Hg levels both in recent and chronic bioindicators of exposure. While the 7-DDR has been shown to constitute a sensitive method to assess short-term food consumption (Hebert et al., 1997), because of its retrospective nature there might have been some level of under- or over-reporting due to recall bias, especially for food items only moderately consumed (Pereira and Koifman, 1999). In addition, although data collection on convenience samples has been shown to appropriately represent the underlying population in other settings (Kelly et al., 2002; Zelinski et al., 2001), this sampling strategy may have introduced some selection bias in the present study. We did, however, achieve a participation rate of 35.7% in this adult population, well represented in most age categories. Moreover, most characteristics of fruit consumers were well distributed in the three categories of fruit consumption.

Another limitation of the present study is that it did not allow us to examine some of the possible physiologic events that may be involved in the interactions between fruit nutrients and MeHg. Studies examining the use of chelating agents as an intervention strategy to reduce blood lead levels raised questions about whether the process of chelation causes potentially dangerous redistribution of lead to susceptible organs from those less susceptible to lead toxicity (Goyer et al., 1995). Further studies should therefore examine the effect of fruit consumption from a toxicokinetic viewpoint.

5. Conclusion

Despite some limitations, this study constitutes strong evidence that fruit consumption provides a protective effect against Hg exposure in Amazonian riparian communities, whose traditional diet is based on daily consumption of Hg-containing freshwater fish. The results of this epidemiologic study are consistent with our previous findings (Passos et al., 2003) in which 26 riparian women presented lower HHg levels associated with consumption of regional fruit. Even though we did not measure toxicological outcomes in this study, it is reasonable to hypothesize that villagers consuming fruit regularly would be less vulnerable to neurological and/or cardiovascular risks linked to chronic Hg exposure. Future studies should be conducted to identify the specific nutrients responsible for this protective effect and examine the pharmacokinetics involved in these relations.

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Biogeochemical Controls on Methylmercury in Soils and Sediments: Implications for Site Management

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ABSTRACT

Management of Hg-contaminated sites poses particular challenges because methylmercury (MeHg), a potent bio-accumulative neurotoxin, is formed in the environment, and concentrations are not generally predictable based solely on total Hg (THg) concentrations. In this review, we examine the state of knowledge regarding the chemical, biological, and physical controls on MeHg production and identify those most critical for contaminated site assessment and management. We provide a list of parameters to assess Hg-contaminated soils and sediments with regard to their potential to be a source of MeHg to biota and therefore a risk to humans and ecological receptors. Because some measurable geochemical parameters (e.g., DOC) can have opposing effects on Hg methylation, we recommend focusing first on factors that describe the potential for Hg bio-accumulation: site characteristics, Hg and MeHg concentrations, Hg availability, and microbial activity, where practical. At some sites, more detailed assessment of biogeochemistry may be required to develop a conceptual site model for remedial decision making. *Integr Environ Assess Manag* 2016;00:000–000. © 2016 SETAC.

Keywords: Methylmercury Site assessment Mercury Sediment Contaminated

Critical Review

INTRODUCTION

Mercury has been used widely in industry and is a contaminant at approximately 50% of all Superfund sites (Mercury Superfund Research Program 2015). At many of these sites, Hg as methylmercury (MeHg) is a risk driver for remediation. Methylmercury is a potent neurotoxin that bioaccumulates in aquatic and terrestrial organisms and is therefore of concern to human and ecological health, primarily due to fish consumption. Prediction of risk associated with Hg in contaminated environments is complicated by the lack of a consistent relationship between MeHg concentrations in fish, soil, sediment, or water and total Hg (THg) concentration in these environmental media. Furthermore, MeHg uptake into the food web and bioaccumulation can vary widely between sites with very similar Hg levels, and elevated Hg concentrations can persist in an ecosystem for decades or longer. A particular concern for site managers is that the development of numerical sediment or water quality guidelines to predict the accumulation of MeHg in fish is difficult because of the lack of a consistent relationship between sediment or water THg concentrations and bioaccumulation into fish tissue (Ingersoll et al. 2000). The US Environmental Protection Agency (USEPA) recognized this challenge in its development of a national recommended water quality criterion for MeHg, which is expressed in terms of fish tissue, for protection of human health exposures due to fish consumption (USEPA 2009).

To effectively manage risk, identification of key parameters that determine the fate of Hg at contaminated sites is critical. Some contaminated sites with relatively high Hg concentrations in soil or sediment have relatively low Hg concentrations in the food web, whereas others exhibit higher Hg concentrations in the biota despite lower Hg in soils or sediments. Our focus is on soils and sediments contaminated by point sources (also known as "legacy sites") rather than by atmospheric deposition of Hg. Although methylation at sites contaminated by atmospheric deposition is controlled by similar geochemical parameters, approaches to management differ.

We synthesize the literature to identify a set of practical parameters to use when evaluating the risk of Hg methylation and bioaccumulation. Most of the discussion is focused on sediment because MeHg concentrations in soil tend to be low (Munthe et al. 2001). Methylation in soil is strongly affected by soil moisture content; otherwise, the processes of microbial methylation in soil and sediment are similar. Much of the research to date and the literature reviewed herein has focused on freshwater systems; however, the basic principles also apply to estuarine or marine sites. Because of the complex interaction of geochemical, biological, and physical parameters, there is no single parameter that will reliably predict the likelihood of Hg methylation and bioaccumulation or the concentration of MeHg in the environment. Thus, from a site management perspective, it is more practical to focus on a suite of measurable parameters that are indicative of risk.

Managing contaminated sites entails the prioritization and implementation of remediation, if warranted. Although a detailed review of remediation technologies is beyond the

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scope of the present article, consideration of the geochemical conditions can help inform remediation options. Some traditional remediation techniques, such as removal or capping, do not depend on site chemistry. However, geochemical controls are especially relevant to emerging remediation technologies such as the application of activated C, biochar, or nitrate to reduce methylation potential at a site (Todorova et al. 2009; Gilmour, Riedel et al. 2013; Gomez-Eyles et al. 2013; Bussan et al. 2016) and the use of natural attenuation.

The goal of the present study was to examine the large amount of biogeochemical information available for Hg methylation in soils and sediments and to identify the most important measurements to help determine whether remediation is warranted. We describe controls on Hg methylation and bioaccumulation based on review of the literature and our experience in evaluation of Hg-contaminated sites. To highlight site-specific controls on Hg methylation and bioaccumulation, a more detailed examination of 3 Hg-contaminated sites with differing geochemical, biological, and physical characteristics is included. We conclude with specific environmental monitoring suggestions for managers of Hg-contaminated sites.

MERCURY CYCLING IN THE ENVIRONMENT

Mercury species

In the environment, Hg cycles between neutral (i.e., elemental mercury) and positively charged species as well as inorganic and organic forms (Figure 1). The 2 oxidation states for Hg in the environment are Hg(0) (i.e., elemental Hg) and Hg(II or 2+) (i.e., divalent Hg). Elemental Hg exists as a liquid under ambient conditions and can be formed in the environment (through reduction of divalent Hg) either by bacteria or by photochemical reduction (Mason et al. 1995). Elemental Hg is relatively volatile and, once volatilized, is dispersed to the atmosphere. At legacy sites associated with Hg cell chlor-alkali or Hg retort facilities, elemental Hg can persist for decades in soil or buildings. Generally, however, Hg is found in soils, sediments, and waters in the divalent form complexed with chlorides, sulfides, or organic matter. Inorganic Hg(II) may be methylated by microorganisms, resulting in the production of MeHg, an organic species that binds to proteins and can pass through biological membranes. Unlike inorganic Hg, MeHg tends to bioaccumulate within the food web. Thus, the tendency of an environment to produce MeHg from inorganic Hg is important in determining the potential impact of Hg on human health and the environment.

Mercury methylation and demethylation

Methylmercury in the environment is the net result of MeHg production and demethylation, which are both largely microbially mediated (Ullrich et al. 2001; Driscoll et al. 2013). MeHg is formed primarily as a cometabolic product by sulfate-reducing bacteria (SRB) and, to a lesser extent, by Fe(III)-reducing bacteria (Compeau and Bartha 1985; Fleming et al. 2006; Kerin et al. 2006). These bacteria are active under anaerobic conditions, that is, in the absence of O_2 and nitrate, which are more favorable electron acceptors for bacterial metabolism. Mercury also can be methylated by methanogenic microorganisms, suggesting that MeHg production may take place in anoxic freshwater sediment depleted of sulfate and Fe(III) (Hamelin et al. 2011; Yu et al. 2013).

Recently, Parks et al. (2013) identified 2 genes, *hgcA* (which encodes a putative corrinoid protein) and *hgcB* (which encodes a 2[4Fe-4S] ferredoxin), which are required for Hg methylation and which may provide a means of assessing methylation potential in the environment. They found homologs of *hgcA* and *hgcB* in genomes of 52 bacterial and methanogenic archaea. Building on this research, Podar et al. (2015) found the *hgcAB* genes in nearly all anaerobic environments evaluated (i.e., in more than 3500 publicly available microbial metagenomes from a wide range of environments). Although these recent studies indicate a broad diversity of known methylators, sulfate-reducing and Fe-reducing bacteria exhibit the highest methylation rates and tend to dominate methylation when they are present, likely because they are so abundant (Gilmour, Podar et al. 2013). Future application of these genetic techniques may shed additional light on the relative abundance of methylating organisms.

Demethylation occurs both biologically and abiotically. Whereas both aerobic and anaerobic organisms have been found to demethylate MeHg, aerobic organisms are considered to predominate (Ullrich et al. 2001), although sulfate-reducing and methanogenic bacteria (which are anaerobic) have been found capable of oxidative demethylation (Marvin-DiPasquale

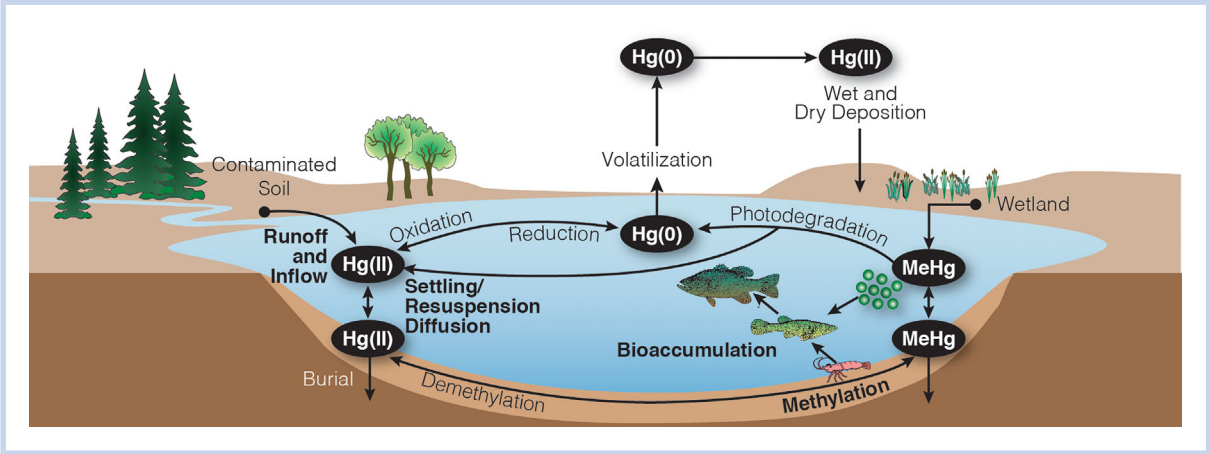

Figure 1. Chemical and biological pathways potentially controlling the fate of Hg. Although the focus of this review is on soils and sediments, methylation (and therefore bio-accumulation) is dependent on the presence of water in all systems. Hg(0) = elemental mercury; Hg(II) = divalent mercury; MeHg = methylmercury.

and Oremland 1998; Marvin-DiPasquale et al. 2000). Photochemical reduction is the only significant abiotic Hg demethylation process (Ullrich et al. 2001) and dominates demethylation in the photic zones of surface waters. Although methylation and demethylation can be studied separately with the help of C and Hg radioisotopes, MeHg concentrations in the environment are the end result of both processes; therefore, the present review focuses on net methylation.

Biogeochemical controls on net methylation

Net methylation is a function of 2 general factors: the geochemical speciation of inorganic Hg(II), which determines its availability to methylating organisms, and the activity of methylating (and demethylating) bacteria, which depends on environmental conditions (Hsu-Kim et al. 2013). Because speciation of inorganic Hg(II) and bacterial activity are important, inorganic Hg(II) concentration in sediment (which is generally well represented by THg) is not a good or consistent predictor of MeHg concentration. Indeed, several authors (e.g., Benoit et al. 2003; Schaefer et al. 2004; Heyes et al. 2006; Cossa et al. 2014) have reported a plateau in MeHg concentration as THg in sediment increases and variable MeHg concentrations at given THg concentrations. This plateau and variability are indications that, as stated by Ullrich et al. (2001), a network of biogeochemical reactions and environmental conditions controls the rate of net MeHg production. The primary parameters involved (S, organic matter, Fe, Se, pH, temperature) as well as 2 other considerations for understanding net methylation (wetting and drying cycles and "new" versus "old" Hg) are reviewed here.

Sulfur. Sulfur biogeochemistry influences Hg methylation by affecting the activity of methylating bacteria and the availability of Hg(II) for methylation. In anaerobic sediment, the presence of sulfate, an oxidized S species, generally increases Hg methylation (Kampalath et al. 2013) because of its role as an electron acceptor for SRB. The end product of sulfate reduction is sulfide, which strongly controls the concentration of dissolved Hg(II) (Paquette and Helz 1997) and may either increase or decrease Hg methylation by influencing the speciation of Hg in sediment. In fact, inorganic speciation of Hg is dominated by Hg sulfide species even at nanomolar sulfide levels. Common dissolved Hg sulfide species in the environment are $Hg(SH)_2$ (aq), $HgHS^{2-}$(aq), $HgS_2{}^{2-}$(aq), and $Hg(Sx)_2{}^{2-}$, whereas HgS(s) is the primary species in solid phase. Uncharged Hg sulfide species (e.g., $Hg(SH)_2$ (aq)) are available for methylation (Drott et al. 2007), because they can pass through bacterial cell membranes where they can be methylated. The formation of solid phases (e.g., HgS(s)) or charged species acts to inhibit methylation (Kampalath et al. 2013) because both are unavailable to bacteria. The extent of Hg methylation has been linked to precipitation and dissolution reactions of HgS(s) and regulation of SRB activity by S(-II) toxicity (Gilmour et al. 1992; Benoit, Gilmour et al. 1999; Gilmour et al. 1992). Although some ligand-promoted dissolution of HgS(s) by dissolved organic matter (DOM) (Waples et al. 2005), sulfide (Paquette and Helz 1995), and polysulfide (Paquette and Helz 1997; Jay et al. 2000; Paquette and Helz 1997) has been noted in experimental systems, the overall solubility of HgS(s) (and thus the availability of Hg(II)) remains extremely low.

Organic matter. Methylmercury and organic C concentrations are often positively correlated in lacustrine waters (Driscoll et al. 1995), and high concentrations of MeHg have been observed in many types of organic C–rich environments. However, because of a myriad of pathways through which organic matter influences the processes controlling methylation, measuring organic C as TOC, DOC, or specific ultraviolet absorbance (SUVA) is informative but not predictive of Hg methylation. "DOM" is a general term that includes the variable and complex ligands that actually bind Hg. However, the units are generally measured in C concentrations (DOC or TOC). We use DOM to refer to both dissolved organic matter that adsorbs ionic Hg and to dissolved organic C that serves as an electron donor for bacterial activity.

In the absence of sulfide, DOM strongly complexes Hg(II) (Ullrich et al. 2001; Haitzer et al. 2002, 2003; Hsu-Kim et al. 2013). In freshwater systems, Hg-DOM complexes are relatively stable; hence, a large portion of Hg(II) is bound to DOM. At equilibrium, DOM can decrease the bioavailability of Hg to methylating microorganisms (Miskimmin et al. 1992; Barkay et al. 1997; Gorski et al. 2008). However, the kinetics of Hg-DOM complexation, rather than its thermodynamic stability, may ultimately control availability to methylating microorganisms (Miller et al. 2009; Chiasson-Gould et al. 2014). For example, Graham et al. (2012) showed that the addition of DOM to mildly sulfidic systems, which would otherwise limit the availability of Hg for methylation, resulted in greater MeHg production. Under nonequilibrium conditions, Chiasson-Gould et al. (2014) showed DOM enhanced Hg(II) bioavailability to bacteria and proposed that Hg(II) becomes less available over time (i.e., within 24 h) due to a series of ligand exchange reactions with some of the thousands of various compounds that comprise DOM and cell membranes (Brown and Markich 2000).

Perhaps the most important and yet poorly understood kinetic species controlling Hg methylation are Hg sulfide (HgS)-DOM nanoclusters. These complex and dynamic species, observed in laboratory studies (Deonarine and Hsu-Kim 2009; Slowey 2010; Gerbig et al. 2011), consist of clusters of particles 10 nm to 100 nm in size. Within this size range, they either pass through the polymer membranes or sorb to smaller pore-sized, metal-oxide membranes that are typically used to filter water, confounding the interpretation of dissolved versus particulate THg analytical determinations (Slowey 2010). HgS-DOM nanoclusters likely play a role in controlling Hg bioavailability when DOM and sulfide are present, which are the same conditions (i.e., anaerobic sulfate-reducing) in which most Hg methylation occurs (Zhang et al. 2012). Dissolved organic C slows but does not prevent the precipitation of Hg(II) and S(-II); rather, DOM facilitates the nucleation of β-HgS (metacinnabar) that is thermodynamically less stable compared to larger and more crystalline α-HgS (cinnabar) (Slowey 2010; Gerbig et al. 2011). Once formed, such nanocrystalline HgS can be redissolved by DOM, after which the newly formed Hg-DOM complexes could be bioavailable to methylating microorganisms (Ravichandran et al. 1998; Ravichandran et al. 1999; Waples et al. 2005).

By forming sorption complexes with Hg, particulate organic C (POC), as well as metal oxyhydroxides, can transport Hg in Hg-contaminated systems such as mine drainage streams (Kim et al. 2004; Lowry et al. 2004; Slowey et al. 2005) and industrial sites (Gagnon et al. 1997; Rolfhus et al. 2003; Bloom

et al. 2004). Settling of particulate sorbed Hg can be a major pathway for Hg transport into the zone of methylation (i.e., sediment) (Lamborg et al. 2002).

Iron. Iron is a redox sensitive element that interacts with S species in anaerobic environments. Fe(III) oxyhydroxides are a common oxidant for S(-II) (Reis et al. 1992; Poulton et al. 2004), and Fe(III) addition to sediment has been hypothesized to decrease MeHg production in sediments by 2 mechanisms. First, it favors Fe-reducing microorganisms rather than sulfate-reducing microorganisms and may shift microbial communities away from ones that are capable of Hg methylation (Derek et al. 1986). Second, it may react with S species to alter the bioavailability of inorganic Hg (Mehrotra and Sedlak 2005). Mehrotra et al. (2003) observed declines in MeHg production from Fe(II)-amended wetland sediment relative to untreated sediment. The authors of this study hypothesized that Fe(II) reaction with S(-II) regulated the concentrations of neutral Hg species [HgS(aq) and $Hg(HS)_2$], which are proposed to be the dominant species available for methylating microorganisms (Benoit, Mason, Gilmour 1999; Benoit et al. 2001). Reactions between Hg(II) and FeS(s) (mackinawite) may result in reduction of Hg(II) to Hg(0), which is volatile, thus reducing exposure to methylating micro-organisms (Bone et al. 2014).

Selenium. Selenium impacts Hg methylation and MeHg uptake into organisms by limiting the availability of Hg for methylation (Jin et al. 1997; Belzile, Chen et al. 2006; Truong et al. 2013). For example, a laboratory incubation study of surface lake sediments from China exhibited slower Hg methylation and faster demethylation at higher solid-phase Se concentrations (Jin et al. 1997). When *Psuedomonas fluorescens* was grown with both Se and Hg, the presence of Se significantly reduced the accumulation of Hg, likely due to the formation of inert Se-Hg complexes such as nano-HgSe clusters, which are analogous to HgS but less soluble (Belzile, Wu et al. 2006). In the presence of both Hg and selenide, laboratory results indicate that the formation of mercuric selenide appears to limit bioavailability of both Se and Hg to SRB (Truong et al. 2013).

In addition to the effect on Hg methylation, an antagonistic effect of Se on both inorganic Hg and MeHg uptake into aquatic food chains has been reported (Khan and Wang 2009). The molar ratio of Se:Hg in fish tissue appears to influence the toxicity of either element, with a ratio greater than 1 purported to limit Hg toxicity to fish consumers (Ralston et al. 2007; Ralston and Raymond 2010). A strong antagonistic relationship between Se and Hg was also reported from lakes in Sudbury, Canada, an area impacted by release of metals due to mining and smelting (Chen et al. 2001). Significant inverse relationships between Se and Hg in perch and walleye tissue were observed, and authors found that Hg concentrations in the fish from lakes near the smelter (where Se concentrations were higher) were low compared to other boreal shield lakes in the region. Also in this region, Se greatly reduced the assimilation of Hg into organisms throughout the food chain (Belzile, Chen et al. 2006). Although Se:Hg ratios greater than 1 are considered protective, some studies have shown wide ranges of Se:Hg ratios in individual freshwater fish from a single site, making it difficult to designate a general ratio for use in risk assessments (Burger et al. 2012), although site-specific assessment may be valuable.

pH. Much of the early research on Hg cycling in the environment focused on lakes experiencing acidification due to atmospheric deposition of S dioxide and N oxide and elevated Hg concentrations in fish tissue. Low pH has generally been thought to stimulate the methylation of Hg (Grieb et al. 1990; Suns and Hitchin 1990; Wiener et al. 1990; Winfrey and Rudd 1990; Driscoll et al. 1994; Watras et al. 1998). Although Winfrey and Rudd (1990) found no significant effect of pH on Hg demethylation rate, other researchers have shown a positive correlation between pH and demethylation rate (Grieb et al. 1990; Suns and Hitchin 1990; Winfrey and Rudd 1990; Miskimmin et al. 1992; Driscoll et al. 1994). However, Gilmour and Henry (1991) concluded that the response was variable, indicating complex interactions between changes in Hg availability and microbial activity.

Similarly, Julian and Gu (2015) concluded that pH and other bulk chemical parameters such as alkalinity, conductivity, and sulfate could be linked to bioaccumulation of Hg in fish, but effects were variable and not well predicted without further insight from more detailed site characterization. Acidic conditions may increase or decrease the ability of Hg to bind to particulate matter and potentially be transported to sediments (Benoit et al. 2001). By itself, pH is not a reliable predictor of methylation or bioaccumulation.

Temperature. The rate of Hg methylation increases with increasing temperature (within the range of ambient conditions) due to an increase in biological activity and chemical reaction rates. For example, Callister and Winfrey (1986) reported a 3-fold increase in methylation rate in Wisconsin, USA, lake sediments incubated in the laboratory when the temperature was increased from 20 °C to 35 °C. Wright and Hamilton (1982) reported a 50% to 70% increase in Hg methylation for temperature increases of 4 °C to 20 °C in lake sediments from Northwestern Ontario in Canada. As summarized by Ullrich et al. (2001), the rate of Hg methylation in aquatic systems typically peaks during the summer months, indicating the strong influence of temperature on overall Hg methylation.

Wetting and drying. Wetting and drying can have a major impact on Hg methylation in soils and sediments. This hydrologic cycling impacts biological activity due to the resulting effect on the O_2 concentration and alternate electron acceptors such as sulfate, the availability of organic C, and the abundance of nutrients. For example, the State of California, USA, investigated 74 reservoirs, mostly impacted by mining wastes, and found that the magnitude of water-level fluctuation was 1 of 3 factors that statistically explained the variability in MeHg concentration in fish (CWB 2013). The 2 other factors were the dissolved THg concentration and the ratio of dissolved MeHg to chlorophyll *a*, which was considered to represent the magnitude of MeHg entering the food web. While this relationship appears to hold at this particular set of similar reservoirs, it is not readily translatable to other sites.

Also in California, managed wetting and drying has been shown to increase sediment and aqueous MeHg concentrations at rice paddies, compared to nonagricultural, permanently flooded and seasonally flooded wetlands (Windham-Myers et al. 2014). Periodic flooding of rice paddies provides abundant water, nutrients, and continuous production of

labile organic C to drive microbial activity. Although flooding promoted MeHg production in the short term, extended flooding promoted the degradation and sequestration of MeHg due to increased concentrations of solid-phase reduced S that lowered Hg bioavailability.

In Everglades, Florida, USA, wetlands, rewetting of dried soils stimulated MeHg production and elevated MeHg concentration in surface water and sediment porewater (Gilmour et al. 2004). Drying of the sediment promoted the oxidation of sulfides in sediment, resulting in high levels of sulfate that were available to SRB upon rewetting. Furthermore, rewetting of sediment also remobilized particle-bound Hg, making additional Hg available for methylation by SRB.

Overall, the cycle of wetting and drying of sediments and soils, especially in managed reservoirs or wetlands, appears to stimulate net MeHg production because it regenerates key reactants such as sulfate, labile DOM, and bioavailable Hg. Further effort is needed to address the potential role of other redox active elements (e.g., Fe, Mn) in regulating MeHg during wetting and drying cycles. The increased MeHg production in managed freshwater reservoirs and wetlands should not be assumed for estuarine tidal marshes that undergo wetting and drying on a diurnal basis, due to differences in hydrodynamics, frequency, and geochemistry. For example, in a comprehensive study of THg and MeHg flux from a Chesapeake Bay tidal marsh in Maryland, USA, Mitchell et al. (2012) reported that the marsh was a net sink for THg and a relatively small net source of MeHg to the estuary, primarily during the growing season.

"New" versus "old" Hg. Mercury that is freshly deposited from atmospheric deposition to freshwater systems appears to be more available for methylation than is Hg that has been present in an environment for a longer period of time (Hintelmann et al. 2002; Chadwick et al. 2013). The variation in reactivity has been demonstrated through the use of enriched stable Hg isotopes applied to a whole lake system (Harris et al. 2007). Newly added Hg was more readily methylated (Harris et al. 2007), volatilized by reduction (Amyot et al. 2004), and available for ligand exchange (Hintelmann and Harris 2004) than was "old" Hg. As the "new" Hg aged, its reactivity declined to that of old Hg in the system. Recent work by Chiasson-Gould et al. (2014) suggests a mechanism to explain the greater bioavailability whereby newly deposited Hg(II) is sorbed to DOM and taken up into aquatic food webs within 24 h of deposition.

In the Everglades, Gilmour et al. (2004) used additions of stable Hg isotopes to examine the influence of sulfate concentration on methylation of new and old Hg in mesocosms with sediments from a low-sulfate Everglades location. Moderate concentrations of sulfate stimulated methylation of new Hg but had little effect on methylation of old Hg (Figure 2).

For legacy sites with elevated Hg concentrations, new Hg from atmospheric deposition is negligible from a mass balance standpoint; however, it may be more rapidly methylated and bioaccumulated than Hg already present in the system. The relative contributions of new and old Hg to bioaccumulation at Hg-contaminated sites has not been assessed, but stable Hg isotope research may provide such insight in the future.

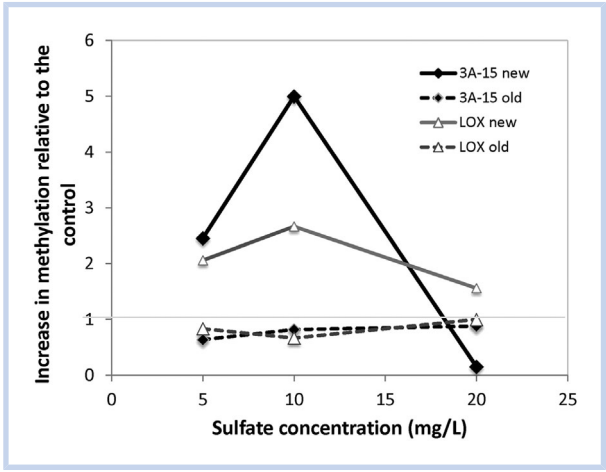

Figure 2. Stimulation and inhibition of Hg methylation in Everglades, Florida, USA, sediments from 2 sites (3A-15 and LOX) based on "new" and "old" Hg measurements. Moderate concentrations of sulfate stimulated methylation of new Hg but had little effect on methylation of old Hg.

Bioaccumulation and exposure pathways

Methylmercury enters the food web through primary producers (e.g., uptake by algae or periphyton) or detritivores and accumulates at each trophic level in a process called "biomagnification." The initial entry of MeHg from water to the food chain is the largest step in biomagnification. For example, the concentration of MeHg in Onondaga Lake, New York, USA, phytoplankton (on a wet weight basis) was 5 orders of magnitude greater than the concentration in filtered water samples (Becker and Bigham 1995). Oligotrophic systems are more susceptible to Hg biomagnification than are eutrophic systems because the lower abundance of primary producers (plankton) in oligotrophic systems results in more concentrated uptake (i.e., less surface area for the uptake of an equivalent mass of dissolved MeHg) (Chen and Folt 2005). The growth rates and lifespans of the organisms inhabiting a system will also affect the ultimate levels measured in the organism themselves. Fast-growing organisms tend to accumulate less MeHg than do more slowly growing organisms, and organisms with longer lifespans tend to accumulate more MeHg (Jenssen et al. 2010).

Consumption of fish is the dominant pathway of Hg exposure to humans (Mergler et al. 2007). Historically, there has been some occupational exposure related to Hg mining or production processes using elemental Hg (e.g., Hg cell chlor-alkali facilities), and humans can be exposed by inhalation of elemental Hg or by incidental ingestion of Hg-contaminated soils and dusts (Nusslein et al. 1995; Davis et al. 1997). Consumption of fish and/or aquatic invertebrates is also the dominant pathway of Hg exposure to most ecological receptors (Tsui et al. 2014); however, recent work suggests that consumption of terrestrial invertebrates (e.g., insects) (Newman et al. 2011) may be an important pathway in some environments.

CASE STUDIES: FACTORS AFFECTING MERCURY METHYLATION AT HG-CONTAMINATED SITES

Three Hg-contaminated sites in the United States—Onondaga Lake (New York), South River (Virginia), and Oak Ridge (Tennessee)—have been the focus of considerable research and monitoring over the past 20 y. Although each is a freshwater system, they vary greatly in physical and chemical

characteristics, Hg source, and management strategy. Nevertheless, they share common factors that impact Hg methylation.

Onondaga Lake

Onondaga Lake is located near Syracuse, New York, and received Hg-containing effluents from the operation of 2 Hg cell chlor-alkali plants. Both plants began operation in 1947; the first plant ceased operation in 1977 and the second in 1988 (Todorova et al. 2009). Remediation of upland sources including the 2 former plant sites, the creek that transported Hg to the lake, and contaminated groundwater (by installation of a barrier wall and groundwater collection and treatment) has significantly reduced releases to the lake (USEPA 2015). Dredging and capping of nearshore sediment was conducted, and natural attenuation of mercury concentrations in sediment underlying deep water continues in order to address sediment as a potential source of Hg to water and biota. In addition, since 2004, increased nitrate loads from the regional wastewater treatment plant (due to installation of a denitrification system to reduce ammonia discharges) have helped limit MeHg concentrations in the anoxic bottom waters of Onondaga Lake during summer stratification (Todorova et al. 2009; Matthews et al. 2013). For microorganisms, nitrate reduction is more energetically favorable than is Fe or sulfate reduction. As a result, once O_2 is depleted in the stratified bottom waters, nitrate can displace Fe and sulfate reduction and therefore can limit Hg methylation and its release from profundal sediment.

The temporal behavior of nitrate, sulfide, and MeHg in Onondaga Lake during stratification demonstrated suppression of sulfate reduction as a major factor limiting MeHg concentrations in the lake (Todorova et al. 2009). Depletion of nitrate was followed by build-up of sulfide and increased MeHg concentrations in the hypolimnion. No nitrate-reducing microorganisms have been found to methylate Hg, so MeHg concentrations remained low as long as nitrate reduction prevailed. Under the supervision of New York State Department of Environmental Conservation (NYSDEC), a 3-y pilot test confirmed that nitrate addition to Onondaga Lake resulted in very low MeHg concentrations in the hypolimnion (Matthews et al. 2013). In conjunction with treatment plant upgrades to reduce ammonia, P, and organic C loading to Onondaga Lake, nitrate addition was accepted by NYSDEC as a means to limit MeHg concentrations in the lake and is currently being implemented during summer months.

South River

South River is a high-gradient and cool-water river located in Virginia. Substrates at South River are primarily composed of coarse materials such as cobbles and boulders with occasional bedrock exposures. From 1929 to 1950, mercuric sulfate was used for the production of acetate flakes and yarn at an industrial facility in Waynesboro, Virginia, along the bank of the river (Carter 1977). During the course of operation, thousands of kilograms of Hg-containing waste were released into the South River, contaminating the river and its floodplain (Flanders et al. 2010). Although use of Hg at the facility stopped more than 60 y ago and Hg loading from this legacy site has declined (Eggleston 2009), MeHg concentrations in fish tissue continue to exceed the USEPA national recommended water quality criterion of 0.3 μg/g in fish tissue (Eggleston 2009).

Biogeochemical and physical conditions of South River typically are not considered optimal for MeHg production. For example, the river has low sulfate and DOM concentrations as well as relatively low abundance of fine-grained substrates. As such, there has been tremendous effort to decipher the physical and biogeochemical controls that impact the fate of Hg and methylation at this site.

Multiple researchers have noted that perpetual river-bank erosion is a key mechanism that transports inorganic Hg into the river, leading to persistent Hg contamination of fish (Flanders et al. 2010). For example, Yu et al. (2012) reported that fine-grained sediment derived from riverbank erosion had higher MeHg concentrations than did coarse sediments from the river, indicating that eroding materials are potential hot spots for methylation. Flanders et al. (2010) found that floodplain soils released more inorganic Hg upon aqueous extraction, compared to fine-grained sediment from the river. The majority of the inorganic Hg released from the floodplain soils was colloidal in nature (Flanders et al. 2010) and was considered to be an ongoing source of Hg(II) for methylation. Sequential extraction coupled to X-ray absorption fine structure (XAFS) analysis showed that Hg speciation in the river-bank sediments mainly consisted of β-HgS with significant amounts of more soluble Hg phases (0.4–33 μg/g) (Desrochers 2013). Desrochers (2013) also conducted erosion simulation experiments that showed that high concentrations of Hg (up to 80 μg/L in water) could be released from riverbank soils.

Although sulfate concentrations are low, there is molecular evidence that sulfate reducers are active, at least seasonally, at the South River (Yu et al. 2012). Sediment RNA extracts showed at least 3 active groups of SRB in South River sediments. A group of Fe reducers was also found in RNA extracts, suggesting a potential role of Fe-reducing bacteria to methylate Hg. Addition of both poorly crystalline Fe oxyhydroxide and sulfate to South River sediment enhanced the Hg methylation rate (Yu et al. 2012). This study shows that both sulfate and Fe-reducing bacteria coexist in South River sediment and likely contribute to Hg methylation. Addition of sulfate and lactate to laboratory columns packed with South River sediments resulted in stimulation of SRB and subsequent production of MeHg (Desrochers et al. 2015). Finally, Yu et al. (2012) reported that demethylation rates were lower than rates found in other systems, which would also contribute to higher net methylation at the South River.

Oak Ridge

During the 1950s and 1960s, roughly 11 million kg of Hg was used at the Y-12 National Security Complex at the Oak Ridge Reservation in Tennessee (Brooks and Southworth 2011). Approximately 108 000 to 212 000 kg of Hg was released into the headwaters of East Fork Poplar Creek (EFPC), which led to high Hg concentrations in floodplain soils and sediments along EFPC on the Oak Ridge Reservation property (Barnett et al. 1995; Campbell et al. 1998; Liu et al. 2006; Jardine 2008). Although remediation is ongoing, a substantial amount of Hg has already been transported downstream (Campbell et al. 1998). Up to several hundred parts per million Hg has remained in the top 8 cm of soil (Barnett et al. 1995), enough of which is accessible to bacteria to induce the expression of detoxification genes (Oregaard and Sorensen 2007).

Although most of the Hg is likely immobilized within EFPC soils in insoluble Hg-sulfide phases, sporadic flooding and anaerobic processes in EFPC soils release Hg that is accessible to methylating bacteria, thus posing long-term ecological risk (Jardine 2008).

Although the occurrence and amount of S(-II) in EFPC is currently unknown, HgS(s) has been found in floodplain soils (Barnett et al. 1997), demonstrating that HgS(s) formed as a secondary phase. The creek contains on the order of 100 μM (~10 mg/L) sulfate (Dong et al. 2010), which is enough to support microbial sulfate reduction but not necessarily enough to impede Fe(III) reduction (Fleming et al. 2006; Kerin et al. 2006). The fact that MeHg is measurable downstream of EFPC (Campbell et al. 1998) suggests that environmental conditions are suitable for sulfate reducers or Fe(III) reducers.

Several researchers have studied the role of DOM on the bioavailability of Hg at EFPC (Miller et al. 2009; Dong et al. 2010), where DOM concentrations range from 2.5 to 3.5 mg/L. Even at this relatively low concentration of DOM, Hg that complexed to S or thiol-like functional groups of DOM appears to control Hg speciation (Dong et al. 2010). Miller et al. (2009) noted that the reaction between Hg and natural DOM is kinetically controlled and complex because of the heterogeneous nature of natural DOM. That is, equilibrium conditions cannot be assumed when assessing Hg speciation at the creek. The importance of Hg interaction with DOM at EFPC has been established; however, the net effect of DOM on Hg methylation is unclear.

Extensive remedial action has taken place at Oak Ridge Reservation and has resulted in the reduction of inorganic Hg concentrations downstream of EFPC (Southworth et al. 2000). However, MeHg concentration in fish has not declined and remains above the USEPA national recommended water quality criterion of 0.3 μg/g fish tissue. At the Oak Ridge Reservation, neither THg concentration nor dissolved inorganic Hg concentration correlates to MeHg concentration, indicating the importance of factors other than THg (e.g., biogeochemical factors) (Dong et al. 2010).

Summary of case studies

Substantial research at Onondaga Lake, the South River, and EFPC has yielded valuable information for understanding and managing Hg-contaminated sites. Identification and control of ongoing releases of Hg was a first step at all 3 sites and is ongoing at South River and EFPC. The primacy of this step is consistent with USEPA (2005) guidance on contaminated sediment remediation. At Onondaga Lake, MeHg concentrations in stratified bottom water resulted from redox conditions suitable for MeHg production in bottom sediment and release into the hypolimnion. When the oxidative potential in overlying water was increased by nitrate addition, MeHg concentrations declined substantially, thereby reducing the exposure to fish at fall turnover. At the South River, ongoing releases from bank erosion were identified as a primary cause for elevated fish tissue concentrations, and remedial measures to control erosion are underway. At EFPC, fish tissue concentrations remain elevated despite reductions in total Hg concentrations.

TARGETED PARAMETERS FOR SITE ASSESSMENT

The first step in managing Hg-contaminated sites is to identify and eliminate, to the extent practicable, ongoing sources of Hg to the system. Then efforts can be focused on understanding the nature, extent, and potential for net Hg methylation and bioaccumulation (Figure 3). Many of the geochemical controls on Hg methylation (and ultimately on bioaccumulation) have confounding effects on the overall process (Table 1) and would require extensive evaluation to decipher their roles at a particular site. Such a detailed analysis is unnecessary for a general understanding of Hg methylation at most sites.

The following parameters were identified as both straightforward to measure and valuable to interpreting the potential

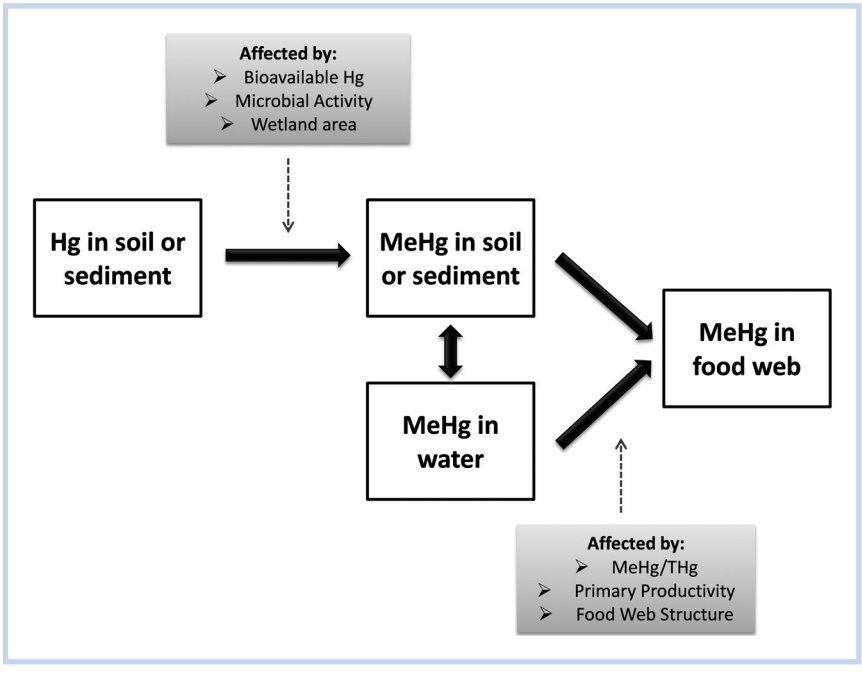

Figure 3. Targets for Hg site assessment. THg = total mercury; MeHg = methylmercury.

Table 1. Effect of geochemical and physical parameters on factors affecting Hg methylation

Geochemical or physical parameter	Bioavailable Hg	Microbial activity	Wetland area	Notes
S	+/–	+	NA	Bioavailability can both increase and decrease based on chemical species formed. The presence of increased sulfate can stimulate activity of sulfate-reducing bacteria, which cause methylation.
Organic C	+/–	+	NA	Organic C can decrease availability through the binding of Hg or increase availability through increased mobility in bound forms. Microbial activity may be enhanced due to the presence of increased electron donors.
Fe	–	+/–	NA	Fe can reduce and bind Hg, making it less bioavailable. It can increase microbial activity through alleviation of toxicity but may shift microbial activity away from methylating populations.
Se	–	–	NA	Se decreases bioavailability of Hg through formation of insoluble selenites.
pH	+/–	+/–	NA	Bioavailability is reduced at high pH, and a pH between 4.5 and 9 is optimum for microbial activity.
Temperature	NA	+/–	+/–	Bacteria have optimal temperatures for growth.
Oxygen availability	+	–	NA	Reduced compounds of Hg tend to be unavailable. Hg methylation occurs under reducing conditions.
Wetting and drying	+	+	+/–	Wetting and drying cycles can increase the release of Hg from particles and provide sulfate to stimulate SRB activity.

SRB = sulfate-reducing bacteria.

for Hg methylation and bioaccumulation: site characteristics, sediment Hg and MeHg concentrations, operationally defined available Hg, and microbial activity, where practical. The measurement of DOC, TOC, and total suspended solids (TSS) also may be helpful and are suggested for measurement due to their relatively low cost. At any site, expenditures for site characterization should be appropriate for the size of the site. For small sites with substantial Hg concentrations, the most expensive remedial action (e.g., removal of contaminated material) may cost less than gathering the data needed to develop a detailed scientific basis for less extensive remedial measures. However, the cost of removal at a large site may be prohibitive, and thorough site evaluation may provide a basis for more effective and efficient remediation and monitoring.

Site characteristics

Site characterization typical of remedial investigations often will provide important information for developing site-specific hypotheses about Hg transport, methylation, bioaccumulation, and risk. First, all point and nonpoint sources to the site must be considered, including background concentrations, especially in urban areas. Remedial investigations at numerous sites have taken much longer than first expected because of difficulties in locating significant sources. For example, the South River site required many years of intensive investigation to understand that erosion of contaminated floodplain soils was a continuing source of new Hg that was methylated in the riverbed. Sites that historically used elemental Hg can be particularly difficult to interpret, because in the presence of O_2, the surfaces of elemental Hg beads in sediments and soils and in building sewers and sumps form an oxide coating (Miller et al. 2015) that is much more soluble than elemental Hg, thus creating a persistent Hg source.

Characterization should include a general understanding of hydrology, redox conditions, and sediment transport. Each of these characteristics has the potential to influence how Hg behaves. For example, hydrological factors, including wetting and drying, affect Hg transport (Liang et al. 2014) and methylation. Another key physical characteristic controlling Hg methylation is the amount of standing water relative to active streams (Krabbenhoft et al. 1999; Yee et al. 2008). Although active streams are typically aerated, standing water is often associated with accumulated sediment and organic debris conducive to microbial activity, anaerobic conditions, and Hg methylation. Standing water could include larger contiguous bodies such as impounded wetlands as well as small-scale riparian zones. Typically, an understanding of redox conditions in sediment will also shed light on the potential for Hg methylation. Because sulfate reduction (and thus MeHg production) occurs under anoxic conditions where sulfate is available, peak MeHg concentrations tend to be at the interface of oxic and anoxic conditions where sulfide produced during sulfate reduction is re-oxidized to sulfate and available again for sulfate reduction. This zone is usually within the top few centimeters of a sediment profile but may be deeper if there is substantial bioturbation, resuspension, or other processes that aerate the sediment column. With respect to sediment transport, erosion of bank or sediment may be a source of ongoing Hg releases to a water body, fine sediment is usually indicative of a depositional environment (and is often correlated with THg and MeHg concentrations), and undisturbed sediment layers such as in cores from the deeper zone of Onondaga Lake may demonstrate natural recovery (i.e., burial of contaminated sediment by cleaner material).

Mercury and methylmercury concentrations

Mercury and MeHg concentrations in biota, sediment, and water provide important information on Hg behavior, methylation, and bio-accumulation. Measurement of Hg concentrations in biota is a direct method for assessing

bioaccumulation potential at a site. For relevance in risk assessment, sampling would include recreationally important fish species for human health risk assessment and important prey species for ecological risk assessment. Although THg in sediment does not necessarily predict the potential for human and ecological exposure, an understanding of the range and distribution of Hg within a site is a fundamental starting point to focus further analyses. Additionally, Hg and MeHg concentrations in water can be important indicators of potential transport and bioaccumulation. Water MeHg concentrations have been correlated to fish concentrations on a site-specific basis in reservoirs (CWB 2013) and, in some systems (i.e., those where accumulation is based on exposure to water via plankton), can be used as an indicator of potential food web exposure.

The ratio of MeHg to THg in sediment has been widely reported to be a strong predictor of net methylation and thus potential Hg bioaccumulation, but the ratio is not constant, and MeHg concentrations tend to plateau at higher THg concentrations. Cossa et al. (2014) recently proposed a Michaelis-Menten–type relationship between THg and MeHg in sediments, which would account for this plateau. Michaelis-Menten is a standard depiction of an enzymatic (i.e., biological) reaction involving a single substrate (in this case, THg) that reaches saturation, meaning that further increases in substrate concentration do not result in an increase in reaction rate (in this case, rate of Hg methylation). The shape of the curve is described using the height of the plateau (Vm) and the substrate concentration at which half of the plateau height is reached (Km). Cossa et al. (2014) focused on a variety of sediment types (marine, freshwater, deep, and surface), plotted MeHg versus THg, and fit a curve to the Michaelis-Menten–type equation. River sediments (the only freshwater sediments in the study and approximately 10% of the total sediments) had low correlations ($R^2 = 0.38$) between MeHg and THg, compared to other categories.

For comparison, published surface sediment data from the 3 previously discussed case studies (Oak Ridge, South River, and Onondaga Lake) were plotted using the approach described by Cossa et al. (2014), and the results (Figure 4) show wide variability in predicted MeHg plateau concentrations but consistent trends within each single site. For example, the 2 samples circled on the plot have very similar THg concentrations and are both river surface sediment samples (South River and EFPC), yet their MeHg concentrations differ by more than an order of magnitude, showing the importance of site-specific characteristics. As noted previously, the South River exhibits higher than expected rates of Hg methylation. This is apparent from Figure 4, where both South River samples plot well outside the typical values found by Cossa et al. (2014) (and, in fact, above the MeHg concentration asymptote defined for their equations). One hypothesis for this variation is the presence of an unusual fraction of highly available Hg continually replenished through bank erosion along the South River. Similarly, Onondaga Lake MeHg concentrations plateau above approximately 1 μg/g THg, well below the plateau described in Cossa's data.

The Onondaga Lake and Oak Ridge EFPC MeHg concentration trends are an order of magnitude lower than the 2 South River samples with similar THg concentrations. Sequestration of Hg as HgS(s) and consequent low bioavailability of inorganic Hg(II) to methylating bacteria may explain the lower MeHg concentrations at these sites compared to South River. Methylmercury concentrations at Onondaga Lake and EFPC, based on the data in Figure 4, would never be expected to reach MeHg concentrations similar to those found in South River, regardless of THg input. Because of differing site characteristics, remediation at these sites may require different THg endpoints in order to reach similar MeHg concentrations.

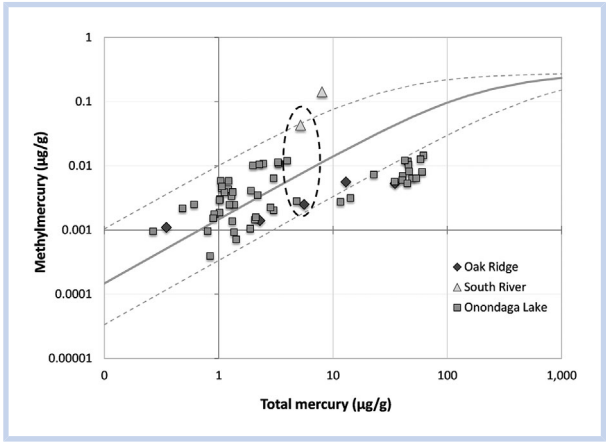

Figure 4. Data from selected sites plotted for comparison with the Michaelis-Menten relationship proposed by Cossa et al. (2014). The dashed circle shows 2 samples with comparable total Hg concentrations but methylmercury values that differ by more than an order of magnitude. The solid and dashed lines represent the curves for $K_m = 188$ (overall fit) and $K_m = 26.5, 825$ (lower and upper 95% confidence interval) determined by Cossa et al. (2014).

We recommend that a new site investigation begin with an initial survey of THg and MeHg concentrations in surface sediment. The results can then be plotted as shown in Figure 4, with or without the Michaelis-Menten half-saturation values as reference (Cossa et al. 2014). This type of plot clearly indicates those samples with the highest methylation efficiency and the THg concentration above which MeHg concentrations plateau.

Available mercury

Although THg concentration is relevant for any investigation of Hg-contaminated soils and sediments, the fraction available for methylation and, ultimately, for accumulation in the food web is of particular importance. As discussed in the previous sections, the geochemistry of the surrounding soil, sediment, or water controls the chemical speciation of inorganic Hg and, therefore, its bioavailability. Because the interactions among Hg, organic matter, and various inorganic constituents are complex, several operationally defined methods have been developed to quantify the Hg fraction that is available for methylation. Identification of the particular chemical species is less important than understanding the overall "available" Hg concentration. In all methods discussed here, the relative amounts in each fractional category are reported in the context of the THg concentration.

Dissolved Hg. In contrast to methods that focus on Hg speciation within the sediment itself, measurement of dissolved Hg in interstitial porewater may serve as a better indicator of the readily bioavailable and mobile fractions of Hg (Zhang and Davison 1995; Hsu-Kim et al. 2013). Besides traditional methods that directly measure chemical concentrations in extracted porewater, technologies such as passive

samplers are being developed to measure dissolved Hg and MeHg. For example, passive sampling with diffusive gradient in thin films (DGTs) has been tested for measurement of bioavailable Hg in river water (Fernández-Gómez et al. 2011) and to measure labile porewater concentrations of MeHg and estimate net methylation rates in sediment (Clarisse et al. 2011). Interpretation of DGT data is challenging because the estimated concentrations of Hg or MeHg are controlled by diffusive rate assumptions and, in the case of Hg, can be strongly influenced by the presence of organic matter. In conjunction with measurements of THg and MeHg in the solid phase, dissolved concentrations can be used to calculate partition coefficients (K_Ds) that indicate the solubility of THg and MeHg. High K_Ds indicate that inorganic Hg is likely bound to the solid phase and less available for methylation.

Chemical extraction techniques to identify the bioavailable fraction of Hg(II) that is reactive with stannous chloride (Marvin-DiPasquale et al. 2006) and with sodium tetraethylborate (Liang et al. 2013) have been developed to quantify bioavailable Hg. More recently, Ticknor et al. (2015) developed a thiol-based sediment extraction technique that uses glutathione to identify bioavailable Hg, mimicking the mechanism involved in Hg binding to methylating bacteria. Results of thiol-based extractions correlated with MeHg production in microcosm methylation experiments using multiple forms of Hg (Ticknor et al. 2015).

Sequential extraction. Two methods, EPA 3200 (USEPA 2014) and the 5-step Selective Sequential Extraction Procedure (Bloom et al. 2003), use a series of sequentially stronger extractants to separate more and less soluble fractions of Hg in a soil or sediment sample. The fractions are then analyzed for THg. The EPA method divides Hg into 4 operationally defined fractions:

1) extractable organic Hg,
2) extractable inorganic Hg,
3) semimobile Hg, and
4) nonmobile Hg.

In general, the extractable inorganic Hg fraction, which includes species such as Hg chloride and Hg nitrate, is considered to be the pool of Hg available for methylation.

Bloom et al. (2003) separated the sample into 5 fractions:

1) F1—water soluble,
2) F2—weak acid soluble,
3) F3—organo-complexed,
4) F4—strong complexed, and
5) F5—mineral-bound.

Tests of the extracts suggest that inorganic Hg extracted in the F4 and F5 fractions is negatively correlated to the fraction of MeHg in sediments (Bloom et al. 2003). Determination of a large Portion of THg in the strongly complexed or mineral-bound fractions can explain why some sites, such as those impacted by Hg mining, have low MeHg (i.e., low availability of Hg for methylation) despite high THg concentrations.

X-ray absorption fine structure spectroscopy. Another approach for identifying the major Hg species in sediment or soil is XAFS. The XAFS spectra can directly reveal the oxidation states and molecular-scale coordination chemistry of Hg (Newville 2001). From this information, one can identify specific chemical forms and abundances of various Hg species. Minor Hg species may not be detected using XAFS, though they might be an important reactive phase. When samples are not subjected to chemical treatments prior to data acquisition, XAFS can provide insightful and direct information on in-situ speciation. The XAFS analysis can complement other operationally defined techniques such as sequential extraction (Kim et al. 2003). However, XAFS measurements require specialized equipment, training, and a synchrotron radiation facility. They are unlikely to be useful as a first-line site assessment method but may be critical for more detailed investigations in which sequestration of Hg in insoluble phases needs to be understood and documented.

DOC, TSS, and TOC

Although DOC concentration in water is not an absolute predictor of Hg methylation or MeHg concentrations (Cossa et al. 2014), it is a straightforward and relatively inexpensive laboratory measurement that may provide important site-specific indicators of methylation potential. As discussed in the context of Oak Ridge, a site-specific correlation between DOC and Hg may provide information about sites of potential elevated Hg methylation. For this reason, it is recommended that DOC in water be measured as part of Hg site assessment. Similarly, TSS in water is routinely analyzed and is essential for interpreting water data for MeHg and especially for THg due to the generally high binding constant for inorganic Hg to particles. Elevated THg concentrations in water are usually correlated with elevated TSS concentrations. Finally, TOC in sediment is a standard site-characterization parameter and often can help to explain patterns of sediment THg and MeHg concentrations. Total Hg and, to a lesser extent, MeHg bind to organic C, and their concentrations are often correlated with TOC.

Microbial activity

Another major factor in understanding the potential for Hg methylation in the environment is the metabolic activity of microorganisms. One proxy for microbial activity is the measurement of redox potential (Eh). This measurement is related to the microbial metabolism present in a specific environment and can range from oxic and nonreducing (O_2 as the terminal electron acceptor, little Hg methylation) to suboxic and mildly reducing (some sulfate reduction occurring, high likelihood of Hg methylation) to anoxic and strongly reducing (sulfate reduction may occur, but sulfide may prevent Hg from being available for methylation). Although there are more sophisticated methods to accurately quantify redox status (e.g., voltammetry), redox potential can be measured inexpensively with a sensor in the field. These results often are considered qualitative, not quantitative, but the general trends from oxic to anoxic can be helpful in predicting locations of potential Hg methylation.

Methodology to directly measure microbial methylation activity in the field is currently unavailable. One laboratory approach to understanding rates of Hg methylation involves adding stable-isotope-enriched Hg or MeHg to sediment samples. The accumulation of the spiked isotope in the

transformation product (e.g., MeHg formed from the added THg) can be measured to determine rates of methylation or demethylation. Results of such incubations may be helpful in determining potential relative methylation or demethylation rates but are unlikely to be truly representative of in-situ rates, which are spatially and temporally variable. Additionally, these are costly and labor-intensive measurements and are generally reserved for academic research.

Other research methods include enumeration of SRB and identification of Hg-methylating bacteria through genetic markers. Sulfate-reducing bacteria, the most widespread Hg methylators, can be enumerated by several commercially available standard methods, including serial dilutions or plate counts, but presence does not necessarily correlate with activity, and not all SRBs methylate Hg. Screening with *hgcAB* genes (Podar et al. 2015) holds promise for describing the distribution and abundance of Hg-methylating genes in the environment, but the applicability to routine site assessment is far off. This is an area of active research and may be an increasingly useful tool for understanding the Hg methylation potential of an environment.

RECOMMENDATIONS

As summarized in the present review, there have been significant advances in deciphering the individual geochemical factors that contribute to the methylation and, ultimately, the bioaccumulation of Hg. While there is no single definitive measurement or equation to quantitatively predict MeHg concentrations, site managers can consider the parameters described in this review in a logical order for designing investigations into the nature and extent of Hg contamination. Understanding site characteristics and the nature of the Hg sources, both point and nonpoint, is the obvious starting point. The form of Hg contamination, whether Hg(II), Hg(0), HgSs, or more unusual forms such as fulminate [$Hg(CNO)_2$], has a strong influence on its availability to be methylated in sediment or soil and can often be deduced from the site history.

The nature of sediment or soil is also a key consideration to guide evaluation of the extent of contamination. Fine-grained substrates typically are more favorable for Hg methylation than are coarse-grained substrates because they tend to contain less oxygen, which is a favorable environment for methylating bacteria. Methylation and methylmercury concentrations tend to be very low in oxic sediments and soils. This generalization, however, can be strongly influenced by other processes, such as the wetting and drying observed in California reservoirs or the continual supply of Hg-contaminated floodplain soil to the South River. Much can be learned by simply plotting THg and MeHg sediment concentrations. Comparing the MeHg and THg results to data from other sites and to the framework developed by Cossa et al. (2014) can provide additional insight on the availability of THg for methylation, including the Hg concentration above which MeHg concentration tends to plateau. If needed, measurements of microbial activity and Hg speciation can help explain anomalous results.

Evaluating potential remediation at Hg-contaminated sites should not rely on THg measurements alone. Ultimately, project managers will need to understand the potential risk to human health and the environment (USEPA 2005), which will entail evaluating exposure pathways and the concentrations of Hg in food sources (e.g., fish). Assessment of THg, MeHg, and a few supporting parameters in sediment provides important information on the site-specific availability of Hg for methylation and of MeHg for bioaccumulation. This site-specific information, along with a broader understanding of biogeochemical controls on MeHg, will help to support identification of cleanup goals and potential remedial actions for Hg-contaminated sites.

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Effects of Dryout and Inflow Water Quality on Mercury Methylation in a Constructed Wetland

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Abstract The sulfate input and the occurrence of dryout and rewetting may promote the production of toxic methylmercury (MeHg) in a constructed wetland, Stormwater Treatment Area 2 (STA-2) in South Florida. Therefore, the aim of this study was to investigate the influences of inflow water quality, especially inflow sulfate, and the dryout and rewetting cycle on the mercury (Hg) methylation in three independent cells of STA-2 from 2000 to 2007. Because the majority of the total Hg (THg) bioaccumulated in fish is in MeHg form, THg concentration in mosquitofish was used to present the MeHg production in STA-2. Mosquitofish THg in Cells 1 and 2 (with median values of 0.101 and 0.02 mg/kg, respectively) were significantly higher than in Cell 3 and inflow (both with a median value of 0.01 mg/kg). The difference in mosquitofish THg among the three cells was likely a result of the drying and rewetting cycles occurred in Cells 1 and 2, which promoted the Hg methylation. Inflow sulfate, inorganic Hg, and chloride exhibited a significant correlation with mosquitofish THg in cells, suggesting that these inflow variables played important roles on the Hg methylation. The results indicate that inflow sulfate may likely stimulate sulfate-reducing bacteria and subsequently lead to produce MeHg in the three cells. Our findings in this study indicate that preventing the occurrence of dryout in wetland will help to decline the Hg methylation, and sulfate input is a key factor to influence the Hg methylation in wetland.

Keywords Wetland · Mercury · Methylation · Sulfate · Dryout

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1 Introduction

Due to its characteristics, such as low melting and boiling points, mercury (Hg) is a globally spread pollutant and released from both natural and anthropogenic sources (Hylander and Meili 2003). As a result of centuries of anthropogenic activities, such as mining and fossil fuel burning, the global atmospheric Hg deposition rate is approximately three times greater than in preindustrial times, leading to increased concentrations in freshwater systems and biota even in remote areas that are free from direct anthropogenic impacts (Ullrich et al. 2001). Hg contamination generally only becomes a

global environmental concern when the methylation of inorganic Hg (IHg) to methylmercury (MeHg) occurs. As a potent neurotoxin, MeHg is the most toxic form of Hg in the environment. Owing to its lipophilic and protein-binding properties, MeHg is also the only Hg compound that is readily bioaccumulated and biomagnified in the food web, which may also pose a threat to humans and other fish-eating animals (Ullrich et al. 2001; Hylander and Meili 2003).

In situ production of MeHg via microbial methylation is the primary source of MeHg to the most aquatic systems (Gilmour and Henry 1991; Gilmour et al. 1992). As far as we know, sulfate-reducing bacteria (SRB) are widely accepted as the primarily methylators of Hg methylation (Compeau and Bartha 1985; Gilmour et al. 1992; Ullrich et al. 2001). SRB thrive in oxygen-free and carbon-rich environments, degrade organic matter, and reduce sulfate to sulfide in both freshwater and estuarine sediments (Ullrich et al. 2001). The formation of MeHg produced in the environments depends on factors that control SRB population growth or metabolic function (Winfrey and Rudd 1990; Gilmour and Henry 1991; Ullrich et al. 2001) and on the bioavailability of Hg for SRB (Ullrich et al. 2001). The significant ecological factors include dissolved organic carbon (DOC) (Ullrich et al. 2001; Aiken et al. 2003), SO_4^{2-}/S^{2-} (Benoit et al. 1999, 2001; Ullrich et al. 2001), pH (Winfrey and Rudd 1990; Regnell 1994; Ullrich et al. 2001), and temperature (Bodaly et al. 1993; Ullrich et al. 2001), which put effect on the microbial growth. The bioavailability of Hg for SRB is likely influenced by complex ligands in environments, such as chlorides (Barkay et al. 1998; Ullrich et al. 2001), sulfides (Benoit et al. 1999, 2001; Ullrich et al. 2001), and organic compounds (Barkay et al. 1997; Ullrich et al. 2001; Aiken et al. 2003), which determine the ability of Hg to cross the microbial cell membranes. Wetlands particularly possess many environmental factors that promote Hg methylation and are recognized as "hot spots" for MeHg production (Gilmour et al. 1992; St. Louis et al. 1994; Branfireun et al. 1999). Besides, the dryout and rewetting cycle in wetland has been found to enhance Hg methylation and microbial sulfate reduction, thereby causing increased Hg methylation in the wetlands (Dmytriw et al. 1995; Gilmour et al. 2004b). Furthermore, Ackerman and Eagles-Smith (2010) reported that agricultural wetlands are potential hot spots for MeHg contamination due to their periodic flooding schedules.

Sulfate at 60 to100 times that of background levels (≤1 mg/L) is delivered to the Everglades in the runoff from Everglades Agricultural Area (EAA) (Orem 2004). Stormwater Treatment Areas (STAs), which are a system of large treatment wetlands, shallow and freshwater marshes, are constructed primarily to remove total phosphorus (TP) from the EAA runoffs before it is discharged to the Everglades Protection Area (Chimney et al. 2000). About 70 % of TP loads was removed through STAs (Orem et al. 2011), but little has been done to reduce sulfate contamination of the ecosystem (i.e., only about 11 % sulfate reduction) (Orem 2004; Orem et al. 2011). Except for the sulfate input, the cycle of dryout and rewetting occurred during the operation in some of STAs, for example, the drought occurred in the early operation period of Stormwater Treatment Area 2 (STA-2). The objective of this work was to investigate the Hg issue in STAs; STA-2 taken as the example for this study. The work included two parts: (1) the effect of dryout and rewetting on the production of MeHg in STA-2; and (2) the relationship between inflow water quality variables and the MeHg production in STA-2, especially the impact of inflow sulfate load on the Hg methylation. This study can obtain the insight into the factors influencing on the Hg methylation and help to better manage and resolve the MeHg issue in the constructed wetlands.

2 Materials and Methods

2.1 Study Area

STA-2 is located in Western Palm Beach County, Florida, immediately west of Water Conservation Area 2 (WCA-2) (Fig. 1), and is divided into four parallel north-south treatment cells with a total surface area of approximately 8,000 ac before 2012 (Cell 4 is constructed in 2007 with about 2,000 ac). Water from flow structures Station 6 (S-6) and Gate 328 (G-328) enter the supply canal and are conveyed southward to the inflow canal, which extends across the northern perimeter of the STA-2. A series of inflow culverts convey water from the inflow canal to the respective treatment cells. Water then flows southward through the treatment cells and eventually discharges into the discharge canal via culverts or gated spillways. The outflow pump station Gate 335 (G-335) conveys water to WCA-2.

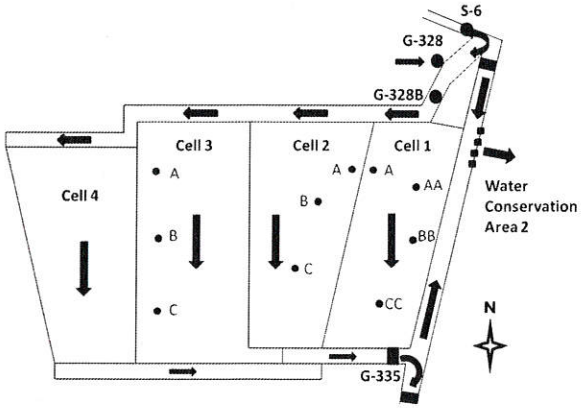

Fig. 1 Schematic diagram of structures and flows at Stormwater Treatment Area 2 (STA-2) before 2012, not to scale. S-6 and G-328 are the inflow structures, G-328B is a sample location in the supply canal, and G-335 is the outflow station

2.2 Data Collection and Analytical Methods

As a condition of its operating permits, the South Florida Water Management District (District) is required to monitor Hg in surface water quality at various locations throughout the Everglades Protection Area. The unfiltered water samples of inflow S-6, G-328, and G-328B (located in the supply canal) were collected biweekly for water quality analysis, including total Hg (THg) and MeHg analyses. The inflow fish was semi-annual sampled in the supply canal. The fish sample in every cell was collected monthly if the fish was available. The fish sampling points for the three cells were showed in Fig. 1; four sampling points (A, AA, BB, and CC, respectively) in Cell 1 and three sampling points (A, B, and C, respectively) both in Cells 2 and 3.

Since only Cells 1, 2, and 3 in STA-2 operated during the study period (from 2000 to 2007), Cell 4 was not included in this study. The following inflow water variables, including sulfate, pH, DOC, temperature, chloride, and IHg (THg minus MeHg), were selected to discuss the influence of inflow water quality on the Hg methylation in the constructed wetland, and the inflow sulfate was the focus of the water quality variables in the present study (Table 1).

It is found that greater than 95 % of THg in fish tissue is in the MeHg form (Celo et al. 2006; Grieb et al. 1990). Furthermore, the analysis of fish tissue for THg, which is a more straightforward and less costly procedure than the analysis for MeHg, can be interpreted as being equivalent to the analysis of MeHg (Fink et al. 2005). Therefore, the fish THg in cells was to represent the in situ MeHg production in the constructed wetland in the present study. The three species of fish, mosquitofish (*Gambusia holbrooki*), sunfish (*Lepomis spp.*), and largemouth bass (*Micropterus salmoides*), were sampled for determining THg bioaccumulation in fish. Among the three species of fish, the mosquitofish is at the low trophic level, which is the prey fish for sunfish and largemouth bass; hence, the THg biomagnifications in sunfish and largemouth bass are greater than in mosquitofish, making the THg data in sunfish and largemouth bass more complicated than in mosquitofish. Moreover, widespread occurrence in the Everglades, relatively small home range, rapid population turnover, and short life span (average life span only 4 to 5 months) make mosquitofish adjust to new condition more rapidly than the populations of sunfish and bass that are longer-lived (Fink et al. 2005; Rumbold and Fink 2006). These characteristics make the mosquitofish a potentially excellent representative indicator of short-term, localized changes in MeHg through time (Fink et al. 2005; Rumbold and Fink 2006). Therefore, in the present study, mosquitofish THg was treated as the MeHg bioindicator. At each sampling site, between 75 and 250 mosquitofish were collected; the individual fish was stored on ice, refrigerated for not more than 48 h, and then composited and homogenized using a Polytron® apparatus. Thereafter, the homogenate was frozen prior to shipment on blue ice or double-bagged wet ice to the Florida Department of Environmental Protection (FDEP) mercury clean laboratory.

All data of the inflow water quality variables and THg in mosquitofish tissue used for this work were obtained from the District's DBHYDRO database (www.sfwmd.gov/dbhydro). Data were generated by the District and the FDEP, both of which are certified by the Florida Department of Health under the National Environmental Laboratory Accreditation Program. For analytes other than THg and MeHg, surface water analyses were conducted by the District's analytical chemistry laboratory on field-preserved samples using standard methods. THg determination in surface water was carried out using US Environmental Protection Agency (USEPA) Method 1631 (Mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry) or a modification of Method 1631. Moreover, THg determination in fish tissue followed either the USEPA Method 245.6

Table 1 Characteristics of multiple inflow water quality variables (sulfate, IHg, chloride, DOC, pH, and temperature) from 2000 to 2007

Inflow water quality parameters	Range	Median	Mean	SD	95 % confidence interval
Sulfate (mg/L)	39.31–110.10	58.16	59.93	14.04	56.66–63.21
IHg (ng/L)	0.21–2.95	0.91	1.06	0.55	0.94–1.19
Chloride (mg/L)	87.62–342	202	197.17	52.66	184.89–209.46
DOC (mg/L)	20.8–43.92	34.02	33.77	5.76	31.93–35.62
pH	6.77–8.06	7.49	7.47	0.20	7.44–7.50
Temperature (°C)	14.31–30.91	25.5	24.95	3.58	24.4–25.5

IHg inorganic mercury, *DOC* dissolved organic carbon

(Determination of mercury in tissues by cold vapor atomic absorption spectrometry) or, if at low level, a modification of Method 1631. MeHg analysis in surface water used modified USEPA Draft Method 1630 (Methylmercury in water and tissues by distillation, extraction, aqueous phase ethylation, purge and trap, isothermal GC separation, and cold vapor atomic fluorescence spectrometry).

Quality assurance (QA) measures were incorporated during the sample collection and laboratory analysis to evaluate the quality of the data. All of the above methods use performance-based standards employing the appropriate levels of QA/quality control (QC) required by the National Environmental Laboratory Accreditation Conference, the specific reference method, and the Protocol. Laboratory QC samples included method blanks, lab-fortified blanks, matrix spikes, standard reference materials, and laboratory duplicates. Field QC samples included trip blanks, field blanks, equipment blanks, both of pre-cleaned equipment at the start of sampling and field-cleaned equipment at the end of sampling, container and processing equipment blanks, and field duplicates (Rumbold and Fink 2006).

2.3 Statistical Analysis

All statistical analyses were conducted using PASW® Statistics 18.0 (SPSS Inc., Chicago, USA). Before correlation analysis, the data of inflow water quality and mosquitofish THg concentration were log-transformed to ensure normal distribution. The correlated relationship between individual inflow water quality variable (sulfate, pH, temperature, DOC, chloride, and IHg, respectively) and mosquitofish THg in the individual cell of STA-2 was evaluated using Pearson moment correlation analysis.

3 Results and Discussion

3.1 The Effect of Dryout on the Hg Methylation in STA-2

During the monitoring period at STA-2 from 2000 to 2007, mosquitofish THg concentration in inflow varied from 0.027 to 0.003 mg/kg with a medium value of 0.01 mg/kg, while mosquitofish THg concentration ranged from 0.321 to 0.0078 mg/kg with a medium value of 0.101 mg/kg in Cell 1, varied from 0.103 to 0.003 mg/kg with a medium value of 0.02 mg/kg in Cell 2, and ranged from 0.0335 to 0.0042 mg/kg with a medium value of 0.01 mg/kg in Cell 3. Overall, during the monitoring period, there was no difference in mosquitofish THg concentration between Cell 3 and inflow (ANOVA, $p>0.05$). Nevertheless, THg concentrations of mosquitofish in Cells 1 and 2 from 2000 to 2007 were significantly greater than in inflow and Cell 3 (ANOVA, $p<0.001$ for both Cell 1 and Cell 2 compared with inflow and Cell 3). The discriminations of THg levels in mosquitofish among the three cells and inflow were pronounced (Fig. 2), the greatest in Cell 1, median in Cell 2, and the lowest in Cell 3 and inflow.

The differences in mosquitofish THg between the three cells and inflow are likely attributed to the severe drought during 2000 and 2001, which occurred in both Cells 1 and 2. Cell 1 went periods of dryout in the fall of 2000 and 2001, and Cell 2 went period dry in the summer of 2001 (Fink et al. 2005). During the severe drought of 2000 through 2001 in Cells 1 and 2, supplemental water deliveries were made to Cell 3 to prevent dryout. The process of drying and rewetting has been found to provide fuel for Hg methylation and microbial sulfate reduction, thereby causing increased Hg methylation in the wetland (Dmytriw et al. 1995; Gilmour et al. 2004b). As soil dryout leads to organic matter, iron(II), and sulfide in the surficial soil oxidized to labile organic

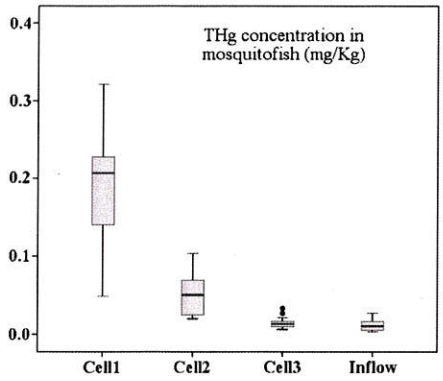

Fig. 2 Box plots for the concentrations of mosquitofish THg in the inflow and Cells 1, 2, and 3 at STA-2 from 2000 to 2007. *THg* total mercury

matter, iron(III), and sulfate, respectively (Dmytriw et al. 1995; Gilmour et al. 2004b), the rewetting of soils after dryout is accompanied by a flush release of sulfate, iron, and labile organic matter (Gilmour et al. 2004b). Following the flush release of sulfate, nutrients, and anoxic conditions, the metabolic activity of SRB is likely to be stimulated and additionally produce MeHg. Thus, the dryout and rewetting cycle made the Hg methylation in Cells 1 and 2 significantly greater than in Cell 3 and inflow, since no dryout occurred in Cell 3 and inflow.

From Fig. 3, it is seen that no clear trend existed in mosquitofish THg concentration in inflow; however, the levels of mosquitofish THg concentrations in all the three cells were decreasing until the beginning of 2004, and kept stabilized from 2004 to 2007. The trends of mosquitofish THg for the three cells indicate that the Hg methylation in all the three cells of STA-2 mainly occurred from 2000 to 2003. Similarly, the mosquitofish THg concentrations in all the three cells along with the concentrations of inflow sulfate (Fig. 4) and IHg (Fig. 5) again clearly demonstrated that the Hg methylation in all the three cells mainly occurred before 2004. Since, the buildup of sulfide (the reduction product of sulfate) and/or depletion of labile organic matter may likely end the pulse of MeHg production that follows the rewetting. The buildup of sulfide in sediment porewater appears to inhibit the Hg methylation through forming insoluble HgS, which decreases the Hg availability to SRB (Gilmour et al. 1992; Benoit et al. 1999; Orem et al. 2011). The labile organic matter provides carbon source for the metabolic activity of SRB (Gilmour et al. 1992; Ullrich et al. 2001). It comes to the conclusion that the conditions in all three cells from 2004 to 2007 were no longer fit for the Hg methylation.

3.2 The Influence of Inflow Water Quality Variables on the Hg Methylation

Since the conditions in all the three cells from 2004 to 2007 were no longer fit for the Hg methylation, accordingly, the correlated relationships between inflow water quality variables and mosquitofish THg in all the three cells were assessed until the beginning of 2004 (Table 2).

Inflow sulfate loading was negatively, significantly correlated with mosquitofish THg in all the three cells (Fig. 6), which accounted for 42, 58.5, and 50.5 % of the variations in mosquitofish THg concentrations in Cells 1, 2, and 3, respectively (Table 2). Among the inflow water quality variables, sulfate loading to STA-2 was of the most concern. The significant correlations between inflow sulfate load and the levels of mosquitofish THg in all the three cells indicate that sulfate input to STA-2 likely stimulated the activity of SRB and played a crucial role in the Hg methylation in all the three cells of the STA-2. The dual effect of sulfur on the Hg methylation, that is, the stimulation effect of sulfate and the inhibition effect of sulfide, produces the so-called "Goldilocks effect", where the levels of sulfate and sulfide are just right for the Hg methylation and the MeHg producing rate is maximum (Orem 2007). This conceptual model for the role of sulfur in the MeHg production has been verified for the Everglades by field, laboratory, and mesocosm experiments (Orem 2007). In the Everglades, Orem (2004) reported that the areas of the highest MeHg production occur where sulfate contamination is moderate (2–10 mg/L), and sulfide levels are low enough to avoid the inhibition of the MeHg formation. Gilmour and Henry (1991) proposed an optimal sulfate concentration range of 19 to 48 mg/L (optimum concentration was ~29 mg/L) for the Hg methylation by SRB in sediments, above which the methylation is inhibited and below which sulfate becomes limiting for the Hg methylation and sulfate-reduction processes. Gilmour et al. (1992) found that the MeHg production increases with sulfate concentrations up to 10 mg/L and declines when porewater sulfide exceeds 0.6 mg/L. Weber (1993) demonstrated that the Hg methylation completely stops at a sulfate concentration exceeding about 480 mg/L. King et al. (1999) observed active MeHg formation in the presence of 2.88 g/L sulfate and millimolar concentrations of dissolved sulfide. In the

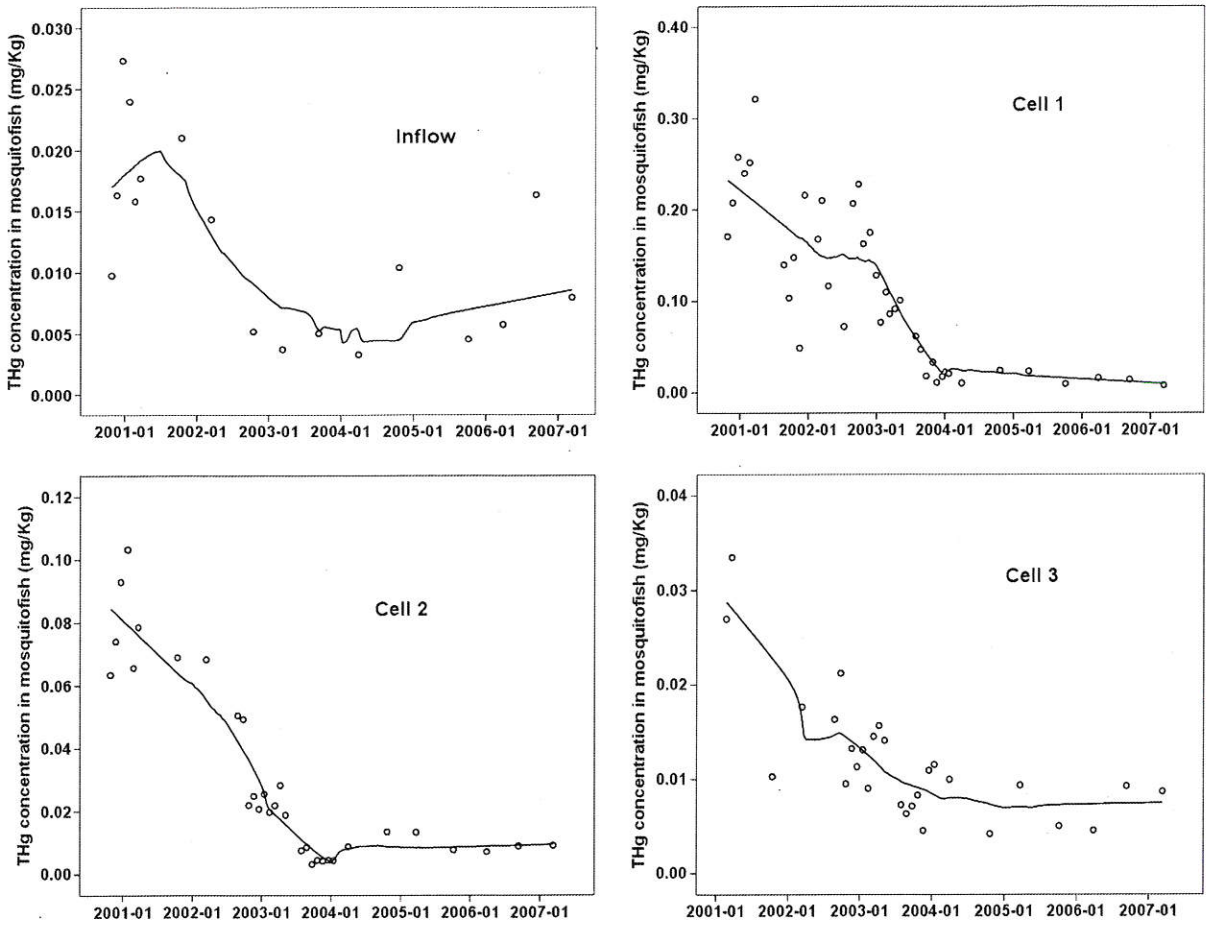

Fig. 3 Trends of the concentrations of mosquitofish THg in the inflow and Cells 1, 2, and 3 at STA-2. *Solid lines* were fitted by locally weighted regression (LOESS) in PASW Statistics 18.0. *THg* total mercury

present study, the negatively correlated relationships between inflow sulfate and mosquitofish THg in all the three cells indicate that the sulfate concentration in inflow was much greater than the optimal concentration for the MeHg production in all three cells of STA-2. Similarly, Selvendiran et al. (2008) also found a significantly negative correlation between MeHg and sulfate concentration (6.33±0.9 mg/L) during the growing season in a forested wetland, along with an increase in MeHg concentration concomitant with the decrease in sulfate concentration in wetland stream waters.

Plenty of studies have recognized that sulfate loading is an important factor in causing the increased Hg methylation in the Everglades (Orem 2004; Gilmour et al. 2007b; Corrales et al. 2011; Orem et al. 2011). Sulfur used in the agricultural application and sulfur released by the oxidation of organic EAA soils (including legacy agricultural applications and natural sulfur) are the primary sources of sulfate enrichment in the EAA canals (Orem 2004; Corrales et al. 2011; Orem et al. 2011). In general, sulfate concentration decreases from north to south in the Everglades ecosystem (Orem 2004; Orem et al. 2011). The dual effect of sulfur on the MeHg production and the north-to-south gradient in sulfate concentrations in the Everglades provide geographic context to the MeHg distributions (Orem et al. 2011). Unenriched areas of the ecosystem with sulfate concentration less than 1 mg/L exhibit low levels of MeHg due to sulfate limitation on the Hg methylation (Orem et al. 2011). In sulfate-enriched areas (concentrations more than 20 mg/L), buildup of sulfide inhibits the MeHg production (Orem et al. 2011). Areas with intermediate concentrations of sulfate (1–20 mg/L) have sulfate and sulfide levels that promote the maximum MeHg production (Gilmour et al. 2007a), where the porewater sulfide concentrations are moderate (5–150 μg/L)

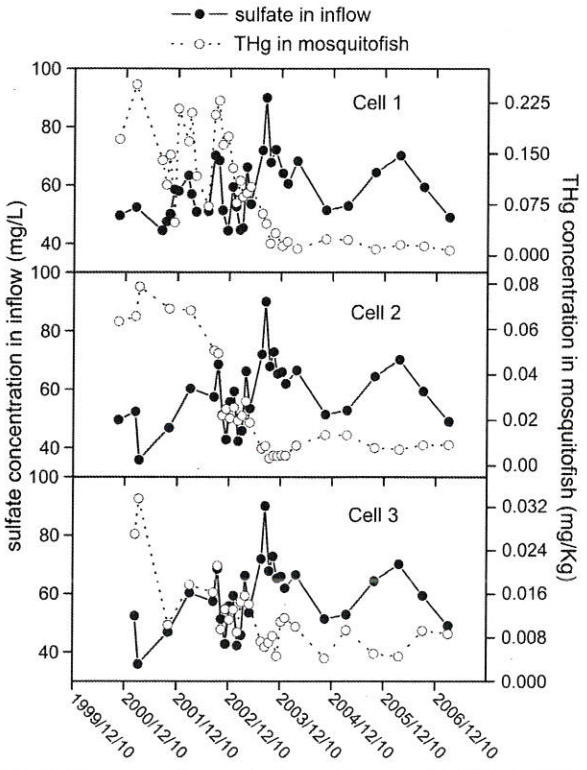

Fig. 4 The temporal concentrations of mosquitofish THg in Cells 1, 2, and 3 along with sulfate concentration in the inflow at STA-2 from 2000 to 2007. *THg* total mercury

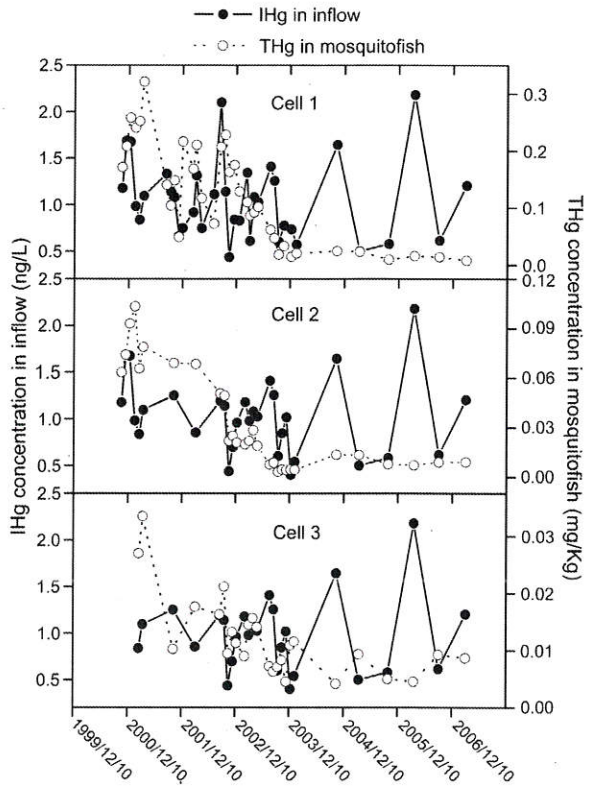

Fig. 5 The temporal concentrations of mosquitofish THg in Cells 1, 2, and 3 along with IHg concentration in the inflow at STA-2 from 2000 to 2007. *THg* total mercury, *IHg* inorganic mercury

(Gilmour et al. 1998; Orem et al. 2011). Several researchers have proposed the sulfate level in surface water to reduce the formation of MeHg in the ecosystem as much as possible. Corrales et al. (2011) recommended 1 mg/L as a sulfate threshold to control the MeHg formation in the Everglades and emphasized that above this level, particularly above 2 mg/L, the ecological risk to the ecosystem increases because at intermediate levels of sulfate, the Hg methylation is optimized. Jeremiason et al. (2006) also demonstrated that sulfate concentrations below 1 mg/L would not favor the Hg methylation process, eventually helping to depress the MeHg levels within the ecosystem as well. Likewise, Orem (2007) stated that a desirable goal for sulfate concentration in the Everglades would be approaching the background level (≤1 mg/L).

Inflow IHg was positively, significantly correlated with the mosquitofish THg in Cells 1 and 2, but not in Cell 3 (Fig. 7), and explained 48 and 51.3 % of the mosquitofish THg variations in Cells 1 and 2, respectively (Table 2). Fink (2002) reported that MeHg is likely to be synthesized primarily from the new IHg being supplied by runoff and wet and dry atmospheric deposition, not from soil release, even following a dryout event. Gilmour et al. (2004a) found that the

Table 2 The correlation coefficients between inflow water quality and THg burden in mosquitofish of the three cells

Inflow water parameters	Mosquitofish THg		
	Cell 1 *R*	Cell 2 *R*	Cell 3 *R*
Sulfate	−0.42*	−0.585**	−0.505*
IHg	0.48**	0.513**	0.171
Chloride	−0.442*	−0.511**	−0.212
pH	−0.004	−0.007	0.478*
DOC	−0.185	−0.292	−0.203
Temperature	−0.093	−0.213	−0.296

All data were log-transformed prior to the correlation analysis

DOC dissolved organic carbon, *IHg* inorganic mercury, *THg* total mercury

*$p<0.05$; **$p<0.01$

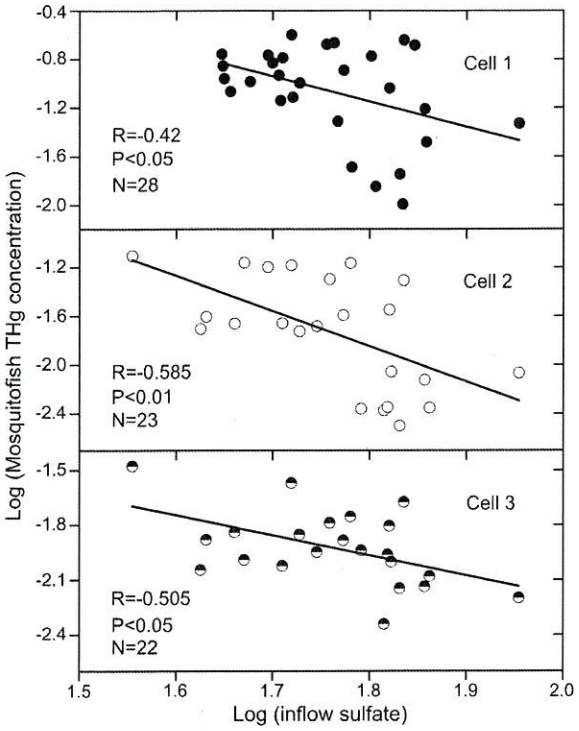

Fig. 6 Correlations between inflow sulfate and mosquitofish THg in Cells 1, 2, and 3 at STA-2 from 2000 until the beginning of 2004. *THg* total mercury

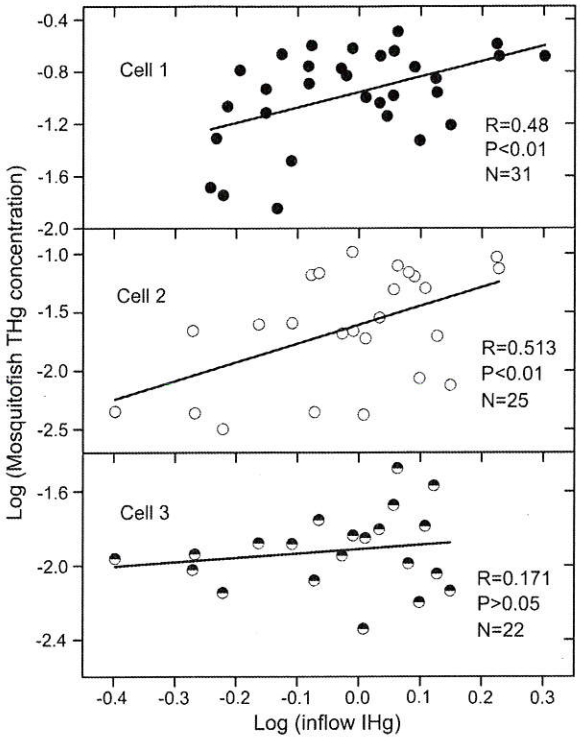

Fig. 7 Correlations between inflow IHg and mosquitofish THg in Cells 1, 2, and 3 at STA-2 from 2000 until the beginning of 2004. *THg* total mercury, *IHg* inorganic mercury

increase in MeHg in surface sediments and in fish shows a linear response to the Hg addition and suggested that the newly deposited Hg is much more available for methylation and bioaccumulation than is existing Hg in surface soils. In this study, the good correlations between inflow IHg and mosquitofish THg in Cells 1 and 2 are consistent with the findings of Fink (2002) and Gilmour et al. (2004a), indicating that the newly supplied IHg from inflow for STA-2 was the Hg source for the methylation. No significant correlation between inflow IHg and mosquitofish THg in Cell 3 demonstrates that together, too high sulfate concentration in inflow and no dryout occurrence made the capability of Hg methylation limited in Cell 3, which caused that the Hg methylation in Cell 3 likely could not respond well to the change in inflow IHg loading.

Inflow chloride was positively, significantly correlated with the mosquitofish THg in Cells 1 and 2, but not in Cell 3, and accounted for 44.2 and 51.1 % of the mosquitofish THg variations in Cells 1 and 2, respectively (Table 2). The influence of chloride on the Hg methylation is likely contributable to the competition of chloride for binding Hg, forming chloride-mercury complexes, which endow negatively charged forms (e.g., $HgCl_3^-$, $HgCl_4^{2-}$). Comparatively, the neutral form ($HgCl_2$) is more bioavailable for microbes than negatively charged forms, because its uptake by microbes is likely a passive diffusion process (Barkay et al. 1997; Ullrich et al. 2001). Barkay et al. (1997) reported that when chloride concentrations were above 1 mM, a decreased bioavailability of Hg(II) to the bioindicator was attributed to an increased proportion of negatively charged chlorine-mercury complexes. Hence, the inversely correlated relationships between inflow chloride and the mosquitofish THg in Cells 1 and 2 indicate that the concentration of chloride in inflow favored the formation of negatively charged chlorine-mercury complexes. No significant correlation between inflow chloride and mosquitofish THg in Cell 3 again suggests that the limited capability of Hg methylation in Cell 3 likely could not respond well to the change in inflow chloride loading.

No correlation was found between inflow pH and mosquitofish THg in Cells 1 and 2, but inflow pH

positively, significantly affected the mosquitofish THg in Cell 3, and accounted for 47.8 % of the variations in mosquitofish THg concentration in Cell 3 (Table 2). Generally, the Hg methylation in acidic environment is prone to be enhanced in comparison with alkaline surrounding, and elevated Hg levels in fish are commonly found in acidified lakes (Gilmour and Henry 1991; Ullrich et al. 2001). It is uncertain whether the stimulation of methylation in lake water is a direct effect of low pH on the methylation process, or whether it is related to other factors that are influenced by pH, such as the loss of volatile Hg species from water surfaces, or changes in Hg solubility and partitioning (Ullrich et al. 2001). The positive effect of inflow pH on the mosquitofish THg in Cell 3 was unexpected to occur, which maybe attributable to the unclear effect of pH on Hg methylation. In the present study, the inflow water condition was slightly alkaline, the pH value in inflow was chiefly within the scope of 7 and 8; therefore, insignificant correlation between inflow pH and the mosquitofish THg in Cells 1 and 2 may indicate that the range of inflow pH was possibly too narrow either to influence the availability of Hg to the methylating microorganisms or to impose any effect on the microbial community.

Both inflow DOC and temperature showed insignificant correlation on the mosquitofish THg in all the three cells (Table 2). The effect of DOC on the Hg methylation is complicated. DOC can both decrease and enhance the bioavailability of Hg for microbes (Gorski 2004). The Hg bioavailability can be reduced by DOC, enhancing photochemical reduction of Hg(II) to Hg^0 (Ravichandran 2004), and can be enhanced by the mixed complexes that contain both DOC and reduced sulfur groups (DOC-Hg-SH) (Hsu-Kim et al. 2005; Miller et al. 2007). DOC also can act as energy source for microbial activity to stimulate the Hg methylation (Ullrich et al. 2001). In the areas of Florida Everglades, DOC concentration is quite high in the Everglades marshes due to the high natural production of organic carbon in the peat soils and wetlands (Liu et al. 2008; Aiken et al. 2011), and DOC has been found to be strongly correlated to THg and MeHg in this region (Liu et al. 2008). However, in the present study, inflow DOC displayed no effect on the Hg methylation in all the three cells of STA-2, suggesting that the effect of inflow DOC on the Hg methylation in STA-2 was likely hard to explain because of DOC bearing the complicated property on the Hg methylation. Moderately high temperatures have been found a stimulating effect on the Hg methylation, which is most likely for the sake of the enhanced microbial activity by the increase in temperature (Bodaly et al. 1993; Ullrich et al. 2001), but in this study, no correlated relationship between inflow temperature and mosquitofish THg was observed in Pearson correlation analysis. Inflow temperature mainly ranged from 20 to 30 °C, kept relatively high and almost stable, so the narrow seasonal change in water temperature may be difficult to impact on the microbial activity noticeably.

The results indicate that inflow sulfate, IHg, and chloride were critical inflow water quality parameters influencing MeHg production in STA-2. Some studies also have evidenced the correlation between MeHg production and surface water quality. MeHg production in a temperate lake is found to be related to the Hg(II), sulfate, and DOC input to the lake (Watras and Morrison 2008).

4 Conclusion

Results from this study indicate that the drying and rewetting cycles in Cells 1 and 2 promoted the Hg methylation in STA-2, leading to the MeHg production greater than in Cell 3 and inflow, where no drying occurred. Pearson correlation results demonstrate that inflow sulfate, IHg, and chloride showed significantly correlated relationships with mosquitofish THg in cells, suggesting that these inflow variables played important roles on the Hg methylation in the cells of STA-2. The significant correlations between inflow sulfate and mosquitofish THg in all the three cells suggest that SRB were likely stimulated by the sulfate input to STA-2 and subsequently produced MeHg. And what is more, the negative impacts of inflow sulfate on the Hg methylation in all the three cells indicate that inflow sulfate concentration was much greater than the optimal concentration for the Hg methylation. Our findings in this study indicate that preventing the occurrence of dryout from wetlands will help to abate the Hg methylation, and sulfate input to wetlands is a key factor to affect the Hg methylation.

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Can mercury in fish be reduced by water level management? Evaluating the effects of water level fluctuation on mercury accumulation in yellow perch (*Perca flavescens*)

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Abstract Mercury (Hg) contamination of fisheries is a major concern for resource managers of many temperate lakes. Anthropogenic Hg contamination is largely derived from atmospheric deposition within a lake's watershed, but its incorporation into the food web is facilitated by bacterial activity in sediments. Temporal variation in Hg content of fish (young-of-year yellow perch) in the regulated lakes of the Rainy–Namakan complex (on the border of the United States and Canada) has been linked to water level (WL) fluctuations, presumably through variation in sediment inundation. As a result, Hg contamination of fish has been linked to international regulations of WL fluctuation. Here we assess the relationship between WL fluctuations and fish Hg content using a 10-year dataset covering six lakes. Within-year WL rise did not appear in strongly supported models of fish Hg, but year-to-year variation in maximum water levels (ΔmaxWL) was positively associated with fish Hg content. This WL effect varied in magnitude among lakes: In Crane Lake, a 1 m increase in ΔmaxWL from the previous year was associated with a 108 ng increase in fish Hg content (per gram wet weight), while the same WL change in Kabetogama was associated with only a 5 ng increase in fish Hg content. In half the lakes sampled here, effect sizes could not be distinguished from zero. Given the persistent and wide-ranging extent of Hg contamination and the large number of regulated waterways, future research is needed to identify the conditions in which WL fluctuations influence fish Hg content.

Keywords Mercury · Water level fluctuations · Fish · Water regulation

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Introduction

Anthropogenic methylmercury (MeHg) contamination of recreational and commercial fisheries is an on-going concern in many temperate lakes of eastern North America due to impacts on both human and wildlife health (Wiener et al. 2003; Driscoll et al. 2007, 2013). The source of this MeHg is primarily derived from atmospheric deposition of material volatilized by anthropogenic activities (e.g., coal burning power plants; Driscoll et al. 2007). Mercury (Hg) is incorporated into aquatic food webs after inorganic Hg delivered via atmospheric deposition to a watershed or directly to a lake is converted into MeHg by bacteria (Benoit et al. 2003), and so relationships between simple atmospheric deposition of Hg and Hg accumulation in fish are often complex (Munthe et al. 2007; Harris et al. 2007). Much of this methylation is done by sulfate-reducing bacteria (SRB; Benoit et al. 2003), and thus among-system variation in the supply of Hg to SRB and the spatial distribution of favorable habitats for SRB may lead to spatial variation in the availability of MeHg to food webs (Wiener et al. 2006).

Favorable conditions for SRB include anoxic, carbon-rich sediments (Benoit et al. 2003) such as those commonly occurring in wetlands (Bodaly et al. 1984; Kelly et al. 1997), or in areas that have been recently inundated (Gilmour et al.

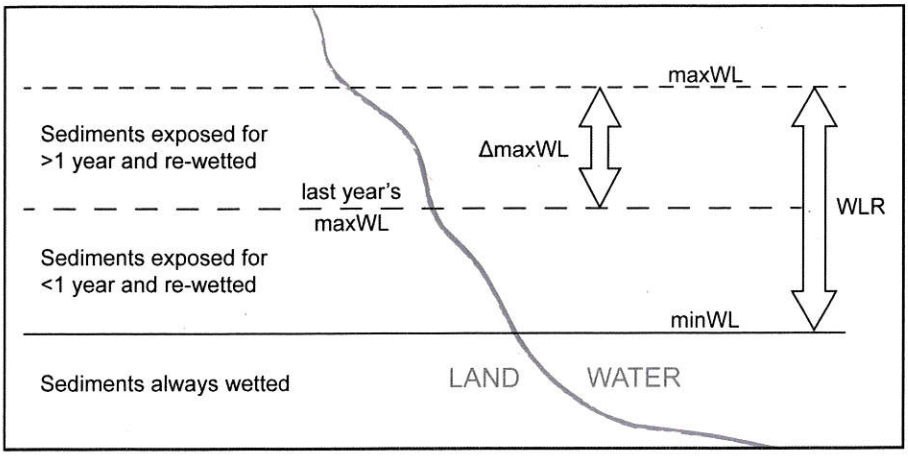

Fig. 1 Conceptual figure of hypothetical sediment classes created by WL fluctuations. Production of MeHg by SRB is hypothesized to be greatest (per unit area) in sediments that have been exposed for more than 1 year, because those sediments have accumulated relatively large quantities of sulfate and organic matter. *maxWL* maximum water level elevation, *minWL* minimum water level, *WLR* water level rise, *ΔmaxWL* change in maximum water level from last year to this year

2004). Studies have generally shown that a combination of water quality parameters associated with the supply of nutrients to SRB (e.g., sulfate concentrations) and the abundance of wetlands (which provide anoxic, carbon-rich sediments) explains much of the considerable spatial variation in fish Hg levels (Wiener et al. 2006). Many areas otherwise considered pristine (i.e., aquatic habitats draining relatively undisturbed watersheds) have high levels of Hg in their food webs because abundant wetlands provide ideal conditions for methylation (Driscoll et al. 2007).

Sorensen et al. (2005) highlighted a link between water level (WL) fluctuations and the MeHg concentrations in young-of-year (YOY) yellow perch (*Perca flavescens*) in Voyageurs National Park (VNP) and surrounding lakes, an area considered relatively pristine. Previous work has established the effect of reservoir establishment (i.e., permanent inundation) on MeHg fluxes into the food web (Bodaly et al. 1984; Kelly et al. 1997), but Sorensen et al. (2005) suggested sediments that have been exposed for months or years and are then re-wetted are a significant source of Hg inputs to the food web (Snodgrass et al. 2000; Selch et al. 2007). The drying and re-wetting of these sediments is controlled by variation in WLs, and Sorensen et al. (2005) found WL fluctuation to have a linear, positive relationship with temporal change in fish Hg content (which is mostly in the form of MeHg; Sandheinrich and Wiener 2011). Indeed, other predictors that are often found to be related to spatial variation in fish Hg were not good predictors of temporal variation in fish Hg after WL fluctuations were taken into account (e.g., total organic carbon content, pH, and Secchi depth). This finding is particularly relevant because WLs in many lakes and reservoirs can be manipulated, and thus might offer a potential management tool for reducing Hg contamination in fish.

Annual WL fluctuations create three sediment classes: sediments that are permanently inundated, sediments that are dried and re-wetted on an annual basis and sediments that are dry for more than 1 year before re-wetting (Fig. 1). These sediment classes likely differ in their production of MeHg due to differences in the delivery and accumulation of sulfur and organic carbon that affect SRB (Driscoll et al. 2013). Exposed sediments receive atmospheric deposition of sulfate and accumulate organic carbon (e.g., via plant growth; Sorensen et al. 2005), both necessary for SRB activity. Sediments exposed for longer time periods (>1 year) may be particularly important, as they not only accumulate more sulfate, but also accumulate organic carbon throughout the growing season. Based on this conceptual understanding, we predicted that either the within-year water level rise (WLR) or the change in maximum water level (ΔmaxWL) from 1 year to the next were likely to be correlated to annual MeHg production and thus annual variation in YOY yellow perch Hg content.

As is the case with many other north temperate lakes, Hg accumulation in fish is a major management issue for the U.S. National Park Service in lakes at VNP (Kallemeyn et al. 2003). WLs in Rainy Lake and the Namakan Reservoir complex (Namakan, Kabetogama, Sand Point, Crane, and Little Vermilion lakes) are actively managed via dams at the outlet of the Namakan Reservoir complex and Rainy Lake (Fig. 2) for hydroelectric power generation (at the outlet of Rainy Lake) and other recognized uses (Kallemeyn et al. 2003). WL management in this system is directed by the International Joint Commission (IJC), a regulatory body comprised of representatives from the United States and Canada.

For the purpose of hydroelectric power generation, WLs in the Namakan complex and Rainy Lake are manipulated

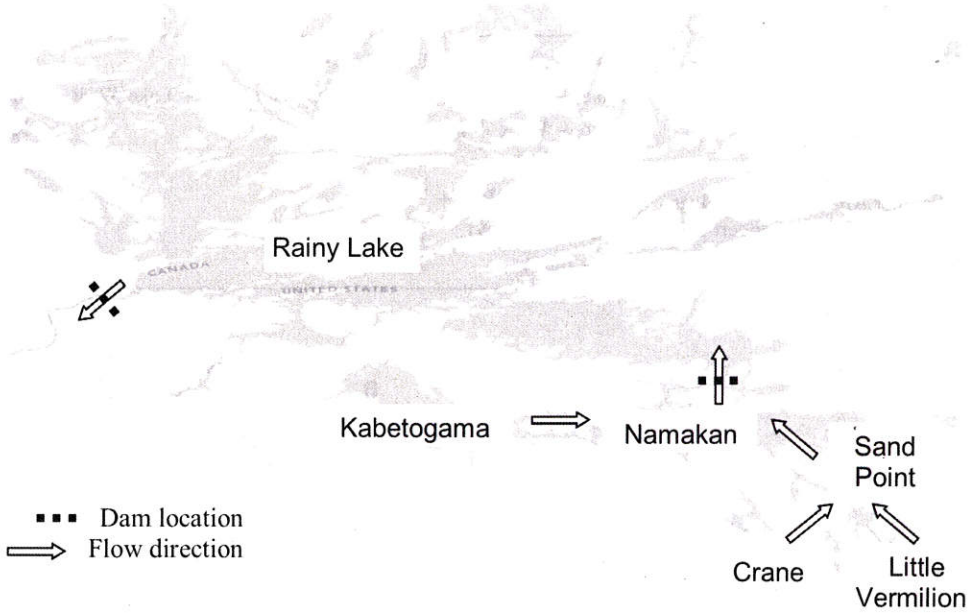

Fig. 2 Hydrologic connections and impoundments in the Rainy Lake–Namakan Reservoir complex on the border between the United States and Canada

so that WL fluctuations in Rainy Lake are reduced. This requires overwinter drawdowns of the Namakan Reservoir and a refilling of the reservoir system to capacity over the spring and summer. The IJC establishes 'rule curves' that prescribe a season-specific range of water elevation values. Dam operators then attempt to keep the water elevation within that range of values, although floods and droughts occasionally limit their success. In 2000, the IJC modified the 'rule curves' governing the range of WLs in these lakes, with the primary change being increased WLs in early spring in the Namakan Reservoir. This increase in minimum WLs also has the effect of reducing the annual WL rise, as ΔmaxWL were not significantly altered. Similar management practices occur in regulated water bodies throughout the developed world for a variety of purposes (e.g., power generation, agriculture, navigation, and waterfowl production).

The primary purpose of this study was to estimate the effects of annual WL variation on fish Hg content in regulated lakes. If the effects of WL fluctuations are evident, then the IJC's rule curves have the potential to influence Hg contamination of aquatic food webs in this reservoir system. The study by Sorensen et al. (2005) is the only analysis to document a strong relationship between annual WL fluctuations and fish Hg content. However, the Sorensen et al. (2005) study was limited to just 3 years in most lakes. Our study builds on the work of Sorensen et al. (2005) by including additional years (for a total of 10 years) on six of those lakes to evaluate whether annual WL fluctuations are related to fish Hg content.

Methods

Sample collection and analysis

Six lakes from the Rainy–Namakan complex, a subset of the lakes sampled by Sorensen et al. (2005), were sampled between 2004 and 2010 (Table 1). Fish were collected between mid-September and mid-October each year. Methods for sampling, aging and determining Hg in YOY yellow perch were the same as those reported in Sorensen et al. (2005) except that fish (between 5 and 20 per lake per year) were collected from only one site per lake. Sorensen et al. (2005) concluded that different sites within the same lake varied in the magnitude of fish Hg content, but the direction and magnitude of year-to-year variation was very similar among sites within a single lake. We incorporated the 2001–2003 data from Sorensen for the six sites we sampled for this study (site locations in S1).

Briefly, fish were collected with 15.2 or 30.5 m bag seines with 6.4 mm mesh (bar). Size thresholds for identifying YOY yellow perch were developed previously (see Appendix F1 from Sorensen et al. 2005) and those lake-specific thresholds were applied in the current dataset as well (see S1 for size thresholds).

WL metrics calculated here were similar to those used in Sorensen et al. (2005). Within-year minimum WL and maximum WL were used to calculate WLR. In addition, change in maximum WL from the previous year was calculated (ΔmaxWL). All WL data were obtained from the Lake of the Woods Water Control Board. WLs in the Rainy–Namakan lake complex follow a seasonal pattern,

Table 1 Results of model selection procedure relating WL parameters and Hg content in yellow perch

Model	−2 log likelihood	AIC[a]	ΔAIC[a]
Lake + ΔmaxWL + Lake[a]ΔmaxWL	5,908.5	5,948.5	0
Lake + ΔmaxWL + WLR + Lake[a]ΔmaxWL + Lake[a]WLR	5,904.5	5,956.5	8
Lake + WLR + Lake[a]WLR	5,920.8	5,960.8	12.3
Lake + WLR	5,938.3	5,968.3	19.8
Lake + ΔmaxWL + WLR	5,936.7	5,968.7	20.2
Lake + ΔmaxWL	5,938.7	5,968.7	20.2
Lake (*null*)	5,945.8	5,973.8	25.7

[a] Smaller AIC and ΔAIC values denote greater data support for the model in question relative to the other models

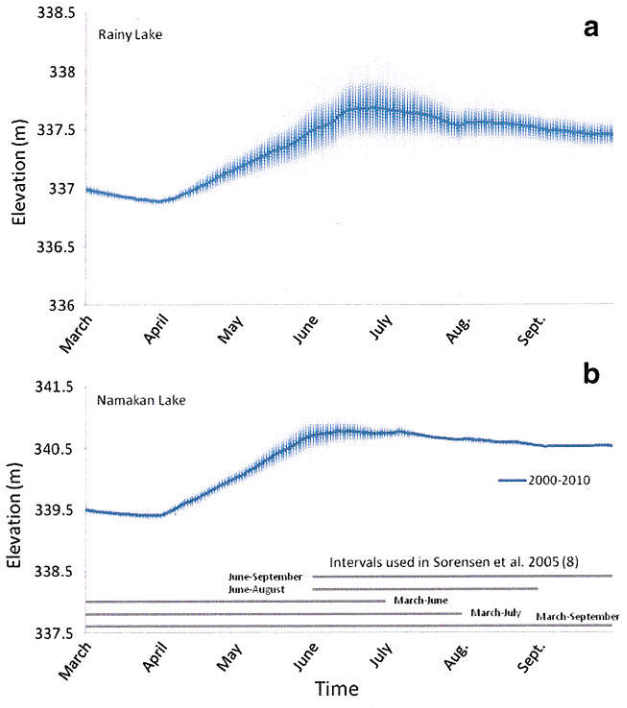

Fig. 3 Daily mean WLs (±SD) from 2000 to 2010 in **a** Rainy Lake and **b** Namakan Lake. At the bottom of **b** are visual depictions of the different intervals used in Sorensen et al. (2005) to evaluate the effect of WL fluctuations

with early-spring minimums and early to mid-summer maximums from 2000 to 2010 (Fig. 3). Sorensen et al. (2005) considered WL fluctuations over several within-year time intervals (Fig. 3). Here, we used WLR over the entire year (January–December), which turns out to be equivalent to WLR in the March–July interval used most often by Sorensen et al. (2005).

Fish Hg analysis

Methods for measuring whole-fish Hg content were identical to those used in Sorensen et al. (2005). Briefly, fish wet weight (WW) and total length are measured, then fish are dried for 24 h at 70 °C and weighed again to estimate moisture content. Length measurements were made using a ruler with 1 mm demarcations (estimates were to the nearest 0.5 mm). Weights were measured using a balance accurate to 0.1 mg. Dried fish were then shredded and ground with mortar and pestle and stored (frozen) until analysis could be completed. Total Hg was measured using USEPA method 245.6 (EPA 1991), as MeHg is generally >90 % of total Hg in fish (Sandheinrich and Wiener 2011). The detection limit for this method was ~3 ng g^{-1} WW^{-1}. Spike recovery was approximately 99 ± 4 % (SD; based on 25 spikes from 2004 to 2010 sampling efforts). Two reference standards were used: NRC Dorm2 (14 runs; recovery ranged between 98 and 105 %) and Mussel NIST 2976 (14 runs; recovery ranged between 96 and 114 %). Other details are described in Sorensen et al. (2005) for samples taken from 2001 to 2003 and reports from the analytical laboratory are available upon request.

Secchi depth, pH and chlorophyll

Secchi depth was collected at each site using methods described in Sorensen et al. (2005). Because field data sheets for 2005 have (apparently) been lost, those Secchi data were treated as missing. No pH was recorded at the time of fish sampling for years 2004–2010, so surface-water pH from mid-lake limnological sampling from 2001 to 2010 was used (US National Park Service, unpublished data). Chlorophyll concentration was also measured at a subset of these mid-lake sites as well. Chlorophyll concentrations were averaged across all sampling dates to give an index of the summer-long average. Mid-lake limnological sampling occurred monthly or bi-weekly (depending on the lake) during the growing season.

Atmospheric deposition of Hg and sulfate

Hg and sulfate deposition were measured by the National Atmospheric Deposition Program. For Hg, annual data from the Fernberg monitoring location (MN18) were obtained from their website (NADP 2012a). For sulfate, annual data from the Sullivan Bay monitoring location (MN32) were collected from their website (NADP 2012b).

Temperature data

Water temperature data are only available from mid-lake locations in these lakes and not available each year in each lake. Vertical water temperatures were taken either monthly or bi-weekly (depending on the lake). Each vertical water temperature profile was averaged, and then all of the measurements taken from May to October were averaged for an estimate of summer-long average water temperature (US National Park Service, unpublished data; water temperature profiles include in S1).

Statistical analysis

YOY yellow perch mean Hg concentration was modeled as a function of lake, year and WL using measurements of individual fish with linear mixed models. In the base model, lake effects were treated as fixed while year and lake × year effects were treated as random (variation at the observation scale occurred by lake). This was compared with models that elaborated the base model by inclusion of WLR, ΔmaxWL and their interactions with lake. We considered the base model to be an appropriate null model for comparisons to models that included WL associations. Data support for the selected models was evaluated using Aikaike's information criterion (AIC; Burnham and Anderson 1998). Smaller AIC values indicate relatively greater data support for given models; the difference between a particular model and the best model is used to rank the models (ΔAIC). Small ΔAIC values (≤2) denote strong support (relative to other models) by the data while ΔAIC values greater than ten indicate essentially no such support (Burnham and Anderson 1998). Models were fitted using maximum likelihood, and SAS's linear mixed modeling procedure (Proc Mixed; SAS 2011).

Associations between ancillary data (water quality, water temperature, Chl *a*, and atmospheric deposition) and YOY perch Hg content were not evaluated in this model selection framework due to the poor data-to-variable ratio and numerous gaps in the ancillary data. Instead a graphical approach was used that allows qualitative evaluation of the effects of ancillary data. Simply put, residuals from the base (null) model and the best model (as selected by AIC) were plotted against ancillary variables.

We estimated associations between fish length and total Hg content using Pearson's correlation statistic (both within individual lakes and among all lakes). The correlation statistic and other descriptive statistics were calculated using R (the "cor()" function). Other descriptive statistics (means, etc.) were also calculated using R. For the purpose of display, annual means were calculated for each lake-year combination: these were strongly correlated to the median (Pearson's $r = 0.997$).

Results

The Hg content of YOY perch collected during the study period varied considerably both among lakes and years (Fig. 4; S1). This variation was most strongly related to a model that included a lake-specific ΔmaxWL association with fish Hg content (Table 1; S1). Other models were only weakly supported (ΔAIC ≥ 8; Table 1). In the best model, the slope of the association between ΔmaxWL and fish Hg content varies by lake (Fig. 5; S1). Although that slope was always positive, the magnitude of the slope varied among lakes and 95 % confidence intervals overlapped zero in half the lakes sampled (Kabetogama, Little Vermilion, and Rainy; Fig. 5). In Sand Point, for example, the linear relationship between ΔmaxWL and fish Hg content had a slope of ~100 (Fig. 5f). This means that in Sand Point an increase in ΔmaxWL of 0.5 m from the previous year was associated with an increase of ~50 ng Hg g^{-1} WW^{-1} (a 50 % increase over the mean Hg content for this lake). The same increase in ΔmaxWL in Kabetogama (where the slope was ~5, Fig. 5b) would have lead to an increase of just ~2.5 ng Hg g^{-1} WW^{-1} (a 6 % increase over the mean Hg content for this lake). Overall, estimates of the magnitude (slope) of the association between ΔmaxWL and fish Hg content were greater than zero in Crane, Namakan and Sand Point lakes (Fig. 5).

YOY yellow perch growth did not appear to be strongly correlated with fish Hg content in our dataset (Pearson's $r < 0.4$ between fish length and fish Hg content) and graphical analysis suggested pH, Secchi depth, chlorophyll concentration, and summer-long average water temperature were not strongly related to model residuals. Visual inspections comparing atmospheric deposition of Hg and sulfate to residuals of the best model or the base model do not suggest these parameters are likely to explain a large portion of the annual variation in fish Hg content (see S2–S13).

Discussion

These results make a subtle but important contribution to our understanding of the relationship between WL fluctuations and fish Hg content. Although the strongest model did include WL fluctuations as a predictor variable, that model also found that WL associations with Hg were limited to a subset of the sampled lakes. Earlier analysis was not able to compare the magnitude of WL associations among lakes (Sorensen et al. 2005), but the current analysis shows that WL associations occur in only a subset of lakes.

Variation in YOY perch Hg content was associated with the year-to-year change in maximum WL, presumably because of variation in the re-wetting of sediments exposed by low WLs. Variation among lakes in WL effects could be

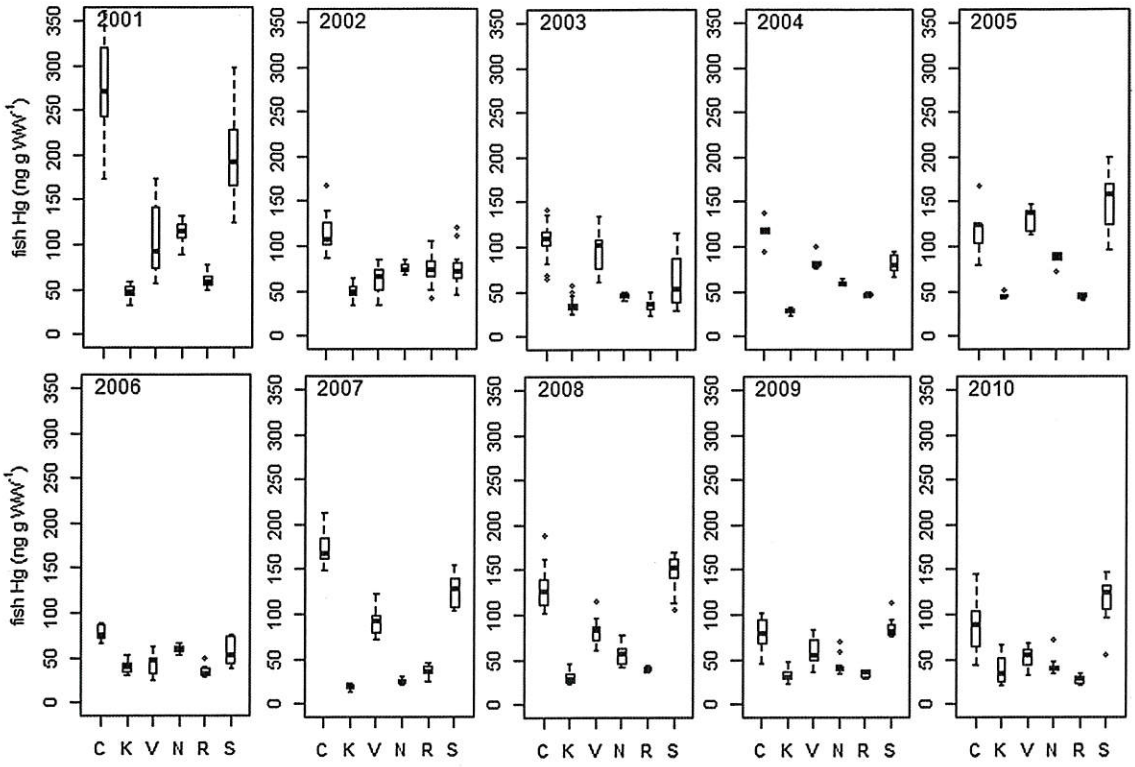

Fig. 4 *Box and whisker plots* showing median Hg content of YOY perch in lakes of the Rainy–Namakan complex from 2001 to 2010. *Boxes* encompass the first and third quartile. The *lines* (*whiskers*) show the largest or smallest observation that falls within 1.5 times the box size. Observations that fall outside the lines are shown individually. *C* Crane, *K* Kabetogama, *V* Little Vermilion, *N* Namakan, *R* Rainy, *S* Sand Point

caused by differences in shoreline characteristics of these lakes. The relationship between WL and the areal extent of exposed sediments is probably not linear in many locations. Locations or lakes with shallow nearshore bathymetries would seem more likely to be strongly influenced by WL fluctuations simply because more sediments are exposed per unit of WL decline. Detailed bathymetry of areas with <1.5 m of depth (areas most likely to be affected) are lacking for the lakes sampled here, but variation in littoral area (defined as area with <4.6 m) of these lakes does not correspond directly to variation in WL effects on fish Hg content. For example, Sand Point and Kabetogama have a similar proportion of littoral areas (Table 2) and very different associations between fish Hg content and WL fluctuations (Fig. 5). Whether "littoral" areas and the area of exposed sediments are directly correlated is unknown. Future efforts to evaluate the effects of WL in these lakes should focus on determining the areal extent of sediments exposed or inundated by WL fluctuations and characterization of those sediments.

Many other lake characteristics influence fish Hg content. The two lakes with large WL effects (Sand Point and Crane) are also the lakes with the highest mean fish Hg content (and highest among-year variability), so perhaps other conditions for high fish Hg content are necessary to detect significant WL effects. Watershed characteristics (Wiener et al. 2006), sediment characteristics (Verta et al. 1986; Bodaly et al. 2004; Gilmour et al. 2004), productivity and fish growth (Essington and Houser 2003) are all known to influence fish Hg content and vary among the lakes sampled here. Watershed and sediment characteristics probably do not change rapidly enough to drive the interannual variation under investigation here (and these data are rarely available on a yearly timescale). Fish growth and productivity certainly do vary among the lakes. For example, Kabetogama is two to three times as productive as the other large lakes in VNP (Kallemeyn et al. 2003). However, we did not observe obvious connections between Hg content and fish length in this study, and model residuals were not well correlated to a surrogate for productivity (Chl *a*). Still, these factors might influence the degree to which MeHg production in sediments contribute to MeHg in the food web, and therefore the magnitude of the WL effect on fish Hg content. Identifying the factors that control the magnitude of WL effects on fish Hg content should be the focus of future research in this area.

Each lake in this study was characterized by a single site (per results in Sorensen et al. 2005). Given our results (i.e., among-lake variation in WL effects), it may be worthwhile

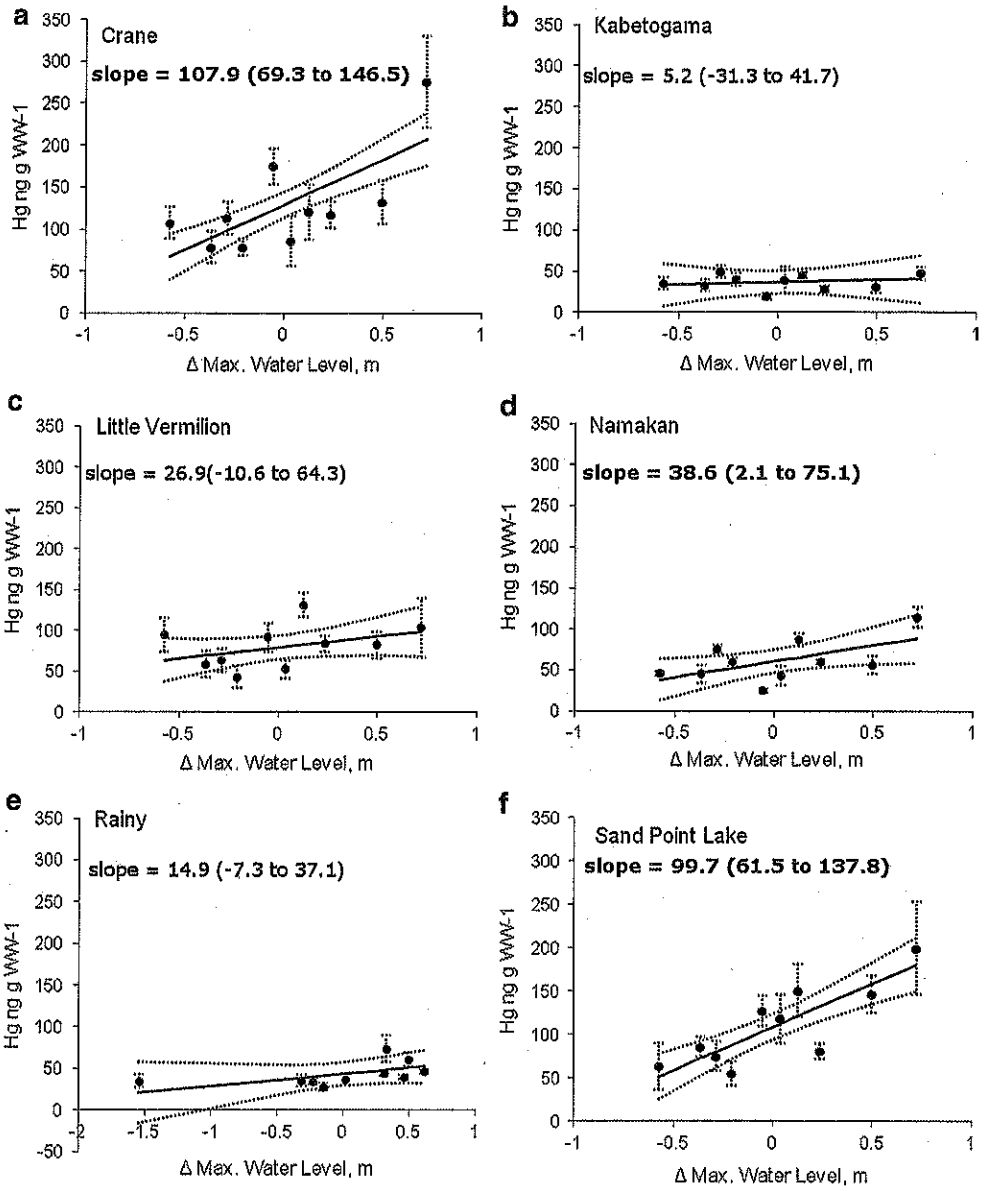

Fig. 5 Annual average Hg content of YOY perch (Hg ng g^{-1} WW^{-1}) as a function of change in ΔmaxWL in lakes of the Namakan–Rainy complex. Data includes samples from 2001 to 2010. *Error bars* denote standard deviation. *Lines* are derived from the best model relating Hg content in YOY perch to ΔmaxWL (see Table 2) with 95% confidence intervals. The slope of the relationship between ΔmaxWL and annual average Hg content of YOY perch (Hg ng g^{-1} WW^{-1}) is included on each figure with 95 % confidence interval. Intervals that do not overlap zero are highlighted in *bold*. Note altered axis scales for Rainy (e)

Table 2 Physical properties of lakes sampled for this study

Lake	Surface area[a] (ac)	Littoral area[a,b] (ac)	Maximum depth[a] (m)	Littoral:total area[a]	Average chlorophyll concentration (μg L^{-1})
Crane	2,920	618	24	0.21	3.21
Kabetogama	24,034	7,440	24	0.31	7.36
Little Vermilion	1,288	231	16	0.18	3.10
Namakan	24,066	5,026	46	0.21	2.10
Rainy	230,301	18,949	49	0.08	2.20
Sand Point	8,526	2,847	56	0.33	3.18

Average chlorophyll concentration was calculated from mid-lake limnological samples collected by the National Parks Service

[a] These data are from the Minnesota Department of Natural Resources

[b] Littoral area was calculated as areas of the lake with depth of <4.6 m (15 ft)

to examine more carefully whether site-specific (as opposed to lake-wide) characteristics influence WL associations with fish Hg content. If spatial controls over variation in the associations between fish Hg content and WL were understood, then estimates of fish Hg content under different WL management strategies could be made both in the Rainy–Namakan complex and in other regulated systems.

Conclusion

WL management for the purpose of reducing Hg accumulation in YOY perch and by proxy the rest of the aquatic food web is an attractive concept (Mailman et al. 2006). Certainly, the flooding of reservoirs leads to increased Hg in fish and other aquatic biota, apparently due to large quantities of terrestrial Hg being rapidly incorporated into the aquatic food web (Bodaly et al. 2004; Driscoll et al. 2007). Reducing the overall area of flooded terrestrial soils has thus been considered a viable strategy to reduce fish Hg contamination (Mailman et al. 2006). Mechanistically this seems similar to the drying and re-wetting of shallow sediments (Snodgrass et al. 2000; Evers et al. 2007). However, large differences in the effects of flooding on fish Hg content exist even during the initial flooding of reservoirs (when effects would be strongest) due to differences in organic matter content and morphology (Bodaly et al. 2004; Evers et al. 2007). Drying shallow sediments for a few months or a few years does appear associated with fish Hg content in some systems (Verta et al. 1986; Snodgrass et al. 2000; three lakes in this study), but appears unimportant in others (three lakes studied here). The current data are insufficient to identify the conditions necessary for annual WL fluctuations to influence fish Hg content, and thus it is not yet possible to quantitatively estimate how much different WL management regimes might influence overall Hg contamination.

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Conflict of interest The authors declare that they have no conflict of interest.

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Experimental Dosing of Wetlands with Coagulants Removes Mercury from Surface Water and Decreases Mercury Bioaccumulation in Fish

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Supporting Information

ABSTRACT: Mercury pollution is widespread globally, and strategies for managing mercury contamination in aquatic environments are necessary. We tested whether coagulation with metal-based salts could remove mercury from wetland surface waters and decrease mercury bioaccumulation in fish. In a complete randomized block design, we constructed nine experimental wetlands in California's Sacramento−San Joaquin Delta, stocked them with mosquitofish (*Gambusia affinis*), and then continuously applied agricultural drainage water that was either untreated (control), or treated with polyaluminum chloride or ferric sulfate coagulants. Total mercury and methylmercury concentrations in surface waters were decreased by 62% and 63% in polyaluminum chloride treated wetlands and 50% and 76% in ferric sulfate treated wetlands compared to control wetlands. Specifically, following coagulation, mercury was transferred from the filtered fraction of water into the particulate fraction of water which then settled within the wetland. Mosquitofish mercury concentrations were decreased by 35% in ferric sulfate treated wetlands compared to control wetlands. There was no reduction in mosquitofish mercury concentrations within the polyaluminum chloride treated wetlands, which may have been caused by production of bioavailable methylmercury within those wetlands. Coagulation may be an effective management strategy for reducing mercury contamination within wetlands, but further studies should explore potential effects on wetland ecosystems.

INTRODUCTION

Mercury contamination of aquatic ecosystems is globally extensive due to natural and anthropogenic mercury emissions and transport through the atmosphere.[1] At more localized scales, hydrologic transport of mercury from point sources, such as historic mining activity, can periodically redistribute mercury throughout a watershed and increase levels of local mercury contamination.[2] After deposition, inorganic mercury can be methylated by microbial activity into methylmercury, the form of mercury that biomagnifies through aquatic food chains and poses a health risk to wildlife and humans.[3] Aquatic environments, especially wetlands, often have biogeochemical conditions that are conducive to methylmercury production.[4−6] Thus, aquatic environments worldwide are an important nexus between inorganic mercury pollution and exposure to wildlife and humans.[1]

Regulatory policies to decrease mercury pollution and subsequent exposure to biota are ongoing at both local and global scales.[7] Although removing sources of mercury pollution would be beneficial, there would still be reservoirs of mercury in the environment that would result in secondary mercury emissions,[1] and legacy point sources that could persist for thousands of years.[2] Thus, strategies for managing local mercury contamination in susceptible aquatic environments are necessary, but there are few wetland-scale management techniques that are known to lower mercury contamination.

Several management strategies that might decrease mercury contamination include manipulating wetland habitat type and hydrology,[8,9] or treating surface waters with chemical amendments, absorbents, and coagulants.[10−13] In particular, it was recently shown that 97% of dissolved inorganic mercury and 80% of dissolved methylmercury could be removed from surface waters by applying metal-based salts to coagulate dissolved

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organic matter.[11] The coagulants interact with dissolved organic matter and suspended particles by charge neutralization, adsorption, and sweep flocculation mechanisms, transferring the dissolved organic matter, and the mercury associated with it, into colloidal and particulate forms, which subsequently can be removed from solution by settling or filtration.[14,15] Coagulation also increases particle sizes resulting in higher settling velocities.[16] Although coagulants are widely used in water treatment applications to remove impurities,[15] they have rarely been examined for use in reducing mercury contamination. The results from the laboratory study by Henneberry et al.[11] were promising, but it remains unclear whether this mercury removal efficiency could be achieved in the field when scaled up to wetlands used as natural retention systems for the flocculants produced following coagulation. Hybrid coagulation wetland treatment systems have been used to enhance removal of other water quality constituents and shown greater efficiency than using wetland systems alone.[16]

We applied coagulants in the field, under environmentally relevant mercury contamination levels, and at a wetland-scale in a hybrid coagulation wetland treatment system. Specifically, we tested whether metal-based coagulants that were applied to agricultural drainage water, and then passed through a wetland to retain particles, could remove inorganic mercury and methylmercury from wetland surface waters and decrease mercury bioaccumulation in wetland fish. In a complete randomized block design with three replicates, we constructed nine experimental wetlands and continuously applied agricultural water that had been either untreated (control), or treated with polyaluminum chloride or ferric sulfate coagulants. At the inlets and outlets of each wetland, we measured total and methylmercury concentrations in both the particulate and filtered fractions of water. Additionally, we introduced western mosquitofish (*Gambusia affinis*) into each experimental wetland and, after 4 months of exposure, we captured mosquitofish near the inlet, center, and outlet of each wetland and assessed their mercury bioaccumulation. We also compared mercury concentrations in mosquitofish within the experimental wetlands to several reference sites which were under typical agricultural operations, including fields growing white rice (*Oryza sativa*) and both irrigation source and drainage water canals.

EXPERIMENTAL SECTION

Experimental Wetland Design and Treatments. We constructed nine experimental wetlands in 2008 at Twitchell Island within the California Sacramento−San Joaquin Delta. The wetlands revegetated naturally and were dominated by cattail (*Typha* spp.). Each wetland cell was approximately 40 m long (from inlet to outlet), 15 m wide, and 0.4 m deep. Water residence time averaged 3 days (range: 2−7 days). We applied three dosing treatments in a complete randomized block design, with three replicates per treatment (see map in Figure S1 of the Supporting Information). Three experimental wetland cells received water that was treated with polyaluminum chloride coagulant (Kemira Water Solutions Inc., Finland), three wetland cells received water treated with ferric sulfate coagulant (Kemira Water Solutions Inc., Finland), and three wetland cells received untreated water and were used as controls. Locations of treatments were randomized within each of three blocks that were spatially clustered from north to south to account for any spatial trends in soil biogeochemistry or hydrology (see Figure S1 of the Supporting Information). Table S1 of the Supporting Information provides ancillary water quality data by treatment.

Coagulants were injected into pipes that imported water from an irrigation canal, which acted as a common water source (see Figure S1 of the Supporting Information). The coagulation treatments were adjusted to achieve between 60% and 80% removal of dissolved organic carbon from the source water based upon the prior results of Henneberry et al.[11] The coagulant dosing rates were monitored continuously and adjusted as needed in response to any changes in source water quality (polyaluminum chloride dose ranged from 5 to 14 mg/L as aluminum and ferric sulfate dose ranged from 13 to 26 mg/L as iron). As such, the small, nonsignificant differences observed in mercury removal between coagulant treatments at the inlets (see the Results section) were likely due to small differences in coagulant dosing rates, rather than a treatment effect. Coagulation treatments were applied continuously starting on July 5, 2012, with the exception of a 3 week period in October 2012 when the coagulation system was off-line due to equipment failures. All treatments were fully operational for at least five continuous months before any mercury sampling occurred starting in March 2013.

Fish Stocking and Fish Collection. Before introducing mosquitofish, we sampled the experimental wetland cells for naturally occurring mosquitofish and confirmed that wild western mosquitofish (*Gambusia affinis*) were present within each cell. Mosquitofish abundance was relatively low, likely because the source water was pumped through a series of screened pipes and mixers and only larval fish could have entered these newly constructed wetlands. We therefore bolstered the fish population by adding western mosquitofish into each of the 9 experimental wetland cells on March 22, 2013, after the coagulation treatments were operational for 260 days. Approximately 2000 mosquitofish were obtained from the Sacramento−Yolo Mosquito and Vector Control District's aquaculture facility (Elk Grove, California, USA) and a few hundred mosquitofish were introduced into each of the 9 wetland cells.

Nearly 4 months later from July 2−19, 2013 (102−119 days after introduction of fish; 362−379 days after experimental wetland treatments became operational), we captured wild mosquitofish from each of the 9 wetland cells using dip nets and seines. We collected 10−16 mosquitofish at each of 3 subsites (inlet, center, and outlet) within each of the 9 wetland cells. Additionally, we collected wild mosquitofish at several reference sites: the experimental wetlands' source water canal, the experimental wetlands' outlet drainage canal, the main drainage canal for all of Twitchell Island, and at the inlets, centers, and outlets of 3 reference rice fields (see Figure S1 of the Supporting Information). We stored collected fish on ice in the field and in a refrigerator overnight until they could be processed in the lab the next day. During processing, we washed each fish in deionized water and then measured its wet weight (±0.001 g) and standard length (±1 mm). Each mosquitofish was individually bagged, labeled, and frozen at −20 °C until mercury determination.

Water Sample Collection and Processing. We collected water samples monthly at the inlet and outlet pipes of each of the 9 wetland cells from March through June when mosquitofish were exposed to the experimental wetland treatments. Water sampling dates were March 26, April 23, May 20, and June 25, 2013. We collected water samples in 2 L PETG Nalgene bottles using clean techniques and immediately stored them on wet ice for transport to the laboratory where they were processed within 24 h of collection. In the laboratory, we homogenized the water sample (by shaking the 2 L bottle vigorously) and immediately poured it into a clean, Teflon vacuum filtration apparatus loaded

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with a 0.3 μm precombusted glass-fiber filter (Advantec MFS model GF-7547 mm; Advantec MFS, Dublin, California, USA). The volume of sample passed through each filter (at least two filters per sample) was recorded to the nearest mL. After filtration, we preserved the filtered water sample with ultraclean HCl (0.5% of sample volume) and stored it in the dark at room temperature until mercury determination within six months. For each water sample, we placed the two filters that were laden with sample particulates into Teflon Petri dishes and immediately froze them at −20 °C until mercury determination.

Total Mercury Determination in Fish. Methylmercury (MeHg) concentrations are highly correlated with total mercury (THg) concentrations in mosquitofish, with 94% of the THg composed of MeHg.[17] We therefore used THg concentrations as an index of MeHg concentrations. We determined THg concentrations in mosquitofish on a whole-body basis. THg concentrations were determined at the U.S. Geological Survey, Dixon Field Station Environmental Mercury Laboratory (Dixon, California) on a Milestone DMA-80 direct mercury analyzer (Milestone, Monroe, Connecticut, USA) or a Nippon MA-3000 direct mercury analyzer (Nippon Instruments North America, College Station, Texas, USA) following Environmental Protection Agency Method 7473,[18] using an integrated sequence of drying, thermal decomposition, catalytic conversion, and then amalgamation, followed by atomic absorption spectroscopy. Prior to THg analysis, each fish was dried at 50 °C for approximately 48 h until completely dried, and then homogenized to a fine powder with a porcelain mortar and pestle. See the Supporting Information for quality assurance measures.

Total and Methylmercury Determination in Water. We determined THg and MeHg concentrations in the filtered and particulate fractions of each water sample at the U.S. Geological Survey, Mercury Research Laboratory in Middleton, Wisconsin. THg concentrations in filtered water were determined according to U.S. Environmental Protection Agency Method 1631.[19] MeHg concentrations in filtered water were determined using standard distillation and ethylation procedures[20] followed by cold-vapor atomic fluorescence spectrometry. Particulate water samples were analyzed for THg and MeHg concentrations using the procedures described above; however, they required a preanalysis extraction step. Filters for THg were digested in Aqua Regia prior to analysis,[21] whereas filters for MeHg were extracted with methylene chloride prior to Hg determination.[22] We summed the Hg concentrations determined separately for the filtered and particulate water samples to calculate the Hg concentration of the whole water sample. See the Supporting Information for quality assurance measures.

Statistical Analysis of Fish. We compared THg concentrations in mosquitofish using linear mixed-effect models in three main analyses. First, we tested whether THg concentrations in mosquitofish differed among experimental wetland treatments. In this test, $\log_e$-transformed THg concentrations in mosquitofish was the dependent variable and block (1, 2, or 3), treatment (control, polyaluminum chloride, or ferric sulfate), and subsite (inlet, center, or outlet) were fixed factors, standard fish length was a covariate, and individual wetland cell was a random effect. Individual wetland cell was nested within treatment.

Second, we tested whether THg concentrations in mosquitofish differed between the experimental wetland treatments and the canal source and outlet waters. In this test, $\log_e$-transformed THg concentrations in mosquitofish was the dependent variable and habitat type (canal source, control wetlands, polyaluminum chloride treated wetlands, ferric sulfate treated wetlands, canal outlet, or Twitchell Island canal outlet) was a fixed factor, standard fish length was a covariate, and site (within each habitat type) was a random effect.

Third, we tested whether THg concentrations in mosquitofish differed between the three experimental control wetlands and the three reference rice fields. In this test, $\log_e$-transformed THg concentrations in mosquitofish was the dependent variable and habitat (experimental control wetland or rice field) and subsite (inlet, center, or outlet) were fixed factors, standard fish length was a covariate, habitat × subsite was an interaction term, and individual wetland cell was a random effect. We included the habitat × subsite interaction in this analysis because the distance (and water residence times) between the subsites were substantially greater in the rice fields than in the wetlands, and thus the differences between inlet, center, and outlet could be more substantial within rice fields as we have found elsewhere.[17]

We used the Satterthwaite method to estimate the degrees of freedom. We used Student's *t*-tests ($\alpha < 0.05$) to compare differences among groups within factors and interactions that were significant. Unless otherwise noted, we report model-based, least-squares mean ± standard error (SE) Hg concentrations based on back-transformed least-squares means ± SEs. SEs were approximated using the delta method.[23] Mean percent moisture in mosquitofish was 73.8% ($n = 508$), which can be used to convert reported dry weight (dw) concentrations into wet weight (ww) concentrations.

Statistical Analysis of Water. Similar to the fish analyses, we compared Hg concentrations in water using linear mixed-effect models. We used nine separate tests to examine whether Hg concentrations in water differed among experimental wetland treatments. The nine tests had the same model structure and differed only in the dependent variable that was tested. The dependent variables included the filtered (f) and particulate (p) forms of THg and MeHg (i.e., fTHg, pTHg, fMeHg, and pMeHg), the sum of the filtered and particulate forms of THg and MeHg (i.e., THg and MeHg), and the proportion of THg in the MeHg form for each of the filtered (fMeHg/fTHg), particulate (pMeHg/pTHg), and sum of the filtered and particulate forms (MeHg/THg). We $\log_e$-transformed Hg concentrations in water, except for the proportions which were normally distributed. Block (1, 2, or 3), treatment (control, polyaluminum chloride, or ferric sulfate), subsite (inflow or outflow), and month (March, April, May, or June) were fixed factors, treatment × subsite was an interaction term, and individual wetland cell was a random effect. Individual wetland cell was nested within treatment.

Similar to the fish analyses, we used the Satterthwaite method to estimate the degrees of freedom and Student's *t*-tests to compare differences among groups within factors and interactions that were significant in each of the nine water models and considered results statistically significant when $\alpha < 0.05$. We report least-squares mean ± SE THg and MeHg concentrations based on back-transformed least-squares means ± SEs when natural log transformations were employed. In these cases, SEs were approximated using the delta method.[23]

RESULTS

Mercury in Fish. We analyzed 508 wild mosquitofish for THg concentrations, of which 361 fish were collected within the 9 experimental wetland cells. THg concentrations in mosquitofish differed among experimental wetland treatments ($F_{2,4.02} = 9.05$, $p = 0.03$), while statistically accounting for the potential effects of block ($F_{2,4.03} = 2.83$, $p = 0.17$), subsite ($F_{2,349.30} = 0.46$, p

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= 0.63), and fish length ($F_{1,352.40}$ = 26.97, p < 0.0001). THg concentrations in mosquitofish were significantly lower in the ferric sulfate treated wetlands (n = 128 fish; 0.13 ± 0.01 μg/g dw) than in either of the polyaluminum chloride treated wetlands (n = 118 fish; 0.21 ± 0.02 μg/g dw) or control wetlands (n = 115 fish; 0.20 ± 0.02 μg/g dw), but the polyaluminum chloride treated wetlands and control wetlands did not differ (Figure 1).

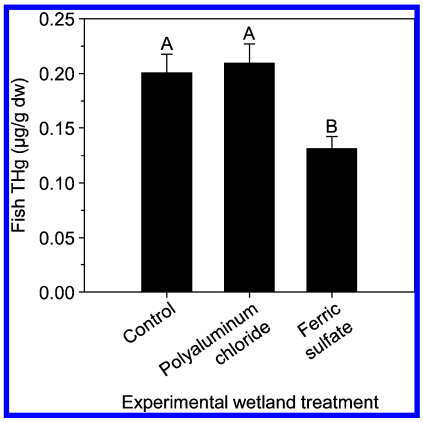

Figure 1. Total mercury concentrations (THg; least-squares means ± SE) in wild mosquitofish from experimental wetland cells that received water that was treated with either polyaluminum chloride coagulant, ferric sulfate coagulant, or untreated water (control) at Twitchell Island, California. Different letters above bars denote significant (p < 0.05) differences between means.

On average, mosquitofish THg concentrations were 35% lower in the ferric sulfate treated wetlands than in the control wetlands. At the time of fish introduction into the experimental wetland cells (4 months prior), THg concentrations in reference mosquitofish from the stock population were very low at 0.01 ± 0.01 μg/g dw (n = 15 reference fish).

In the next stage of our analyses, we compared THg concentrations in fish collected from the source and outlet water canals to those collected from within the experimental wetland cells. THg concentrations in mosquitofish differed among the canal and experimental wetland habitats ($F_{5,7.36}$ = 9.27, p = 0.01), while statistically accounting for the effect of fish length ($F_{1,382.00}$ = 31.80, p < 0.0001). THg concentrations in mosquitofish collected from the canal source water for the experimental wetlands (n = 10 fish; 0.07 ± 0.02 μg/g dw) were lower than in any other habitat type (Figure 2). THg concentrations in mosquitofish collected from the outflow canal for the experimental wetlands (n = 10 fish; 0.20 ± 0.04 μg/g dw) were no different than those in the polyaluminum chloride treated wetlands (n = 118 fish; 0.21 ± 0.02 μg/g dw), the control wetlands (n = 115 fish; 0.20 ± 0.02 μg/g dw), or the ferric sulfate treated wetlands (n = 128 fish; 0.13 ± 0.01 μg/g dw; Figure 2). THg concentrations in mosquitofish collected from the main drainage canal for Twitchell Island (n = 10 fish; 0.42 ± 0.09 μg/g dw) were higher than in any other habitat type (Figure 2).

In the last stage of our fish analyses, we compared THg concentrations in the experimental control wetlands to reference rice fields (Figure 3). THg concentrations in mosquitofish differed among wetland habitats ($F_{1,4.03}$ = 7.57, p = 0.05), subsites ($F_{2,221.00}$ = 4.35, p = 0.01), and fish length ($F_{1,221.10}$ = 4.25, p = 0.04); however, there was a significant habitat × subsite interaction ($F_{2,221.00}$ = 6.91, p = 0.001). THg concentrations in mosquitofish within rice fields (n = 117 fish; 0.47 ± 0.11 μg/g dw) were 139% higher, on average, than those within the

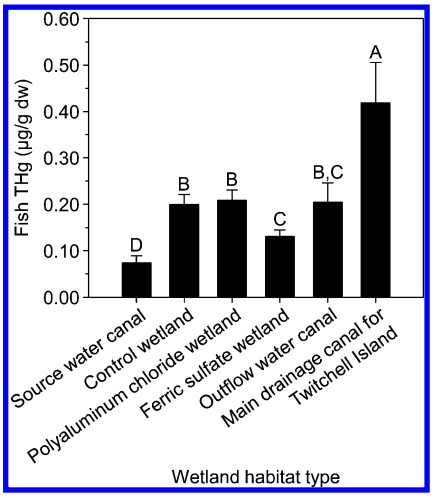

Figure 2. Total mercury concentrations (THg; least-squares means ± SE) in wild mosquitofish differed among the canal and experimental wetland (control, polyaluminum chloride coagulant, or ferric sulfate coagulant) habitat types at Twitchell Island, California. Different letters above bars denote significant (p < 0.05) differences between means.

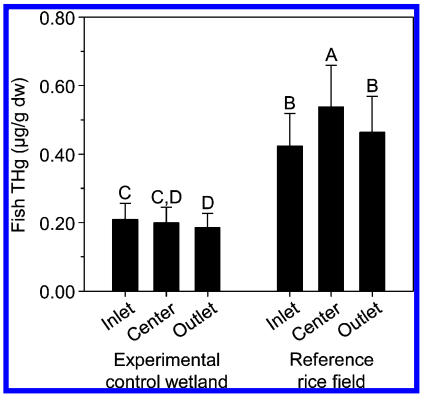

Figure 3. Total mercury concentrations (THg; least-squares means ± SE) in wild mosquitofish within experimental control wetlands and reference rice fields at inlets, centers, and outlets of each wetland type at Twitchell Island, California. Different letters above bars denote significant (p < 0.05) differences between means within each wetland habitat type.

experimental control wetlands (n = 115 fish; 0.20 ± 0.04 μg/g dw), and were consistently higher at each of the subsites (Figure 3). Pairwise comparisons indicated that THg concentrations in mosquitofish collected from the experimental control wetlands did not differ between inlets (n = 40 fish; 0.21 ± 0.05 μg/g dw) and centers (n = 40 fish; 0.20 ± 0.05 μg/g dw), and THg concentrations in mosquitofish at the outlets (n = 35 fish; 0.19 ± 0.04 μg/g dw) were barely lower than those at the inlets (Figure 3). In contrast, THg concentrations in mosquitofish increased in rice fields by 27% from the inlet (n = 39 fish; 0.42 ± 0.10 μg/g dw) to the center (n = 38 fish; 0.54 ± 0.12 μg/g dw), but THg concentrations in mosquitofish at the outlets (n = 40 fish; 0.46 ± 0.10 μg/g dw) were no different from the inlets (Figure 3).

Total and Methylmercury in Whole Water. We collected 72 water samples for Hg analysis. THg concentrations and MeHg concentrations in water differed among experimental wetland treatments (THg: $F_{2,3.30}$ = 32.73, p = 0.01; MeHg: $F_{2,3.82}$ = 8.51, p = 0.04) and months (THg: $F_{3,53.99}$ = 4.47, p = 0.01; MeHg: $F_{3,54}$ = 6.36, p = 0.001), and THg concentrations in water also differed among subsites (THg: $F_{1,53.38}$ = 81.80, p < 0.0001; MeHg: $F_{1,53.90}$

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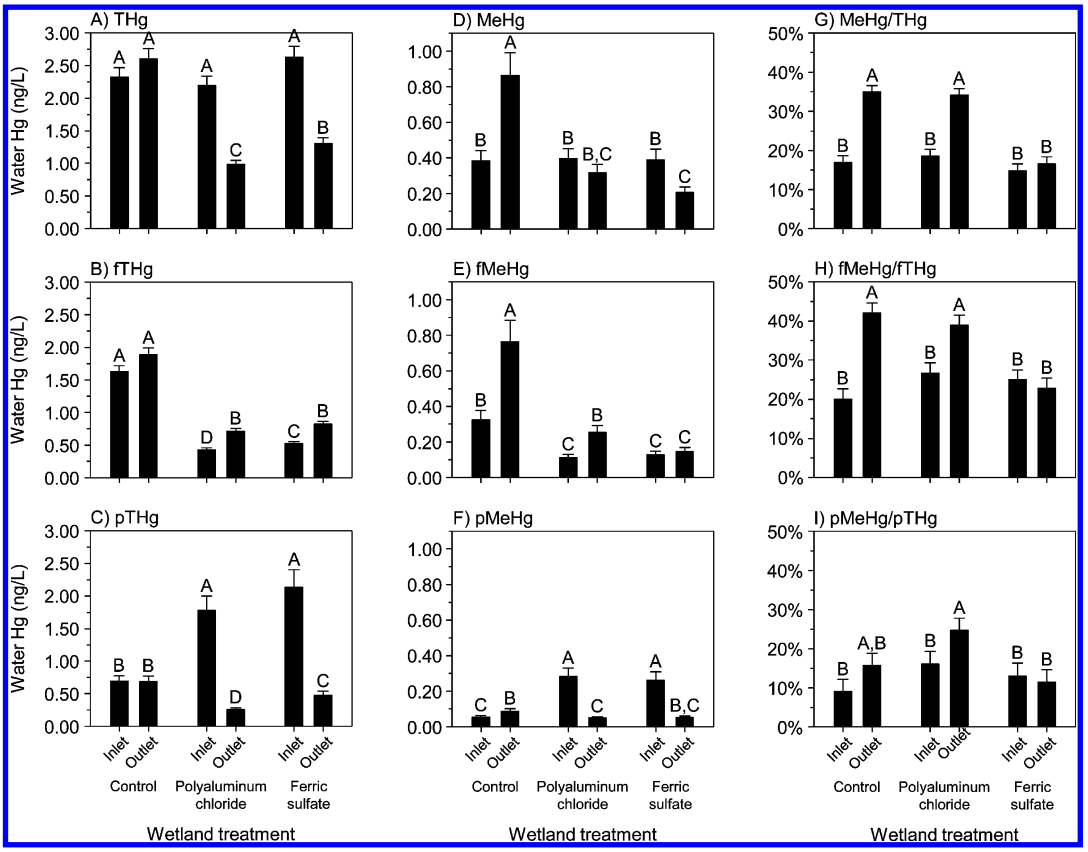

Figure 4. Least squares means ± SE total mercury concentrations (THg), methylmercury concentrations (MeHg), and the percentage of mercury in the methylmercury form (MeHg/THg × 100) in whole water, filtered (f) fraction of water, and particulate (p) fraction of water sampled from water entering (inlets) and exiting (outlets) wetlands treated with different experimental coagulants at Twitchell Island, California. Experimental wetland cells received water that was treated with either polyaluminum chloride coagulant, ferric sulfate coagulant, or untreated water (control). Different letters above bars denote significant ($p < 0.05$) differences between means.

= 0.03, $p = 0.87$), while accounting for block (THg: $F_{2,3.32} = 0.17$, $p = 0.85$; MeHg: $F_{2,3.82} = 0.67$, $p = 0.56$). However, there was a significant treatment × subsite interaction (THg: $F_{2,53.38} = 32.72$, $p < 0.0001$; MeHg: $F_{2,53.95} = 19.22$, $p < 0.0001$).

As expected, pairwise comparisons indicated that THg and MeHg concentrations in water did not differ among inlets of control, polyaluminum chloride, and ferric sulfate treated wetlands (Figure 4a,d). In contrast, at the outlets, THg and MeHg concentrations in water were significantly lower in the polyaluminum chloride (THg: 62% lower; MeHg: 63% lower) and ferric sulfate (THg: 50% lower; MeHg: 76% lower) treated wetlands compared to the control wetlands (Figure 4a,d).

Within wetlands, THg concentrations in water did not differ between inlets and outlets of control wetlands, but THg concentrations in water were 55% and 50% lower at the outlets than at the inlets in the polyaluminum chloride and ferric sulfate treated wetlands, respectively (Figure 4a). MeHg concentrations in water increased by 125% from the inlets to the outlets in the control wetlands, did not differ between inlets and outlets of the polyaluminum chloride treated wetlands, and decreased by 47% from the inlets to the outlets in the ferric sulfate treated wetlands (Figure 4d).

Filtered and Particulate Total Mercury in Water. THg concentrations in water fractions differed among experimental wetland treatments (fTHg: $F_{2,4} = 224.68$, $p < 0.0001$; but not pTHg: $F_{2,3.60} = 5.83$, $p = 0.07$), subsites (fTHg: $F_{1,57} = 4.95$, $p = 0.01$; pTHg: $F_{1,53.70} = 155.10$, $p < 0.0001$), and months (fTHg: $F_{3,57} = 4.95$, $p = 0.01$; pTHg: $F_{3,54.17} = 3.83$, $p = 0.01$), while accounting for block (fTHg: $F_{2,4} = 0.81$, $p = 0.51$; pTHg: $F_{2,3.60} = 0.27$, $p = 0.78$). However, there was a significant treatment × subsite interaction (fTHg: $F_{2,57} = 6.27$, $p = 0.01$; pTHg: $F_{2,53.70} = 41.24$, $p < 0.0001$).

Pairwise comparisons indicated that filtered and particulate THg concentrations in water at the inlets and outlets of control wetlands differed from those in the polyaluminum chloride and ferric sulfate treated wetlands (Figure 4b,c). At the inlets, filtered THg concentrations in water were 73% lower in the polyaluminum chloride treated wetlands and 68% lower in the ferric sulfate treated wetlands compared to the control wetlands (Figure 4b). At the outlets, filtered THg concentrations in water were 62% lower in the polyaluminum chloride treated wetlands and 57% lower in the ferric sulfate treated wetlands compared to the control wetlands (Figure 4b). In contrast, due to the transfer of the dissolved THg into the particulate fraction, particulate THg concentrations in water at the inlets were 157% higher in the polyaluminum chloride treated wetlands and 209% higher in the ferric sulfate treated wetlands compared to the control wetlands (Figure 4c). At the outlets, particulate THg concentrations in water were 63% lower in the polyaluminum chloride treated wetlands and 30% lower in the ferric sulfate treated wetlands compared to the control wetlands (Figure 4c).

Within wetlands, filtered THg concentrations in water did not differ between inlets and outlets of control wetlands, but were 65% and 57% higher at the outlets than at the inlets in the polyaluminum chloride and ferric sulfate treated wetlands, respectively (Figure 4b). Particulate THg concentrations in

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water also did not differ between inlets and outlets of control wetlands, but were 86% and 78% lower at the outlets than at the inlets in the polyaluminum chloride and ferric sulfate treated wetlands, respectively (Figure 4c).

Filtered and Particulate Methylmercury in Water. MeHg concentrations in water fractions differed among experimental wetland treatments (fMeHg: $F_{2,4.00} = 33.12$, $p = 0.01$; but not pMeHg: $F_{2,3.79} = 4.60$, $p = 0.10$), subsites (fMeHg: $F_{1,56.09} = 26.75$, $p < 0.0001$; pMeHg: $F_{1,54.85} = 73.08$, $p < 0.0001$), and months (fMeHg: $F_{3,56.09} = 3.39$, $p = 0.02$; pMeHg: $F_{3,54.91} = 12.97$, $p < 0.0001$), while accounting for block (fMeHg: $F_{2,4.00} = 0.68$, $p = 0.55$; pMeHg: $F_{2,3.79} = 0.03$, $p = 0.97$). However, there was a significant treatment × subsite interaction (fMeHg: $F_{2,56.09} = 4.07$, $p = 0.02$; pMeHg: $F_{2,54.85} = 40.77$, $p < 0.0001$).

Pairwise comparisons indicated that filtered MeHg concentrations in water at the inlets and outlets of control wetlands differed from those in the polyaluminum chloride and ferric sulfate treated wetlands (Figure 4e). Particulate MeHg concentrations in water at the inlets of control wetlands also differed from those in the polyaluminum chloride and ferric sulfate treated wetlands, but differences were smaller at the outlets (Figure 4f). At the inlets, filtered MeHg concentrations in water were 65% lower in the polyaluminum chloride treated wetlands and 60% lower in the ferric sulfate treated wetlands than in the control wetlands (Figure 4e). At the outlets, filtered MeHg concentrations in water were 67% lower in the polyaluminum chloride treated wetlands and 81% lower in the ferric sulfate treated wetlands than in the control wetlands (Figure 4e). In contrast, the transfer of the dissolved MeHg into the particulate fraction resulted in particulate MeHg concentrations in water at the inlets to be 413% higher in the polyaluminum chloride treated wetlands and 377% higher in the ferric sulfate treated wetlands than in the control wetlands (Figure 4f). At the outlets, particulate MeHg concentrations in water were 43% lower in the polyaluminum chloride treated wetlands and 40% lower (but not statistically significant) in the ferric sulfate treated wetlands than in the control wetlands (Figure 4f).

Within wetlands, filtered MeHg concentrations in water did not differ between inlets and outlets for the ferric sulfate treated wetlands, but were 126% and 136% higher at the outlets than at the inlets in the control and polyaluminum chloride treated wetlands, respectively (Figure 4e). Particulate MeHg concentrations in water increased by 58% between inlets and outlets for the control wetlands, but were 83% and 80% lower at the outlets than at the inlets in the polyaluminum chloride and ferric sulfate treated wetlands, respectively (Figure 4f).

Percentage of Total Mercury in the Methylmercury Form in Water. The proportion of THg in the MeHg form in whole and filtered fraction of water differed among experimental wetland treatments (MeHg/THg: $F_{2,2.73} = 33.98$, $p = 0.01$; fMeHg/fTHg: $F_{2,4.06} = 6.59$, $p = 0.05$), subsites (MeHg/THg: $F_{1,51.35} = 54.19$, $p < 0.0001$; fMeHg/fTHg: $F_{1,56.19} = 25.95$, $p < 0.0001$), and months (MeHg/THg: $F_{3,52.74} = 9.73$, $p < 0.0001$; fMeHg/fTHg: $F_{3,56.18} = 5.99$, $p = 0.001$), while accounting for block (MeHg/THg: $F_{2,2.84} = 0.14$, $p = 0.87$; fMeHg/fTHg: $F_{2,4.06} = 0.22$, $p = 0.81$; pMeHg/pTHg: $F_{2,4.08} = 1.06$, $p = 0.42$). However, there was a significant treatment × subsite interaction (MeHg/THg: $F_{2,51.58} = 9.43$, $p = 0.001$; fMeHg/fTHg: $F_{2,56.18} = 11.03$, $p < 0.0001$). The proportion of THg in the MeHg form in the particulate fraction of water did not differ significantly among experimental wetland treatments (pMeHg/pTHg: $F_{2,4.08} = 3.90$, $p = 0.11$), subsites (pMeHg/pTHg: $F_{1,53.34} = 3.69$, $p = 0.06$), months (pMeHg/pTHg: $F_{3,53.74} = 1.18$, $p = 0.32$), or block (pMeHg/pTHg: $F_{2,4.08} = 1.06$, $p = 0.42$), and there was not a treatment × subsite interaction (pMeHg/pTHg: $F_{2,53.29} = 1.64$, $p = 0.20$).

Pairwise comparisons indicated that the proportion of THg in the MeHg form in whole, filtered, or the particulate fraction of water did not differ among treatments at the inlets (Figure 4g,h,i). At the outlets, the proportion of THg in the MeHg form in water was higher in the control wetlands (MeHg/THg: 111% higher; fMeHg/fTHg: 84% higher; pMeHg/pTHg: 37% higher) and polyaluminum chloride treated wetlands (MeHg/THg: 106% higher; fMeHg/fTHg: 70% higher; pMeHg/pTHg: 116% higher) than in the ferric sulfate treated wetlands (Figure 4g,h,i).

Within wetlands, the proportion of THg in the MeHg form in water increased between the inlets and outlets in the control wetlands (MeHg/THg: 107% higher; fMeHg/fTHg: 111% higher; pMeHg/pTHg: 72% higher) and polyaluminum chloride treated wetlands (MeHg/THg: 84% higher; fMeHg/fTHg: 46% higher; pMeHg/pTHg: 54% higher), but were no different in the ferric sulfate treated wetlands (Figure 4g,h,i).

DISCUSSION

Experimentally treating water with metal-based coagulants had large influences on THg and MeHg concentrations in surface water, due to precipitation of dissolved and colloidal forms of Hg and increased settling of particles (formed by the coagulation process) as the surface water passed through the treated wetlands. By the time the water reached the experimental wetland outlets, THg and MeHg concentrations were decreased by 62% and 63% in polyaluminum chloride treated wetlands and 50% and 76% in ferric sulfate treated wetlands compared to control wetlands. The coagulants' largest effect occurred by the time the water reached the experimental wetland inlets, with THg and MeHg being removed from the filtered fraction of water and coagulated into the particulate fraction of water. Because the coagulants were added to achieve a 60% to 80% removal of dissolved organic carbon, we expected to see similar reductions in Hg concentrations in the filtered fraction of water.[11] Accordingly, THg and MeHg concentrations in the filtered fraction of water at the inlets were 73% and 65% lower in the polyaluminum chloride treated wetlands and 68% and 60% lower in the ferric sulfate treated wetlands than in the control wetlands. As a direct consequence of this loss of Hg from the filtered fraction of treated water, there was a corresponding increase in Hg concentrations in the particulate fraction of water at the inlets. In fact, particulate THg and MeHg concentrations in water at the inlets were 157% and 413% higher in the polyaluminum chloride treated wetlands and 209% and 377% higher in the ferric sulfate treated wetlands than in the control wetlands.

Experimentally treating water with ferric sulfate coagulants also influenced Hg bioaccumulation in fish. Whereas THg concentrations in mosquitofish were decreased by 35% in the ferric sulfate treated wetlands compared to the control wetlands, there was no reduction in THg concentrations in mosquitofish within the polyaluminum chloride treated wetlands. Because both the ferric sulfate and polyaluminum chloride treated wetlands showed similar decreases in MeHg concentrations in the filtered fraction of inlet water (i.e., immediately following the addition of the coagulant), the lack of an effect on fish THg concentrations within the polyaluminum chloride treated wetlands may have been caused by greater production of bioavailable MeHg within those wetlands compared to the ferric sulfate treated wetlands. Although THg and MeHg concen-

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trations in surface water were decreased by the polyaluminum chloride coagulant, the proportion of THg in the MeHg form increased from inlets to outlets in the polyaluminum chloride treated wetlands, just as it did in the control wetlands. Similarly, MeHg concentrations in the filtered fraction of water increased from the inlets to the outlets by 136% within the polyaluminum chloride treated wetlands and 126% in the control wetlands. Yet, in the ferric sulfate treated wetlands, MeHg concentrations in the filtered fraction of water and the proportion of THg in the MeHg form did not differ between inlets and outlets and remained low. Thus, while both coagulants were successful at initially precipitating THg and MeHg into the particulate fraction of water by the time the water reached the inlets, the polyaluminum chloride coagulant was not as successful at reducing MeHg in the filtered fraction of water by the time the water reached the outlet. Although ferric iron and sulfate are both known substrates for MeHg production, when reduced, both iron and sulfide are known to inhibit inorganic Hg availability for MeHg production[24,25] and iron amendments have proven effective at reducing MeHg production.[10] In contrast, the availability of inorganic Hg bound to organo-complexes created in the polyaluminum chloride wetlands may be relatively high compared to the iron-sulfide complexes produced in the ferric sulfate wetlands.[26] Although other explanations are possible, fish were likely exposed through their diet to bioavailable MeHg produced within both the control and polyaluminum chloride treated wetlands whereas minimal net MeHg appeared to be produced in the ferric sulfate treated wetlands. This result underscores the importance of simultaneously considering both the abiotic and biotic compartments of Hg cycling in order to fully understand how management actions, such as applying coagulants, can impact Hg contamination.

Although we found that adding coagulants to wetlands, particularly ferric sulfate, can decrease Hg concentrations in both surface water and fish, wetlands are known to be one of the most effective habitats for producing MeHg.[5,6,27,28] For example, THg concentrations in mosquitofish were 170% higher in the control wetlands than in the source water canal. We therefore used THg concentrations in fish to further examine whether using coagulants in combination with small settling wetlands can decrease THg concentrations in biota more than what they would have been without the coagulation wetlands. Although THg concentrations in mosquitofish were lower in the ferric sulfate treated wetland than those in the control wetlands, they were still 77% higher in the ferric sulfate treated wetland than in the canal source water. This outcome highlights the potential for MeHg production within wetlands relative to canals, but it is also important to note that all the experimental treatment wetlands had significantly lower THg concentrations in mosquitofish than in the main drainage canal for Twitchell Island. Moreover, THg concentrations in mosquitofish were substantially lower (63% lower at field centers) in the experimental treatment wetlands than in the reference rice fields, which were the other main wetland habitat type at Twitchell Island. Indeed, fish within shallowly flooded rice fields are known to have elevated Hg concentrations relative to other wetland habitat types.[17] Overall, 62% of mosquitofish in rice fields at Twitchell Island exceeded a proposed dietary benchmark for behavioral impairment in piscivorous birds (0.10 μg/g ww[29]), and 27% exceeded a proposed dietary benchmark for reproductive impairment in piscivorous birds (0.18 μg/g ww[29]), compared to only 3% and <1%, respectively, of mosquitofish in the experimental wetlands. Only 2% of mosquitofish exceeded 0.10 μg/g ww in the ferric sulfate treated wetlands, compared to 1% of mosquitofish in the control wetlands, and 7% of mosquitofish in the polyaluminum chloride treated wetlands. Thus, although wetlands often increase MeHg production and bioaccumulation, the ferric sulfate treated wetlands produced THg concentrations in mosquitofish that were considerably lower than the majority of other aquatic environments at the study site.

Together with the laboratory study by Henneberry et al.,[11] our results indicate that metal-based coagulation can be an effective technique for removing both inorganic and organic forms of Hg from surface water and reducing MeHg bioaccumulation in fish. Despite similar reductions in surface water Hg concentrations, the two coagulants were not similarly effective at reducing biotic uptake of MeHg likely due to their different effects on MeHg production within the wetlands. Important considerations before large-scale implementation of this potential management practice include (1) identifying coagulants and key factors that optimize reduction of both water Hg concentrations and bioaccumulation, (2) quantifying whether coagulants have any harmful effects on wetland ecosystems and wildlife, and recommendations to mitigate those effects,[30,31] and (3) identifying appropriate operation and management plans, including the fate of flocculants and whether particulate byproducts should be removed from wetlands and disposed of elsewhere.

■ ASSOCIATED CONTENT

Supporting Information

Map of experimental wetland design (Figure S1), ancillary water quality data (Table S1), mercury determination methods, and quality assurance methods and results. The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.est.5b00655.

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The authors declare no competing financial interest.

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Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States

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Eastern North America receives elevated atmospheric mercury deposition from a combination of local, regional, and global sources. Anthropogenic emissions originate largely from electric utilities, incinerators, and industrial processes. The mercury species in these emissions have variable atmospheric residence times, which influence their atmospheric transport and deposition patterns. Forested regions with a prevalence of wetlands and of unproductive surface waters promote high concentrations of mercury in freshwater biota and thus are particularly sensitive to mercury deposition. Through fish consumption, humans and wildlife are exposed to methylmercury, which markedly bioaccumulates up the freshwater food chain. Average mercury concentrations in yellow perch fillets exceed the Environmental Protection Agency's human health criterion across the region, and mercury concentrations are high enough in piscivorous wildlife to cause adverse behavioral, physiological, and reproductive effects. Initiatives are under way to decrease mercury emissions from electric utilities in the United States by roughly 70%.

Keywords: atmospheric deposition, bioaccumulation, methylmercury, mercury contamination, northeastern United States

Mercury (Hg) is a potent neurotoxin of significant ecological and public health concern. Human and wildlife exposure to Hg occurs largely through the consumption of contaminated fish. It is estimated that over 410,000 children born each year in the United States are exposed in the womb to methylmercury (MeHg) levels that are associated with impaired neurological development (Mahaffey 2005). Eight percent of US women of childbearing age have blood Hg levels in excess of values deemed safe by the US Environmental Protection Agency (USEPA; Schober et al. 2003). Studies have also linked elevated Hg in the blood or tissue of fish, birds, and mammals with negative effects such as reduced reproductive success, hormonal changes, and motor skill impairment (Wiener and Spry 1996, Nocera and Taylor 1998, Evers et al. 2004).

To protect human health, the USEPA set a fish tissue criterion for MeHg at 0.3 μg per g under section 304(a) of the Clean Water Act (USEPA 2001). Similar criteria for wildlife are under development or promulgation in several states (e.g., Maine, New York). As of 2004, fish consumption advisories regarding Hg contamination have been issued for 44 states, including 21 statewide advisories for fresh waters and 12 for coastal waters. These advisories represent more than 53,000 km^2 of lakes and 1,230,000 km of rivers. The extent of fish consumption advisories underscores the extensive human and ecological health risk posed by Hg pollution.

Important sources of Hg to the environment include electric utilities, incinerators, industrial manufacturing, wastewater treatment plants, and improper disposal of consumer products (e.g., batteries, fluorescent light bulbs, Hg switches). Considerable public policy attention is directed toward airborne Hg emissions, since they constitute the largest source

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of Hg in the United States and globally (UNEP 2002). Although estimates suggest that US emissions of Hg peaked in the 1970s and have since declined (Pirrone et al. 1998), atmospheric concentrations remain approximately three times higher than preanthropogenic levels (Mason et al. 1994).

Neither atmospheric Hg emissions nor ambient concentrations of Hg in water constitute a direct public health risk at the levels of exposure usually found in the United States. The risk to humans and wildlife occurs as Hg is transported to watersheds and accumulates in the aquatic food chain. Airborne Hg is transported over variable distances (i.e., local to global scales), depending on the speciation of Hg emissions and reaction pathways, and is deposited to the Earth's surface.

Following deposition, ionic Hg (i.e., oxidized mercuric species, including complexes and particulate forms) may be reduced and reemitted to the atmosphere or converted to a more bioavailable form, MeHg. Through a bioaccumulation factor of about 10 million, MeHg accumulates to toxic levels at the top of the aquatic food chain. This Hg linkage, from air to water to fish and other biota, challenges the state and federal regulators charged with controlling airborne emissions and with decreasing Hg deposition to levels that meet standards for concentrations in water and in fish tissue.

To improve understanding of the Hg air–water–biota connection, the Hubbard Brook Research Foundation convened a team of eight scientists to synthesize scientific information concerning (a) Hg sources and inputs; (b) Hg transport, transformations, exposure, and environmental effects; and (c) Hg policy impacts in the Northeast. This synthesis includes the analysis of a large Hg data set compiled for eastern North America as part of a NERC (Northeastern Ecosystem Research Cooperative) initiative (Evers and Clair 2005). The NERC Hg project published summaries for water, sediment, and major taxonomic groups. Here we distill these studies into a regional overview with policy applications.

Efforts have been under way at state, regional, national, and global scales to reduce Hg emissions. Notably, in May 2005 the USEPA adopted a rule pertaining to Hg emissions from coal-fired power plants (the Clean Air Mercury Rule, or CAMR). This rule calls for a two-phase reduction in emissions through a cap-and-trade approach that is predicted to produce by approximately 2025 a 70% decrease in total US emissions from electric utilities. Rather than imposing an emission rate limit or requiring the use of maximum achievable control technology, the cap-and-trade approach allows facilities to purchase Hg allowances in order to comply with the regulations.

Mercury emissions and deposition in the northeastern United States

The northeastern United States (i.e., New England and New York) is an important region in which to investigate Hg, because it receives elevated Hg deposition and contains ecosystems sensitive to Hg inputs. Mercury-sensitive areas are typically forested areas with shallow surficial materials, abundant wetlands, and low-productivity surface waters. In the Northeast, the fish in many lakes and streams and the associated wildlife have elevated Hg, which in some instances is high enough to constitute a "biological Hg hotspot," which requires special attention from both a scientific and a policy perspective (Evers et al. 2007). A biological Hg hotspot is a location on the landscape that, compared with the surrounding landscape, is characterized by elevated concentrations of MeHg in biota (e.g., fish, birds, mammals) in excess of established human health or wildlife criteria as determined by a statistically adequate sample size.

Mercury emissions. Globally, approximately 6600 metric tons of Hg are emitted to the atmosphere annually, with 33% to 36% attributed to direct anthropogenic emissions. The remainder originates from natural sources or from past anthropogenic emissions that are rereleased (Mason and Sheu 2002). These values suggest that about two-thirds of atmospheric Hg emissions are derived from either direct or reemitted anthropogenic sources. Coal-fired power plants are the largest single category of Hg emissions, with 1450 metric tons per year, comprising about 50% of anthropogenic sources (Pacyna et al. 2003).

Total anthropogenic Hg emissions from all sources in the United States are calculated to be 103 metric tons per year, with the Northeast contributing about 4.7 metric tons per year (USEPA 1999). Mercury emissions in the United States have declined markedly over the past decade (table 1) as a result of federal regulations that mandated large reductions in Hg emissions in medical waste incinerators and in municipal incinerators (USEPA 2005). Unlike incinerator emissions, emissions from electric utilities have remained largely unchanged, and their relative contribution to total US emissions has increased from 25% to 40%. Municipal waste incinerators (23%) and electric utilities (16%) are the largest point-source categories in the Northeast.

Mercury is emitted to the atmosphere from point sources in three forms: elemental Hg (Hg^0), gaseous ionic Hg (reactive gaseous mercury, or RGM), and particulate Hg (PHg). This speciation exerts significant control over the fate of atmospheric Hg emissions and varies widely among sources (table 2). Therefore, Hg can be a local, regional, or global pollutant, depending on the speciation of the emissions and the associated residence times in the atmosphere (Dastoor and Larocque 2004).

In 1999, 57% of calculated point-source Hg emissions in the Northeast occurred as Hg^0, 33% as RGM, and 10% as PHg (USEPA 1999). Studies indicate that emissions from coal combustion in the United States are roughly 50% Hg^0, 40% RGM, and 10% PHg (Pacyna et al. 2003). However, emissions from coal combustion in the northeastern states have a higher percentage of RGM (68%) and a lower percentage of Hg^0 (30%) and PHg (2%; NESCAUM 2005). The actual Hg emission speciation profile for a specific power plant depends on the type of coal used and the air pollution control technology employed (NESCAUM 2003).

Table 1. Mercury (Hg) emissions (in metric tons per year), by source category, in the United States from 1990 through 2002 and in the Northeast region in 2002.

Source	Emissions (metric tons per year)				
	United States				Northeast,
	1990	1996	1999	2002	2002
Utility coal boilers	54	46	44	45	0.74
Medical waste incinerators	46	36	3	0.3	0.015
Municipal waste combustors	52	29	5	4	1.1
Industrial/commercial/ institutional boilers and process heaters	13	11	11	10	0.33
Chlorine production	9	7	6	5	0
Electric arc furnaces	7	–	–	10	–
Hazardous waste incineration	6	4	6	5	0.001
Total	222	168	109	103	4.7

Note: Individual source categories do not sum to the totals because area sources and minor point-source categories are not shown.
Source: USEPA 2002, 2005, NESCAUM 2005.

Elemental Hg, which is relatively unreactive and generally slowly oxidized, constitutes by far the largest pool of Hg in the atmosphere because of its relatively long residence time (0.5 to 2 years) and long-range transport potential (tens of thousands of kilometers). However, under some conditions Hg^0 can be rapidly oxidized and deposited locally or regionally, as observations have shown in the Arctic and Antarctic (Lindberg et al. 2002), at the marine and continental boundary layer, and in areas downwind of urban areas (Weiss-Penzias et al. 2003). Elemental Hg can also be directly deposited to forested ecosystems through stomatal gas exchange (Grigal 2002). As a result, the atmospheric lifetime of Hg^0 is probably closer to 0.5 year than to 2 years.

Reactive gaseous Hg consists predominantly of gaseous chloride and oxide forms of ionic Hg. This species is highly soluble in water and readily deposits to surfaces within tens to a few hundreds of kilometers from emission sources. Because of RGM's short atmospheric residence time (0.5 to 2 days), elevated Hg deposition can occur near RGM emission sources.

The atmospheric residence time of PHg is also relatively short (0.5 to 3 days). Although the fraction of PHg in ambient air in remote areas is generally less than 5% of total atmospheric Hg (Horvat 1996), concentrations may be higher near Hg emission sources and under certain atmospheric conditions (Lu et al. 2001).

Atmospheric deposition. Atmospheric deposition of Hg occurs in two forms: wet deposition (the deposition of Hg associated with rain and snow) and dry deposition (the deposition of PHg and RGM, cloud and fog deposition, and stomatal uptake of Hg^0). Although some areas have been contaminated by land disposal of Hg or discharge of Hg in wastewater effluent, the predominant input of Hg to most watersheds is atmospheric deposition. Fitzgerald and colleagues (1998) systematically rule out alternate hypotheses, such as natural weathering, as a significant cause of the observed widespread Hg contamination.

Judging from global models (Hudson et al. 1995), reconstructions of mass balances (Mason et al. 1994), and paleolimnological techniques (Engstrom and Swain 1997), it appears that deposition of Hg has increased two- to threefold over the past two centuries, following increases in Hg emissions associated with industrialization and Hg use. Paleolimnological studies in the Northeast typically show Hg deposition starting to increase in the late 1800s or early 1900s and increasing 2.5- to 15-fold by the late 20th century (1970s to 1990s) (figure 1; Kamman and Engstrom 2002). Decreases in sediment Hg deposition in the Northeast (approximately 25%) have been evident in recent years, coincident with reductions in US emissions and with static global emissions. Because inventories of Hg emissions have been limited, it is not clear what is responsible for the declines in Hg deposition

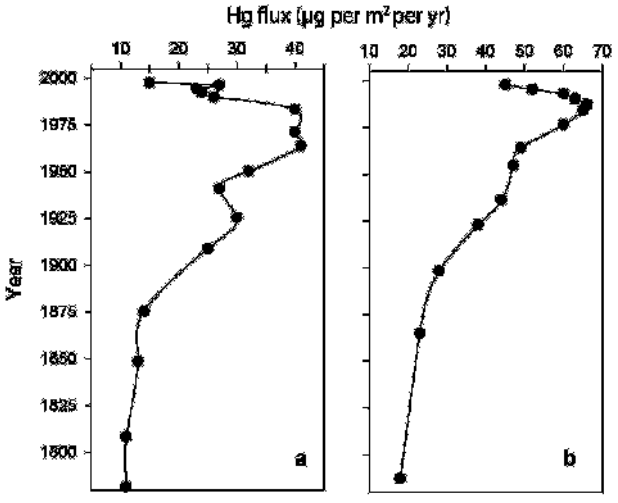

Figure 1. Changes in historical deposition of mercury (Hg) to sediments in (a) Spring Lake and (b) Wallingford Pond, Vermont, from 1820 to the present (after Kamman and Engstrom 2002). The sediment patterns reflect changes in Hg emissions and deposition over time.

Table 2. Percentage of mercury species emitted, by source category.

Source	Particulate mercury (percentage)	Reactive gaseous mercury (percentage)	Elemental mercury (percentage)
Coal-fired electric utilities (United States)	10	40	50
Coal-fired electric utilities (Northeast)	2	68	30
Utility oil boilers	20	30	50
Municipal waste combustors	20	58	22
Medical waste incinerators	20	75	5
Pulp and paper production	20	30	50
Chlorine production	0	5	95
Hazardous waste incinerators	22	20	58
Primary and secondary metal production	10	10	80
Municipal landfills	10	10	80

Source: USEPA 1999, Pacyna et al. 2003, NESCAUM 2005.

over the past few decades. However, it seems likely that controls on particulate matter and sulfur dioxide from electric utilities, and reductions in consumer and industrial Hg use, are important factors (Engstrom and Swain 1997).

In the eastern United States, Hg deposition is high (USEPA 1997), but it is difficult to identify its specific sources. Of the estimated 52 metric tons of Hg deposited per year in the United States from US sources, 24 metric tons (46%) are likely to originate from domestic utility coal boilers (half of the 48 metric tons of Hg that the coal-fired utilities emit each year is likely to be deposited within the United States; USEPA 1997). Likewise, for regions of New York it is estimated that 11% to 21% of the Hg deposited is derived from emissions within New York, 25% to 49% originates from other US sources, and 13% to 19% originates from Asia (Seigneur et al. 2003). Given that most coal-fired utilities emit 50% to 70% of Hg as RGM and PHg (table 2), local sources are most likely an important component of the deposition in areas within 50 km of these sources. An analysis of emissions and deposition in southern New Hampshire shows a local region of high deposition associated with local electric utility emissions (Evers et al. 2007).

In the United States and Canada, measurements of wet Hg deposition, which are largely made through the Mercury Deposition Network (MDN), show that wet Hg deposition is highest in the Southeast (e.g., Florida, Mississippi) and lowest in the West. There are currently seven MDN sites in the Northeast, with average annual wet deposition ranging from 3.8 to 12.6 μg per m^2 per year (*http://nadp.sws.uiuc.edu/mdn/*). There do not appear to be broad spatial patterns in wet Hg deposition across the region, but the network is sparse. Because of the placement of collectors in rural areas, the deposition values for the region do not include elevated deposition that would be expected near Hg sources and in urban areas.

Estimates of dry Hg deposition are highly uncertain because of the complex interrelationships of atmospheric conditions, collection surface characteristics and terrain, and chemical properties of the contaminants. Several modeling efforts have been used to estimate dry deposition of Hg, however. In regions of New York, estimated dry Hg deposition was 4 to 10 μg per m^2 per year (Seigneur et al. 2003). Another model estimate specifically for the Northeast suggests that dry deposition of RGM plus Hg^0 was 37 μg per m^2 per year (Xu et al. 2000). Both studies indicate that dry deposition provides a significant pathway of Hg inputs (50% to 75% of total deposition) and agree with USEPA predictions that Hg dry deposition in the Northeast is the highest in the country, in part as a result of the abundant forests whose canopies effectively collect Hg from the atmosphere.

Because of the large surface area associated with canopy foliage, atmospheric deposition of contaminants is elevated in forests compared with other types of ecosystems. Forest studies have indicated that total atmospheric Hg deposition may be estimated using fluxes of throughfall (precipitation that passes through the canopy) plus litterfall (plant material that falls to the forest floor; Rea et al. 2001). Grigal (2002) suggests that the ratio of Hg fluxes resulting from wet deposition, throughfall, and litterfall, respectively, is 1.0 to 1.8 to 2.2. So for the 5 μg per m^2 per year of wet deposition that might be typical of the Northeast, anticipated throughfall would be 9 μg per m^2 per year, and litterfall would be 11 μg per m^2 per year, resulting in total Hg deposition of 20 μg per m^2 per year and dry deposition of 15 μg per m^2 per year (75% of total).

Some portion of the Hg deposited to Earth's surface is reemitted to the atmosphere. However, rates of volatilization vary widely in association with differences in vegetation, soil moisture, temperature, solar radiation, and landscape characteristics. In general, volatilization rates from soil are high immediately after inputs of ionic Hg to the soil (Schluter et al. 1995). On the basis of a review of the literature, Grigal (2002) estimated a mean rate of Hg^0 volatilization from soil of approximately 11 μg per m^2 per hour. This rate is more than adequate to reemit most of the atmospheric Hg deposition. The magnitude and uncertainty of this process demonstrate the acute need for additional research on Hg reemissions.

Transport and transformation of mercury in forest–wetland–lake ecosystems

Following deposition to the landscape, Hg may be sequestered in soil, reemitted to the atmosphere, or transported through the watershed, with a fraction of these inputs ultimately supplied to surface waters. Watershed and water chemistry characteristics influence the transport of Hg to surface waters. Anoxic zones in wetlands and lakes provide suitable conditions for the methylation of ionic Hg to MeHg. The extent to which MeHg is biomagnified in the freshwater food chain depends on the nature and length of the food chain and on water chemistry characteristics.

Mercury transport and fate in upland forest ecosystems. Although there have been few direct studies of soil sequestration of Hg, immobilization of Hg in forest soil is known to correspond with the retention of organic carbon (Schwesig et al. 1999). Pools of Hg in upland soil in northern temperate regions are about 7 mg per m^2, although higher levels have been reported in central Europe (Grigal 2003).

The export of Hg by waters draining upland soils to surface waters is generally low. Concentrations and fluxes of Hg in soil waters, as in soil, are closely related to dissolved organic carbon (DOC; Schwesig et al. 1999). In northern forests, concentrations of total Hg are highest in waters draining the upper soil, coinciding with high concentrations of DOC. Concentrations and fluxes of total Hg decrease as DOC is immobilized with depth in mineral soil (Grigal 2002).

Limited studies suggest that MeHg concentrations in upland soils and groundwaters are generally low, although higher concentrations occur in upper soil waters and decrease with soil depth (Grigal 2002). Low concentrations and fluxes of MeHg in drainage waters suggest that rates of methylation are low, and freely draining upland soils are generally not important in the supply of MeHg to downstream surface waters, with the possible exception of recently harvested forests (Porvari et al. 2003).

Transport and transformation of mercury in wetlands. Wetlands are important features of the landscape that influence the supply of different Hg species to adjacent surface waters. Wetlands are typically net sinks of total Hg and sources of MeHg (Grigal 2002, 2003). Rates of total Hg accumulation are greater in wetlands than in upland soils because of the strong association of Hg with organic matter (Grigal 2003). Annual rates of MeHg production in wetlands are approximately 0.1 to 1 μg per m^2 per year (Galloway and Branfireun 2004). The factors controlling methylation of Hg in wetlands are not completely understood, but they most likely involve the amounts and types of organic matter, hydrologic flow paths, and rates of microbial activity (Galloway and Branfireun 2004). Wetlands are also a major source of DOC. Organic matter produced in wetlands forms complexes with both ionic Hg and MeHg, enhancing the transport of these Hg species to surface waters but decreasing their bioavailability (Hudson et al. 1994). An elevated supply of DOC to downstream surface water could also stimulate methylation and limit photodegradation of MeHg and photoreduction of ionic Hg. Furthermore, wetlands support sulfate-reducing bacteria, which appear to be largely responsible for Hg methylation (Benoit et al. 2003). Concentrations of MeHg in wetland porewaters (waters filling the spaces between solid material in sedimentary deposits) and surface waters vary seasonally, with the highest concentrations evident during the late summer, presumably as a result of warmer temperatures, higher rates of microbial activity, and longer hydraulic residence times (Galloway and Branfireun 2004).

Mercury concentrations and transformations in surface waters. Freshwater ecosystems are among the most sensitive to Hg pollution. Total Hg concentrations in surface waters in the Northeast vary by more than an order of magnitude, from less than 0.5 to 12.7 nanograms per liter (5th to 95th percentile; figure 2; Dennis et al. 2005). Most of the Hg in surface water occurs as ionic Hg, with MeHg ranging from 1% to 35% of total Hg (figure 3). Under conditions of high total Hg loading, MeHg production can vary widely, depending on the methylation efficiency of a particular ecosystem (Krabbenhoft et al. 1999).

Mercury enters remote surface waters through direct atmospheric deposition and through soil water, wetland, or groundwater drainage. Streams and rivers can exhibit marked temporal variation in Hg concentrations, which is associated with variations in concentrations of DOC or suspended matter. Large increases in Hg concentrations can occur during high flow events (Shanley et al. 2005).

Some inputs of Hg to lakes are removed from the water column by the volatilization of Hg^0 and by sediment deposition. In freshwater lakes, photochemical processes are largely responsible for the reduction of ionic Hg to Hg^0 (Amyot et al. 1997). Microbial reduction has been observed in laboratory studies, but only at higher than ambient concentrations of Hg (Morel et al. 1998). Biogeochemical processes in lakes also result in net production of MeHg due to methylation in anoxic sediments and in the water column.

The geographic distribution of average surface water Hg concentrations in the Northeast (figure 2) shows landscape-level heterogeneity in lake and river Hg concentrations, and areas where concentrations are elevated across several contiguous 18-minute grid cells. Areas of elevated Hg concentrations in surface waters can be explained by high concentrations of DOC, as in the Adirondacks; by high inputs of suspended solids, from rivers along Lake Champlain, related to high flow events; and by elevated atmospheric Hg deposition, as in lakes in southeastern New Hampshire and eastern Massachusetts. A large portion of the variation in total Hg and MeHg across the region can be explained by variation in DOC (Dennis et al. 2005). Areas with the highest mean surface water Hg concentrations also have the greatest range in Hg concentrations (figure 2). This variation may be attributed to heterogeneity in watershed characteristics or to high flow events (Shanley et al. 2005).

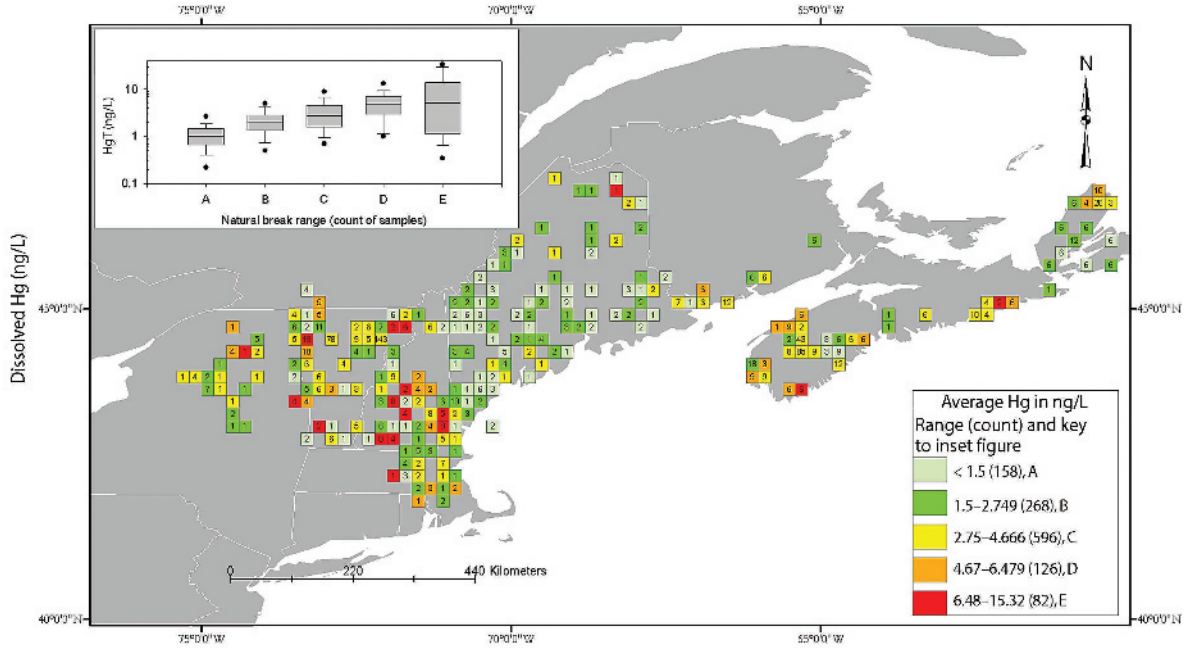

Figure 2. Average water mercury (Hg) concentrations within 18-minute grid cells for lakes and streams across northeastern North America. Inset shows the distribution of Hg concentrations comprising the mean for each quintile.

Other factors controlling mercury dynamics in surface waters. Other factors, such as water chemistry, land cover and land use, and watershed disturbances, alter the transport, transformation, and bioavailability of Hg in surface waters.

The Northeast receives elevated loading of acidic deposition as well as Hg deposition, and contains a relatively large number of acidified surface waters. Acidic deposition and the associated sulfur alter the acid–base status of surface waters, thereby influencing Hg transformation and accumulation in fish. Sulfur transformations are closely coupled with Hg dynamics. The solubility of Hg increases with increasing sulfide concentrations in anoxic waters through complexation reactions, potentially increasing the pool of Hg available for methylation (Benoit et al. 2003). Experimental observations show that when sulfate is added to wetlands or lakes, sulfate reduction is enhanced, leading to increased methylation and MeHg export (Branfireun et al. 1999, Watras et al. 2006).

Widespread observations show an inverse relationship between fish Hg concentrations and surface water pH (e.g., Kamman et al. 2004). Hrabik and Watras (2002) used reference data and observations from a lake experimentally acidified with sulfuric acid to examine the relative contribution of atmospheric Hg deposition and acidic deposition to Hg concentrations in fish. They found that half of the decrease in fish Hg over a six-year period during which the lake was recovering from acidification could be attributed to decreases in sulfuric acid loading.

In a study of 21 river basins nationwide, watersheds with mixed agriculture and forest land cover had the highest methylation efficiency, even where these watersheds had low total Hg in sediments (Krabbenhoft et al. 1999). Some waters draining largely agricultural lands have relatively high concentrations of total Hg and MeHg, but lower concentrations in fish, presumably due to algal "bloom dilution" associated with high phosphorus loading (Kamman et al. 2004; see below) or elevated DOC concentrations (which could stimulate methylation but limit bioaccumulation), or both.

Land disturbance influences Hg export and availability for methylation. Forest harvesting has been shown to increase export of total Hg and MeHg (Porvari et al. 2003). Fire results in a complex pattern of Hg loss from watersheds. During and shortly after fire, elevated Hg losses are associated with volatilization and drainage losses (Grigal 2002). Over the longer term, Hg transport to surface waters is reduced in burned areas as a result of decreases in soil carbon and DOC concentrations.

In reservoirs, rates of Hg methylation can be altered by water level fluctuation associated with hydropower production or flood control. Many large bodies of water in the Northeast are impounded to increase their storage or daily peaking capacity, and these water bodies may fluctuate tens of centimeters on a daily basis or several meters over the course of a summer. As the littoral zone experiences periodic wetting and drying, varying cycles of reduction and oxidation may enhance the production of MeHg, depending on a variety of factors (Sorensen et al. 2005, Evers et al. 2007).

Trophic transfer of mercury in surface waters of the Northeast. Concentrations of total Hg or MeHg in surface waters often do not correlate well with the Hg content of freshwater biota, such as fish. There are many physical, chemical, ecological, and land-use factors controlling the trophic transfer

of MeHg, which are key to predicting MeHg concentrations in fish and other freshwater organisms.

Trophic transfer of Hg in freshwater food webs begins with the bioaccumulation of ionic Hg and MeHg by primary producers. Bioaccumulation factors in the transfer of Hg from water to algae are by far higher (approximately 10^5 to 10^6) than at subsequent trophic levels (figure 3). Although both ionic Hg and MeHg are taken up by aquatic organisms, MeHg is assimilated four times more efficiently than ionic Hg (Mason et al. 1994). However, the absolute and relative assimilation efficiencies of ionic Hg and MeHg vary with trophic level, uptake pathway, and water chemistry conditions. Freshwater grazers and predators acquire MeHg mainly from their food rather than from water (Harris and Bodaly 1998). Methylmercury is efficiently transferred to the higher levels of the food web and largely incorporated within proteins, as in muscle tissue.

The NERC data show that MeHg increases in concentration and comprises a greater percentage of the total Hg in freshwater consumers and predators as it progresses up the food chain (figure 3). Thus organisms consuming prey at higher trophic levels are exposed to higher concentrations of total Hg and MeHg (Vander Zanden and Rasmussen 1996). Fish Hg occurs almost entirely as MeHg.

A variety of physical, chemical, and biological factors influence the biomagnification of MeHg. Fish Hg concentrations tend to vary positively with lake or watershed area and negatively with pH, acid neutralizing capacity (ANC), nutrient concentrations, zooplankton density, and human land use (Chen et al. 2005). Furthermore, the Hg added to the lake surface each year appears to be more available for conversion to MeHg than Hg that has been in the ecosystem for longer periods (Gilmour et al. 2003).

Both experimental and field studies show that nutrient enrichment diminishes Hg bioaccumulation in phytoplankton through the biodilution of Hg under algal bloom conditions (Pickhardt et al. 2002). Mercury concentrations in zooplankton also decrease with increasing zooplankton densities that in turn are correlated with lower Hg concentrations in fish (Chen and Folt 2005). Growth dilution in fish, also under conditions of high productivity and food availability, may be related to lower Hg concentrations in fish (Essington and Houser 2003).

Within given fish populations, Hg burdens increase with the age and size of individuals in part because of the slower rates of elimination and longer exposure in larger individuals, and in part because of the consumption of higher-trophic-level foods by older and larger individuals (Wiener and Spry 1996). Mercury concentrations in top predator fish are higher in food webs with longer chain lengths and less omnivory (Stemberger and Chen 1998).

Indicators of mercury sensitivity. Four simple and common measures of water quality—DOC, ANC, pH, and total phosphorus—have been shown by Chen and colleagues (2005) and many others to be related to fish Hg concentrations. To develop indicators of Hg sensitivity, we combined data from two stratified, random-probability surveys of northeastern lakes (USEPA EMAP [Environmental Monitoring and Assessment Program], Northeast Lakes Program, 1991–1994, and Vermont–New Hampshire REMAP [Regional EMAP], 1998–2000) with the survey data sets of Chen and colleagues (2005) to examine these four water-chemistry characteristics in lakes with standard-age yellow perch (*Perca flavescens*) whose tissue contained mean concentrations of Hg above and below the USEPA criterion (0.3 μg per g; figure 4). The standard age for yellow perch examined in this analysis was 4.6 years (Kamman et al. 2004). This analysis showed that lakes with Hg levels above 0.3 μg per g in yellow perch had significantly higher DOC (t = –3.099, p = 0.003) and lower pH (t = –6.282, $p < 0.001$), ANC (t = 2.835, p = 0.007), and total phosphorus (t = 3.840, $p < 0.001$) than lakes with fish Hg concentrations below 0.3 μg per g. As yellow perch have low to moderate Hg concentrations, these thresholds are conservative and help identify the most sensitive lakes.

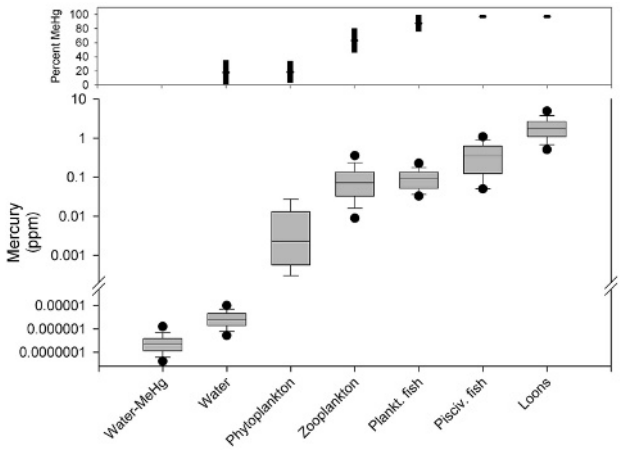

Figure 3. Box and whisker plots of mercury (Hg) concentrations in water and aquatic biota in eastern North America. Also shown are the ranges for the percentage of total Hg occurring as methylmercury (MeHg). All values were obtained from NERC (Northeastern Ecosystem Research Cooperative) data and represent wet weight, except those for phytoplankton, which were obtained from Watras and colleagues (1998).

Twenty percent of lakes in the region had total phosphorus concentrations above 30 μg per L. In those lakes, Hg concentrations in yellow perch were below 0.3 μg per g. In the remaining 80%, we found that most lakes (75%) had yellow perch Hg concentrations exceeding 0.3 μg per g when surface waters had a DOC level of more than 4.0 mg carbon per L, a pH of less than 6.0, or an ANC of less than 100 microequivalents (μeq) per L. These commonly monitored indicators provide natural resource managers with a useful tool for evaluating the likelihood of high fish Hg concentrations in individual lakes.

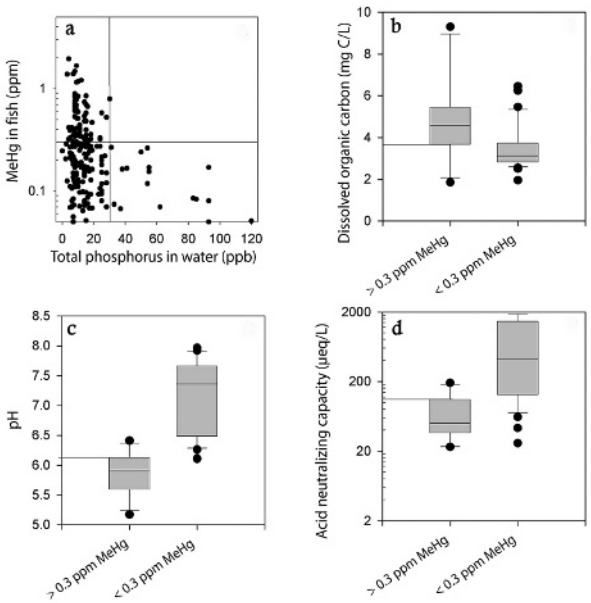

Figure 4. Relationship between methylmercury (MeHg) concentrations in standard-length yellow perch and total phosphorus concentration in lakes (a), and box and whisker plots of concentrations of dissolved organic carbon (b), pH (c), and acid neutralizing capacity (d) for lakes in the northeastern United States containing average concentrations of standard-age yellow perch with MeHg concentrations less than and greater than 0.3 µg per g.

Taxonomic patterns of mercury exposure

Biota are exposed to MeHg primarily through fish and insect consumption. The NERC data establish robust Hg exposure profiles for fish, birds, and mammals (table 3; Evers and Clair 2005), and highlight the importance of habitat type, foraging guild, trophic structure, and demographics on MeHg exposure (Evers et al. 2005).

In general, Hg concentrations vary by taxonomic group, with a higher proportion of MeHg at higher trophic levels. Mercury in benthic invertebrates and larval insects has been extensively studied in northeastern lakes and reservoirs, and is found to increase with trophic level (odonates > hemipterans and coleopterans > trichopterans > dipterans and ephemeropterans; Tremblay et al. 1996). The NERC data on Hg in over 15,000 fish show that the mean fillet Hg levels in 10 of the 13 species are above 0.3 µg per g, with the highest levels in large predatory fish such as walleye (*Sander vitreus*) and lake trout (*Salvelinus namaycush;* figure 5; Kamman et al. 2005).

Habitat type also has an important influence on MeHg concentrations. Data for two-lined salamanders (*Eurycea bislineata*) suggest that amphibians found in headwater streams have significantly higher MeHg concentrations than those in lakes (Bank et al. 2005). Larval insects in reservoirs have total Hg concentrations that are 3 to 10 times higher than those in natural lakes (Tremblay et al. 1996). Northern crayfish (*Orconectes virilis*) in headwater streams have Hg concentrations up to five times greater than those in lakes (Pennuto et al. 2005).

Comprehensive bird studies illustrate differences in MeHg exposure in foraging guilds. Piscivorous species with particularly high MeHg levels include the common loon (*Gavia immer;* Evers et al. 2005), wading birds (Frederick et al. 1999), and the bald eagle (*Haliaeetus leucocephalus;* Bowerman et al. 2002). Exposure studies in common loons have shown hormonal changes, reduced reproductive success, and motor skill impairment, resulting in the establishment of a wildlife criterion for blood Hg of 3.0 µg per g (Evers et al. 2004).

Table 3. Mercury exposure for selected biota in representative habitats in the Northeast.

Major habitat and organism	Sample size	Tissue sampled	Mercury level (µg per g) Mean ± SD	Mercury level (µg per g) Range	Reference
Lakes					
Yellow perch	841	Whole body	0.29 ± 0.07	< 0.05–3.17	Kamman et al. 2005
	2888	Fillet	0.35 ± 0.20	< 0.05–5.03	Kamman et al. 2005
Common loon	770	Adult blood	2.04 ± 1.39	0.05–8.63	Evers et al. 2005
	660	Egg	0.78 ± 0.60	0.01–9.00	Evers et al. 2005
Estuaries					
Saltmarsh sharp-tailed sparrow	108	Adult blood	0.63 ± 0.26	0.18–1.68	Lane and Evers 2005
Rivers					
Belted kingfisher	117	Adult blood	0.99 ± 0.82	0.07–4.57	Evers et al. 2005
Mountains					
Bicknell's thrush	242	Adult blood	0.08 ± 0.38	0.03–0.80	Rimmer et al. 2005
General aquatic					
Bald eagle	108	Juvenile blood	0.30 ± 0.27	0.01–1.20	Evers et al. 2005
Tree swallow	53	Adult blood	0.41 ± 0.21	0.11–1.00	Evers et al. 2005
Mink	126	Fur	20.7	1.78–68.5	Yates et al. 2005
Otter	160	Fur	18.0	1.14–73.7	Yates et al. 2005

SD, standard deviation.

Exposure to MeHg is not limited to piscivorous birds. Data for insectivorous songbirds, such as the northern waterthrush (*Seiurus noveboracensis*) and red-winged blackbird (*Agelaius phoeniceus*), show blood Hg levels that can exceed levels in piscivorous birds (Evers et al. 2005). Moreover, elevated MeHg has been measured in several breeding populations of saltmarsh sharp-tailed sparrows (*Ammodramus caudacutus*) in some New England estuaries (Lane and Evers 2005), and in terrestrial species such as Bicknell's thrush (*Catharus bicknelli*) and other montane songbirds (Rimmer et al. 2005).

Terrestrial mammals, particularly mink (*Mustela vision*) and river otter (*Lontra canadensis;* table 3), also experience elevated MeHg in the Northeast. Yates and colleagues (2005) found that Hg levels tend to be higher in mink than in otter, in interior than in coastal populations, and in females than in males. Recent evidence for MeHg exposure in insectivores has led to ongoing investigations in bats and other nonpiscivorous mammal species.

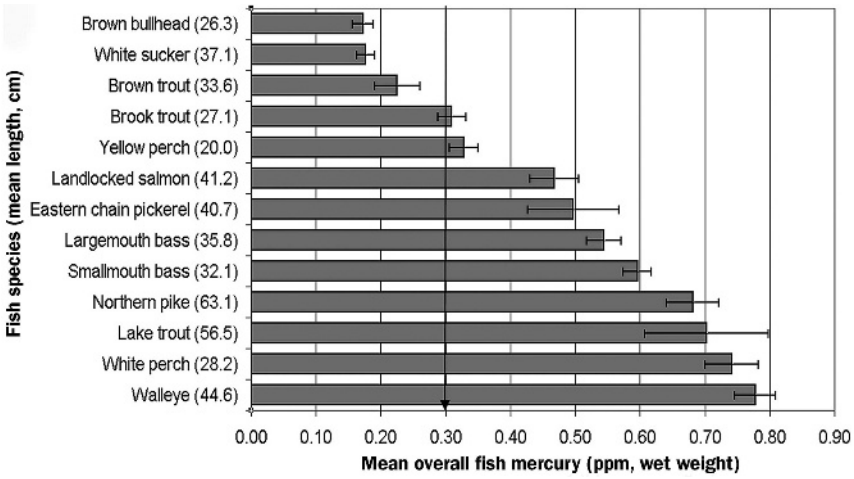

Figure 5. Mean and standard deviation of mercury (Hg) concentrations of 13 species of fish in eastern North America (Kamman et al. 2005). The downward-pointing arrow indicates the US Environmental Protection Agency's criterion for fish Hg concentrations.

Comprehensive data on fish and wildlife exposure are being used to identify species, habitats, and regions that are likely to be at the highest risk for MeHg contamination, and will be useful for measuring progress resulting from future management actions.

Evaluating reductions in mercury emissions

At present, most state and national policy attention is focused on Hg emissions from electric utilities (i.e., coal-fired power plants). Although controlling other sources (e.g., emissions from incinerators, discharges from wastewater treatment plants) and implementing other management options (e.g., biomanipulation, land-use management) may also hold promise for reducing and mitigating Hg bioaccumulation, we focus on the potential effect of reducing Hg emissions from electric utilities, because they are the largest single source of airborne emissions in the United States and the second largest source in the Northeast, and because their emissions have remained unchanged both regionally and nationally over the past decade (NESCAUM 2005). Although municipal waste combustors are the largest Hg emission source in the Northeast, effective strategies for reducing their emissions are under way, as evidenced by the decline of approximately 80% in emissions from this source between 1998 and 2003 (NESCAUM 2005).

Many proposals have been introduced at both the federal and the state level to control Hg emissions from electric utilities. The main differences among them include (a) the level and timing of the cuts, (b) the existence of an emissions cap or emissions rate limit, and (c) whether or not trading is allowed. In general, the level and timing of Hg emission reductions are likely to control the extent and rate of recovery in the region, and the use of trading has prompted questions regarding the persistence or expansion of biological Hg hotspots (Evers et al. 2007).

Here we estimate the changes in emissions and deposition that are associated with the CAMR and discuss the potential effect of these changes on freshwater ecosystems using field data. The USEPA estimates that the CAMR will result in a 70% decrease in Hg emissions from electric utilities by 2025. We estimate that the CAMR, when fully implemented, would result in a decrease of approximately 18% to 30% in deposition in the northeastern United States. This estimate is based on an analysis of US emissions and deposition that assumes (a) that current and reemitted anthropogenic emissions each constitute one-third of the emissions in the United States, and (b) that electric utilities account for 50% of each of these two emission categories. It follows that if electric utilities reduce their emissions by 70%, current and reemitted anthropogenic emissions would each decrease by 35%.

We further assume that US emissions are responsible for 40% to 65% of Hg deposition in the Northeast (Seigneur et al. 2003) and that reemitted US emissions contribute another 10% to 20%. If deposition attributed to these emission categories were reduced by 35% as a result of the CAMR, then total deposition would decline by approximately 18% to 30%. These predictions are consistent with the decrease of approximately 25% in sediment Hg deposition that occurred coincident with decreases in Hg emissions in the United States between 1970 and 1999.

An 18% to 30% decrease in Hg deposition is likely to provide significant ecological benefits in the region. Detailed biological data from a group of nine lakes in New Hampshire show that the Hg concentrations in the blood and eggs of the common loon declined 50% between 1999 and 2002 as emissions in the vicinity were cut 45% between 1997 and 2002, suggesting that some ecosystems in close proximity to large

emissions sources may experience rapid improvement (Evers et al. 2007). Hrabik and Watras (2002) found that Hg fish concentrations declined 30% between 1994 and 2000 as a result of decreased atmospheric Hg loading to a lake in northern Wisconsin; they concluded that modest changes in Hg or acidic deposition can significantly affect Hg bioaccumulation over short timescales. The range and rate of ecosystem response are most likely related to the variation in the physical, chemical, and biological characteristics of lakes and watersheds.

We expect that the CAMR will produce important results, but these changes may not be sufficient to protect human and environmental health. Given that *average* fish Hg concentrations sampled across the region currently exceed the USEPA human health criterion by 10% to 88%, depending on the species, significant additional reductions in Hg emissions from other US and global sources will probably be necessary to bring about widespread recovery to Hg levels that are below this criterion in most fish species in the northeastern United States.

Conclusions

A large Hg database produced by the NERC Hg working group was used to document and examine the widespread Hg contamination across eastern North America. From this synthesis, it is evident that the Northeast receives elevated Hg deposition derived mostly from direct emissions and reemissions of anthropogenic sources. Paleolimnological studies suggest that Hg deposition is substantially influenced by US emissions and responds to reductions in these sources.

Direct anthropogenic emissions of Hg originate largely from electric utilities, incinerators, and industrial processes. Current understanding of speciation and deposition processes suggests that, while speciation exerts important influence over patterns of atmospheric transport and deposition, all forms of Hg have the potential to deposit locally or regionally.

Forest regions are particularly sensitive to Hg inputs as a result of numerous factors: the filtering effects of the canopy and the associated elevated deposition; the prevalence of wetlands, which are critical in the transport of Hg and the production of MeHg; and low-productivity lakes, which promote high concentrations of Hg in fish. Although Hg is highly variable in surface waters across the region, we have identified several chemical thresholds to predict high fish Hg: total phosphorus concentrations of less than 30 μg per L; pH of less than 6.0; ANC of less than 100 μeq per L; and DOC of more than 4 mg carbon per L. Freshwater food chains are characterized by marked bioaccumulation of MeHg (10^6 to 10^7), with the largest increase occurring from water to plankton (10^5). Many freshwater and terrestrial animals in the Northeast exhibit high concentrations of Hg. For the common loon, existing Hg concentrations can cause adverse individual (behavioral and reproductive) and population-level effects.

Our analysis suggests that (a) cuts in Hg emissions from electric utilities in the United States will decrease Hg deposition in the region; (b) decreased Hg deposition will result in lower Hg levels in biota, although significant time lags may exist in many ecosystems; and (c) widespread recovery to Hg levels that no longer pose a human health risk or population risk to the common loon will be a long-term process that is likely to require additional reductions in Hg emissions.

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Mercury concentrations in coastal California precipitation: Evidence of local and trans-Pacific fluxes of mercury to North America

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[1] Because of mercury's (Hg) relatively high vapor pressure and long (0.5–2 years) atmospheric residence, there is the potential for long-range transport of contaminant Hg. Many studies have focused on that transport and deposition in central and eastern North America, Europe, and the Arctic, but there has been little research on the cycling of Hg in the western coast of North America. That deficiency is addressed in this preliminary study, which indicates there is long-range transport of Hg across the North Pacific. This transport is evidenced by the elevated (relative to equatorial and theoretical baseline) Hg concentrations in rainwater collected on the coast of California, as well as by the positive correlation between North Pacific storm tracks and Hg concentrations, with maximum concentrations associated with storms from 20°–40° latitude. Those tracks trace air masses containing industrial emissions with peak O_3 concentrations moving eastward off the Asian continent. The Asian fluxes appear to enhance Hg concentrations both directly, through the emission of particle-bound Hg and reactive Hg^{2+}, and indirectly, by increasing the rate of oxidation of Hg^0 in the atmosphere. Superimposed on the trans-Pacific background of industrial Hg is a local signal, with elevated concentrations at the urban site relative to the more pristine coastal site in California. This secondary enrichment is tentatively attributed to elevated local emissions of redox species, including O_3 and its precursors, which increase oxidation rates of Hg^0 in the atmosphere and Hg concentrations in precipitation. *INDEX TERMS:* 0365 Atmospheric Composition and Structure: Troposphere—composition and chemistry; 0368 Atmospheric Composition and Structure: Troposphere—constituent transport and chemistry; 0345 Atmospheric Composition and Structure: Pollution—urban and regional (0305); *KEYWORDS:* Mercury, atmosphere, oxidation, precipitation, transport, concentrations

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1. Introduction

[2] A large body of evidence has accumulated to support the hypothesis that, due to the relatively long residence time (0.5–2 years) of Hg^0 in the atmosphere [*Lamborg et al.*, 2000; *Lindqvist and Rodhe*, 1985; *Mason et al.*, 1994; *Seiler et al.*, 1980; *Slemr et al.*, 1985], Hg contamination is pandemic [*Fitzgerald et al.*, 1998; *Hudson et al.*, 1995; *Lindqvist et al.*, 1991; *Petersen et al.*, 1995]. The contamination is attributed to the oxidation of Hg^0 from the atmosphere to reactive species (e.g., Hg^{2+}) that are rapidly scavenged by settling particles and rain washout [*Lamborg et al.*, 2000; *Lin and Pehkonen*, 1999; *Munthe*, 1992; *Pleijel and Munthe*, 1995]. Those labile species are then readily available for biologically mediated methylation and accumulation in terrestrial and aquatic food chains [*Fitzgerald et al.*, 1998; *Lamborg et al.*, 1999; *Mason et al.*, 1997a; *Schroeder and Munthe*, 1998].

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[3] Recognition of the long-range atmospheric transport and transformation of Hg has coincided with an increased interest in the influence of atmospheric emissions from industrialized Asian countries on the environment. Asia has been identified as the major source of atmospherically deposited metals to the North Pacific [*Merrill*, 1989], and recent studies have evidenced the transport of Asian dust and industrial contaminants across the Pacific to western North America [*Berntsen et al.*, 1999; *Husar et al.*, 2001; *Jaffe et al.*, 1999]. In addition, coal combustion in China accounts for roughly 10% of the total industrial emissions of Hg [*Wang et al.*, 2000]. Consequently, this study was initiated to investigate the influence of Asian industrial emissions on Hg deposition rates in western North America.

2. Methods

[4] Rainwater samples were collected at two sites in central California (Figure 1). One was located on the coast at the University of California Santa Cruz's (UCSC) Long Marine Laboratory (LML), and the other was at Moffett

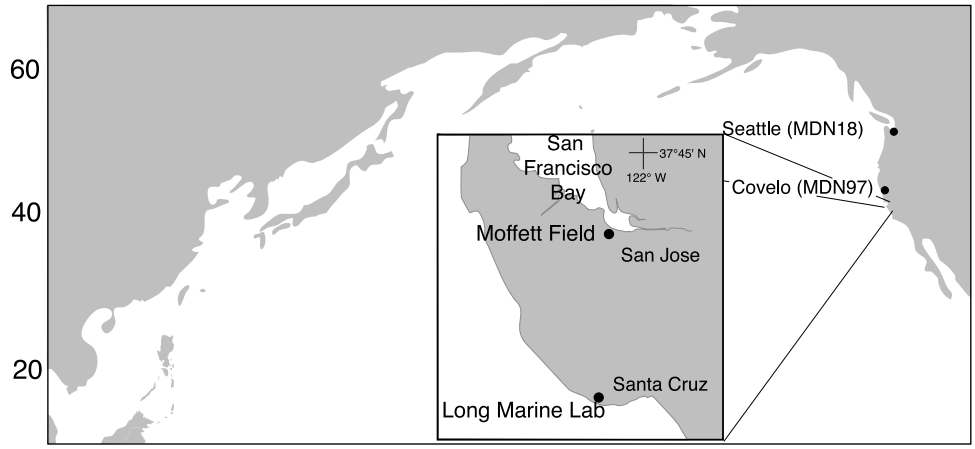

Figure 1. Location of sampling sites (inset) and MDN sites at Covelo, California, and Seattle, Washington.

Field (MF), on the other side (~50 km) of California's coastal range in the southern part of the San Francisco-San Jose-Oakland megalopolis. The coastal site (LML) was chosen to quantify the background concentration of Hg in storms directly off the Pacific, and the more inland site (MF) was chosen to investigate the impacts of local urbanization on Hg concentrations in rainwater. For reference, we compared our results at the two sites to those from two west coast Mercury Deposition Network (MDN) sites, which are located in Covelo (MDN97), California, and Seattle (MDN18), Washington (Figure 1).

[5] Collections were made using modified Aerochem Metrics 301 automated precipitation collectors, glass funnels, and Teflon™ receiving bottles using established methods, with trace metal clean techniques and high-purity reagents [*Dvonch et al.*, 1995; *Mason et al.*, 1992; *Mason et al.*, 1997b]. All sample handling and preparation was done in a HEPA filtered air (Class 100), trace metal clean room. The funnels and bottles were thoroughly cleaned in Trace Metal Grade (TMG, Fisher) acids (8N HNO_3 and 6N HCl) and rinsed (5 times) with Milli-Q (18 MΩ cm) water prior to deployment. Between events, the funnels and receiving bottles were rinsed 5 times with high-purity water, soaked in TMG 1.2N HCl, and then rinsed (5 times) before the next deployment.

[6] Immediately after an event, samples were returned to the lab, subdivided, and frozen prior to Hg analysis. Total Hg was measured after oxidation with 0.5 mL of 0.2 M BrCl using cold vapor atomic fluorescence spectroscopy, using established methods [*Bloom and Crecelius*, 1983; *Bloom and Fitzgerald*, 1988]. Method blanks averaged 10±5 pg, and the detection limit was 0.75 pM for a 100 mL sample.

[7] Aluminum was quantified by high-resolution inductively coupled plasma mass spectrometry (Finnegan Element 1). The analysis followed a HF/HNO_3/HCl (Seastar quartz distilled acids) digestion of 20 mL of sample, which was acidified with 0.5ml 12N HCl prior to digestion. This sample was dried down, digested with 1 mL 14N HF, then dried and digested with 1 mL 18N HNO_3 followed by 1 mL 12N HCl.

[8] Joyce Harris of the Climate Monitoring and Diagnostics Laboratory (CMDL) in Boulder, Colorado, provided air mass trajectory calculations. The calculations were performed using the CMDL isentropic model [*Harris and Kahl*, 1994], with 4 km arrival height for each event. The model was run to provide trajectory data for 10 days prior to each event.

3. Results and Discussion

3.1. Mercury Concentrations in Rain at Long Marine Lab

[9] Concentrations of Hg measured in rain at LML varied from 4–84 pM, with a volume weighted average of 30 pM (Figure 2). The range of concentrations are similar to that measured in the North Pacific (14–85 pM), but are elevated relative to concentrations measured in the equatorial Pacific (6.5–22.5 pM) [*Mason et al.*, 1992]. The volume-weighted concentration at LML was also similar to those (average = 28 pM) measured at the MDN97 in Covelo, California [*NADP*, 2001].

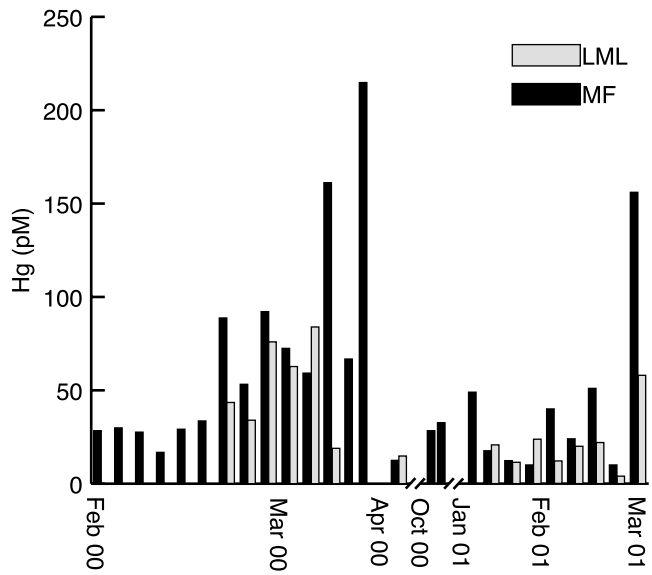

Figure 2. Concentration of Hg (pM) in rainwater at Moffett Field and Long Marine Lab.

Table 1. A Comparison Between Events at Moffett Field and Long Marine Lab[a]

	Moffett Field		Long Marine Lab	
Event Date	Hg, pM	Rainfall, mm	Hg, pM	Rainfall, mm
30 January 2000	28.38	1.51		
3 February 2000	29.89	4.26		
10 February 2000	27.61	2.73		
12 February 2000	16.78	18.73		
14 February 2000	29.17	22.07		
20 February 2000	33.60	10.10		
23 February 2000	88.74	22.58	43.35	1.82
24 February 2000	53.23	1.55	34.00	1.74
27 February 2000	92.13	9.03	76.09	10.95
28 February 2000	72.47	6.76	62.74	9.08
2 March 2000	59.21	1.95	151.54	0.45
5 March 2000	161.20	11.73	83.92	25.97
9 March 2000	66.76	13.92	18.94	13.30
10 March 2000	214.82	6.32		
14 April 2000	12.31	7.22	14.78	19.59
28 October 2000	28.07	8.41		
30 October 2000	32.30	25.16		
14 January 2001	49.11	24.87		
24 January 2001	17.60	3.56	20.74	16.18
25 January 2001	12.31	12.86	11.42	8.21
29 January 2001	9.92	1.12	23.78	1.37
11 February 2001	40.08	28.19	12.36	15.61
18 February 2001	24.28	4.64	19.59	12.09
22 February 2001	50.85	24.71	21.94	3.02
25 February 2001	10.22	4.76	4.04	28.32
2 March 2001	156.04	5.95	58.08	5.59
3 March 2001			22.78	26.66

[a]The RSD on the Hg concentration measurements is ±10%, as determined by duplicate analyses of samples.

[10] Since that latter site is in a very rural location along the California coast, its Hg concentrations are considered to represent the background concentration of Hg in rainwater on the west coast of North America. The similarity between the MDN97 Covelo site and LML substantiates the proposal that Hg concentrations at LML also approach background concentrations, although there is the possibility that some of the Hg at LML is from local emissions.

3.2. Mercury Concentrations in Rain at Moffett Field

[11] Mercury concentrations measured at MF ranged from 4–214 pM and averaged 58 pM, (Figure 2). By comparison, integrated two-week samples collected concurrently at the MF site, at MDN72, averaged 48 pM [*Tsai and Hoenicke*, 2001]. Since other sites in San Francisco Bay have reported averages of 32–36 pM [*Tsai and Hoenicke*, 2001], the marginally higher concentrations observed at MF are tentatively attributed to its downwind location from areas of industrialization and urbanization within the Bay area. The concentrations from MF also compare well to those in samples collected at MDN18 in Seattle, where the long-term (3 years) average is 53 pM [*National Atmospheric Deposition Program*, 2001]. In contrast, the maximum Hg concentrations at all of the west coast sites (MDN18, MDN97, LML, MF) are lower than maximums (~400 pM) observed at the east coast of the United States [*Mason et al.*, 1997b].

3.3. Enrichment in Hg Concentrations at MF Relative to LML

[12] A simple linear, regression analysis comparing MF and LML indicates a highly significant (P = 0.006, paired t-test), 44% enrichment in the Hg concentration of individual rain events at MF compared to LML (Figure 2). Since there is less rainfall at MF than at LML, these higher concentrations might be due to lower dilution of individual events. However, the enrichment is present at MF regardless of relative rainfall at each site (Table 1).

[13] The enrichment, therefore, is tentatively attributed to a combination of factors related to urban activity. These include higher soot particle concentrations, which effectively scavenge reactive mercury species; higher ozone concentrations, which increase atmospheric Hg^0 oxidation rates; and greater local emissions of natural and industrial Hg, from cinnabar deposits and diverse anthropogenic activities in the San Francisco Bay area, respectively.

[14] Another possible explanation for the enrichment at MF is its proximity to San Francisco Bay. Moffett Field, located in the Bay's wetlands, may be influenced by natural processes, which are similar to those observed in oceanic environments [*Mason*, 2001; *Schroeder et al.*, 1998]. Specifically, the influence of Bay surface waters may result in higher Hg deposition rates through boundary layer recycling of Hg^0, which has been hypothesized to react with Cl and Br gas, allowing for local deposition of oxidized Hg [*Mason*, 2001]. This potential source of enrichment, however, does not account for the variability seen in Hg concentrations at both sites, because the consistent magnitude of this enrichment suggests that it is superimposed on another, nonlocal, mechanism, which is governing Hg concentrations in rain on the West Coast.

3.4. Depositional Fluxes

[15] While volume weighted concentrations of Hg in rainwater are lower at LML (30 pM) relative to MF (58 pM), the annual wet deposition at LML (20 nmol m^{-2} yr^{-1}) and MF (22 nmol m^2 yr^{-1}) are similar (Table 2). The similarity is primarily due to the higher amount of rainfall at LML, which is consistent with the relationship between flux and rainfall observed in both terrestrial [*Mason et al.*, 1997a] and open ocean [*Lamborg et al.*, 1999] environments.

[16] The Hg:^{210}Pb correlation in rainwater recently observed in Wisconsin [*Lamborg et al.*, 2000] and the Atlantic Ocean [*Lamborg et al.*, 1999] has been used to calculate Hg deposition using known ^{210}Pb deposition rates [*Lamborg et al.*, 2000]. We have tested the validity of this model at our sites using (1) the ^{210}Pb deposition estimates [*Turekian*, 1977] for the west coast of North America and (2) the slope of the proposed global Hg:^{210}Pb relationship (0.06 ng*m Bq^{-1}). The resultant ratio indicates an annual Hg deposition rate of 25–50 nmol m^{-2} yr^{-1} in this coastal region, comparable with our independent calculations based on measured Hg concentrations in rainwater (Table 2).

[17] Finally, the total pre-industrial flux of Hg to the world's oceans is estimated at 3 Mmol/yr [*Mason et al.*, 1994], which averages 8.3 nmol/m^2/yr [*Mason et al.*, 1994]. Assuming that the pre-industrial flux at LML is comparable to that in the open ocean, the modern value is about twofold to threefold enriched relative to the pre-industrial flux estimate. While there are numerous limitations to this estimate, the twofold to threefold increase in deposition of Hg at LML, compares well to other estimates of the magnitude of the increase (~3 times) of Hg deposition

Table 2. Deposition Estimates of Hg at Long Marine Lab and Moffett Field[a]

Site	Volume Weighted Average Hg Concentration, pM	Annual Average Rainfall, cm	Deposition, μmol/m^2/yr
Moffett Field	58	35	22
Long Marine Lab	30	74	20

[a]Estimates are based on the data collected during the study period, and should be considered representative for that period. A longer study period is necessary to generate long term wet deposition estimates, and to quantify the annual variability in that deposition. In addition, roughly 80% of the events during the study period were sampled at MF and roughly 70% at LML. As a result, there is the potential that the volume-weighted averages used in these calculations are biased by the exclusion of extremely low- or high-concentration events. However, as our data at MF compares well to independent measurements made at MF during the same period as part of the MDN, we do not believe that these estimates are biased.

globally as a result of anthropogenic activities [*Mason et al.*, 1994].

3.5. Enrichment Factors

[18] To assess the relative contribution of natural Hg in crustal material, enrichment factors [*Duce et al.*, 1991] were calculated using published crustal concentrations [*Mason and Moore*, 1982; *Taylor*, 1964]. The enrichment factors, which ranged from 900–5700 at both sites, are much higher than those (4–40) reported in Atlantic rainwater, [*Lamborg et al.*, 1999]. The factors calculated for the Atlantic, however, involved samples with a large component of Saharan dust with a very low Hg/Al ratio that diluted the atmospheric signal.

[19] The relatively high enrichment factors at LML and MF do not necessarily imply enrichment from local anthropogenic fluxes of Hg, as the contribution from industrial emissions and natural oxidation would be difficult to tell apart using enrichment factors alone. The high enrichment factors do indicate that Hg in rainwater is not primarily derived from terrestrial dust. They are also indicative of an atmospheric source of Hg^{2+} to rainwater, which is consistent with the accepted models of Hg cycling in the atmosphere [*Lamborg et al.*, 2000; *Lin and Pehkonen*, 1999; *Munthe and McElroy*, 1992; *Pleijel and Munthe*, 1995].

3.6. Sources of Hg in the North Pacific

[20] In the Pacific basin, the dominant anthropogenic source of Hg to the atmosphere is coal combustion in China, an annual flux of 1.5 Mmol of Hg to the atmosphere [*Wang et al.*, 2000]. For comparison, this flux is double the estimated total anthropogenic Hg emissions (0.78 Mmol/yr) in the United States [*USEPA*, 1997], and accounts for roughly 10% of global industrial emissions (16.5–22 Mmol/yr) [*Mason et al.*, 1994]. With a 0.5–2 year residence time in the atmosphere, Hg^0 emissions from Chinese coal combustion are distributed on a global scale. However, emissions from coal combustion occur in both the vapor (Hg^0) and reactive Hg^{2+} states, and the reactive proportion is likely scavenged and deposited in Asia and the Pacific basin.

[21] Contrasted to anthropogenic emissions, natural emissions in the North Pacific are relatively minor, with the two dominant natural sources of Hg^0 being evasion from surface waters and emissions from volcanoes. In the case of evasion from surface waters, the majority of emissions are the result of reduction of atmospherically deposited Hg^{2+} in surface waters [*Mason et al.*, 1994]. On a global scale, this deposition and resulting evasion is estimated to be enriched 3 times over pre-anthropogenic values; and, as a result, the majority of emissions from surface waters are assumed to have anthropogenic origins [*Mason et al.*, 1994]. While there are few estimates of emissions from volcanoes within the Pacific Basin, the available estimates suggest low emissions (e.g., 5.75 mol/yr, for Kilauea Volcano in Hawaii) relative to anthropogenic emissions in the Pacific basin [*Varekamp and Buseck*, 1986]. Similarly, global emission estimates from volcanic activity range from 0.1–0.45 Mmol/yr [*Fitzgerald*, 1996]. These emissions are minor relative to both total anthropogenic emissions, and the estimated Chinese emissions, especially considering only a fraction of these volcanic emissions occur in the Pacific Basin. Therefore, the majority of Hg^0 in the atmosphere, and the majority of that Hg^0 which is reduced and deposited to land and sea surfaces is anthropogenic in origin.

3.7. Washout of Particle-Bound Hg

[22] A local washout of particle-associated Hg is not seen at MF or LML, with relatively homogenous Hg concentrations over a highly variable precipitation (1–25 mm) event size (Figure 3). Washout of particle-bound Hg is interpreted to be the cause of the strong exponential decrease in Hg concentration with increasing rainfall as observed in both continental [*Mason et al.*, 1997b] and open ocean [*Lamborg et al.*, 1999] environments. The lack of an exponential decrease in concentration with increasing event size in our data suggests that primarily nonlocal processes control the observed variability in Hg concentrations.

[23] The hypothesis that nonlocal processes are the major control on the variability of the concentrations observed was assessed by calculating the particle concentrations required to produce the concentrations observed. This was done with determination of the scavenging ratio [*Duce et al.*, 1991], which defines a relationship between rainwater concentrations and atmospheric particle concentrations as

$$W = [Hg_{rain}]^{*}\rho/[Hg_{atm}],$$

where

W = Scavenging ratio
$[Hg_{rain}]$ = Concentration of Hg in rain
ρ = Density of atmosphere
$[Hg_{atm}]$ = Concentration of Hg in the atmosphere.

Reported scavenging ratios range from 300–600 in midcontinental regions [*Fitzgerald et al.*, 1994; *Lamborg et al.*, 1995], to 1100 on the east coast of the United States [*Mason et al.*, 1997b], and ~1300 in the equatorial Pacific [*Mason et al.*, 1992]. Using a range of 500 to 1000, the volume weighted average concentrations in rainfall could be explained by atmospheric Hg particle concentrations of 71–141 fmol/m^3 at MF and 52–105 fmol/m^3 at LML. These values compare to reported atmospheric Hg particle concentrations of 2–9 fmol/m^3 in the North Pacific [*Fitzgerald*, 1989], 12 fmol/m^3 in the Atlantic [*Lamborg et al.*, 1999] and ~100 fmol/m^3 in continental settings [*Dvonch et al.*, 1995; *Keeler et al.*, 1995; *Lamborg et al.*, 1995; *Mason et al.*, 1997b].

[24] Given the rural, coastal location of LML, and the direction of prevailing winds (from the northwest, off the

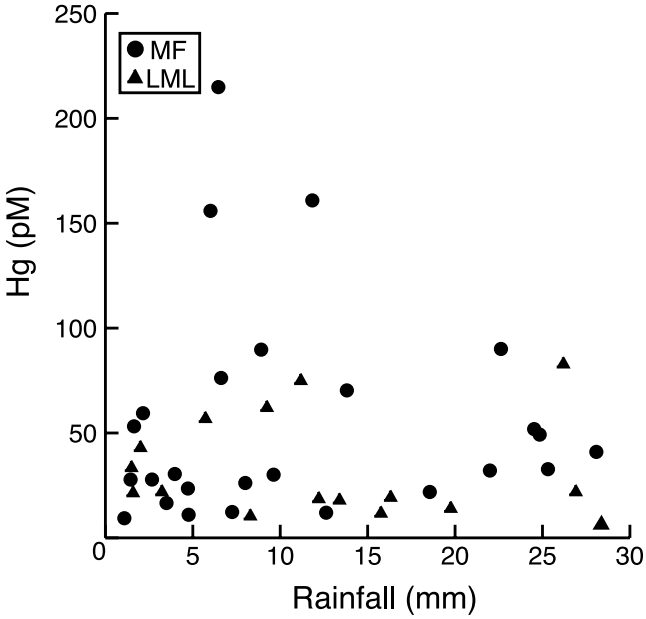

Figure 3. Total Hg versus rainfall for individual events at Long Marine Lab (triangles) and at Moffett Field (circles).

ocean) atmospheric Hg concentrations at LML are, as discussed above, assumed to be similar to those of open ocean sites. With this assumption, the particle concentration needed to account for the observed average rain concentrations is at least double that observed in open ocean environments. This disparity suggests that there is another source of Hg^{2+} to rainwater besides particle-bound Hg, which is consistent with an atmospheric source suggested by the high enrichment factors.

3.8. Air Mass Trajectory Calculations

[25] The preceding analyses indicate that a mechanism, other than local particle washout, is needed to explain the observed variability in rainwater Hg concentrations at both LML and MF. Trajectory calculations of air parcels associated with each event demonstrate a pattern of Hg concentration in rain, which is controlled by storm tracks across the North Pacific (Figure 4). Comparing the data in this study with samples from the North Pacific collected in the 1980s [*Fitzgerald*, 1989] and with equatorial samples collected in 1990 [*Mason et al.*, 1992] reveals a pattern of low Hg concentrations in rainwater in equatorial regions, higher concentrations in the midlatitudes, and slightly decreasing concentrations in the northern latitudes (Figure 4). This latitudinal pattern suggests that large-scale processes are involved in controlling the variability of Hg concentrations observed in this study. Most notably, the peak concentrations at middle latitudes suggest a source in Asia, which appears to influence Hg concentrations in rain on the coast of California.

3.9. Long-Range Sources of Hg

[26] Additional analyses of the sources of Hg in rain in the Pacific Basin are necessary in order assess the validity of the proposal that industrial emissions from Asia are the primary source of Hg in North Pacific rain. The dominant species of Hg in the atmosphere is Hg^0, but reactive Hg^{2+} has been demonstrated to be the dominant species of Hg in rainwater. Given the evidence for a nonlocal atmospheric source of Hg in precipitation, consideration of the atmospheric processes responsible for the generation of Hg^{2+} in the atmosphere is necessary in evaluating potential sources of Hg in rainwater.

[27] While our understanding of the atmospheric chemistry of Hg is far from complete, there are two current accepted processes by which Hg^0 is oxidized and incorpo-

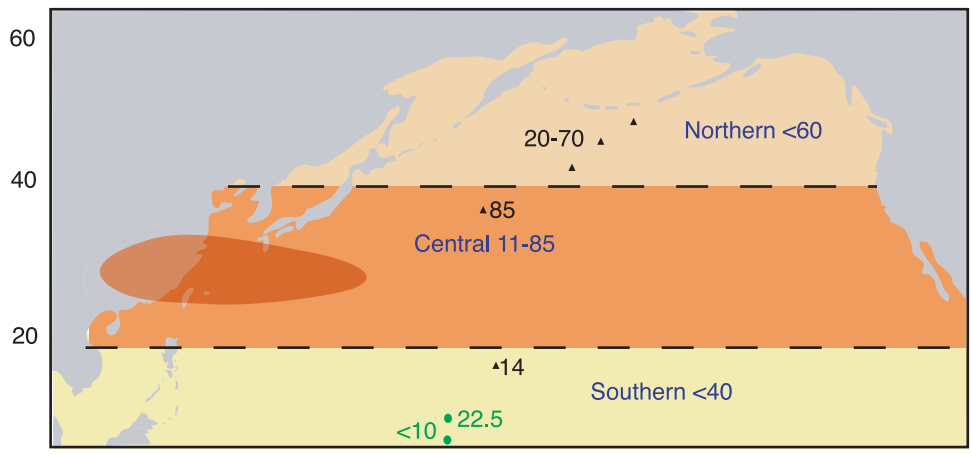

Figure 4. Relationship between storm tracks and Hg concentrations at Long Marine Lab. Storm tracks have been sorted into three categories, represented by dashed lines. Concentrations (pM) are given in blue for each category, with peak concentrations associated with the midlatitude storm tracks. For comparison, previous measurements of Hg in rainwater in the Pacific are given; circles are from *Mason et al.* [1992], triangles from SEAREX [*Fitzgerald*, 1989]. In addition, the area of maximum ozone production and export is plotted [*Mauzerall et al.*, 2000], which corresponds to the peak Hg concentrations observed in this study. See text for discussion.

rated in rainwater. One of these mechanisms, the Cloud Conversion Model (CCM), proposed by Pleijel and Munthe [*Munthe and McElroy*, 1992; *Pleijel and Munthe*, 1995], focuses on the oxidation of Hg^0 in the aqueous phase, and then scavenging of the reactive Hg by soot contained in raindrops. The other mechanism suggests the production of Hg^{2+} in the gas phase (reaction of Hg^0 with either O_3 or H_2O_2) may be the dominant mechanism [*Lamborg et al.*, 2000].

[28] Other models [*Bergan and Rodhe*, 2001] have built on this work, and suggest that the kinetics of O_3 oxidation of Hg^0 is too slow to explain the observed trends in atmospheric Hg speciation and distribution. Work on depletion of Hg^0 during polar sunrise in the Arctic has shown a positive correlation with O_3 [*Schroeder et al.*, 1998], which is attributed to the generation of free halogen species, highly effective oxidizers of Hg^0 [*Schroeder and Munthe*, 1998], during the photodegradation of O_3 [*Lu et al.*, 2001]. The production of halogen species has also been demonstrated to occur during O_3 degradation at lower latitudes [*Dickerson et al.*, 1999], and these halogen species are thought to play an important part in the oxidation of Hg^0 in the marine boundary layer [*Mason*, 2001]. As a result, the oxidation of Hg^0 in the marine environment will be strongly influenced by the concentration of O_3, either directly, through oxidation of Hg^0 or indirectly through the production of reactive halogen species as that O_3 photodegrades.

[29] Asia, and in particular, China, has received a great deal of scientific attention recently as a result of increasing impacts on atmospheric O_3 concentrations due to industrial activities [*Carmichael et al.*, 1998; *Mauzerall et al.*, 2000; *Pochanart et al.*, 1999]. During wintertime, there is a maximum in O_3 production in China as a result of biomass burning, coal combustion and other industrial activities, and, coupled with strong northwesterly continental outflow, these activities result in maximum O_3 concentrations in the western Pacific [*Mauzerall et al.*, 2000]. This O_3 is available for oxidation of ambient Hg^0 through the mechanisms described above, and, if the resulting reactive Hg^{2+} is incorporated in developing storms, it will be effectively transported across the Pacific to the west coast of North America as indicated in Figure 4.

[30] Therefore, O_3 should be considered a tracer for potential oxidation of Hg^0, through both direct and indirect oxidation of Hg^0. The elevated Hg concentrations in rain observed in this study, then, are most likely the result of Asian emissions of both Hg and O_3 and its precursors, although the later may play a more important role in supplying Hg^{2+} to rainwater. These emissions will combine to enhance Hg^0 oxidation rates in the Pacific basin, ultimately resulting in elevated Hg concentrations in rainwater sourced within the basin. This phenomenon has been used to explain Hg deposition in Florida, where recent work suggests that up to 80% of deposition to the Florida Everglades is the result of production of reactive Hg^{2+} species in the marine boundary layer that is then scavenged and deposited by storms in Florida [*Guentzel et al.*, 2001].

4. Conclusions

[31] This initial study demonstrates the impact of Asian industrial emissions on Hg concentrations in rain in western North America. The analyses substantiate previous reports on the influence of those emissions on Hg deposition in the North Pacific, first proposed by Bill Fitzgerald and his colleagues during the SEAREX program [*Fitzgerald*, 1989]. The increased Hg concentrations in rainwater in central California are attributed to a series of atmospheric reactions, and are not dependent solely on emissions of industrial Hg to the atmosphere. Rather, the concentrations may be due to a combination of particle-bound Hg emissions from Asia and a series of redox reactions centered around the destruction of O_3 in the marine troposphere, that increases production of atmospheric Hg^{2+} above background levels. Rainwater, contained in storms forming in the Western Pacific, then transports this contaminant Hg across the Pacific to the west coast of North America.

[32] Superimposed on this long-range transport of Hg in storms are local inputs due to human activities. Those inputs are evidenced by the 44% enrichment of Hg concentrations in precipitation at the urban site (MF) relative to the coastal site (LML). The enrichment could be the result of local industrial Hg emissions, soot, or redox species emissions, which result in higher concentrations of Hg in rainwater at MF relative to LML. Alternatively, the enrichment may be the result of higher O_3 concentrations, which will facilitate direct and indirect oxidation of Hg^0. Additionally, San Francisco Bay, which abuts MF, may supply the sea salt aerosols necessary to generate free halogens during O_3 degradation.

[33] Both of these apparently local and trans-Pacific fluxes demonstrate the increasing importance in understanding the atmospheric chemistry of Hg. Our understanding of the sources of Hg deposited to terrestrial and aquatic environments is directly linked to our understanding of the redox reactions governing the production of Hg^{2+} in the atmosphere, and here we demonstrate how the influence of anthropogenic emissions impact Hg on both regional and hemispheric scales. These data corroborate other recent reports that indicate efforts to regulate Hg concentrations in fish and waterways must focus not only on Hg emissions, but also on emissions of redox species such as O_3 if they are to achieve their desired reductions in concentrations.

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Treatment Technology Review and Assessment

Association of Washington Business
Association of Washington Cities
Washington State Association of Counties

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Acronyms

Acronym	Definition
AACE	Association for the Advancement of Cost Engineering
AOP	advanced oxidation processes
AWB	Association of Washington Businesses
BAC	biological activated carbon
BAP	benzo(a)pyrene
BOD	biochemical oxygen demand
BTU	British thermal unit
CEPT	Chemically-enhanced primary treatment
cf	cubic feet
CIP	clean in place
CRITFC	Columbia River Inter-Tribal Fish Commission
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
FCR	fish consumption rate
g/day	grams per day
GAC	granular activated carbon
gal	gallon
gfd	gallons per square foot per day
GHG	greenhouse gas
gpd	gallons per day
gpm	gallons per minute
GWh	giga watt hours
HDR	HDR Engineering, Inc.
HHWQC	human health water quality criteria
HRT	hydraulic residence time
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
KWh/MG	kilowatt-hours per million gallons
lb	pound
MBR	membrane bioreactor
MCL	maximum contaminant level
MF	microfiltration
mgd	million gallons per day
mg/L	milligrams per liter
MMBTU	million British thermal units
MWh/d	megawatt-hours per day
NF	nanofiltration
ng/L	nanograms per liter
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
O&M	operations and maintenance
ODEQ	Oregon Department of Environmental Quality
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PE	population equivalents
PIX	potable ion exchange

Acronym	Definition
ppm	parts per million
RO	reverse osmosis
SDWA	Safe Drinking Water Act
sf	square feet
SGSP	salinity gradient solar pond
SRT	solids retention time
Study Partners	Association of Washington Businesses/Association of Washington Cities and Washington State Association of Counties consortium
TDS	total dissolved solids
TMDL	total maximum daily load
TSS	total suspended solids
UF	ultrafiltration
µg/L	micrograms per liter
USDA	U.S. Department of Agriculture
UV	ultraviolet
WAC	Washington Administrative Code
WAS	waste activated sludge
WLA	waste load allocation
WWTP	wastewater treatment plant
ZLD	zero liquid discharge

Executive Summary

This study evaluated treatment technologies potentially capable of meeting the State of Washington Department of Ecology's (Ecology) revised effluent discharge limits associated with revised human health water quality criteria (HHWQC). HDR Engineering, Inc. (HDR) completed a literature review of potential technologies and an engineering review of their capabilities to evaluate and screen treatment methods for meeting revised effluent limits for four constituents of concern: arsenic, benzo(a)pyrene (BAP), mercury, and polychlorinated biphenyls (PCBs). HDR selected two alternatives to compare against an assumed existing baseline secondary treatment system utilized by dischargers. These two alternatives included enhanced secondary treatment with membrane filtration/reverse osmosis (MF/RO) and enhanced secondary treatment with membrane filtration/granulated activated carbon (MF/GAC). HDR developed capital costs, operating costs, and a net present value (NPV) for each alternative, including the incremental cost to implement improvements for an existing secondary treatment facility.

Currently, there are no known facilities that treat to the HHWQC and anticipated effluent limits that are under consideration. Based on the literary review, research, and bench studies, the following conclusions can be made from this study:

- Revised HHWQC based on state of Oregon HHWQC (2001) and U.S. Environmental Protection Agency (EPA) "National Recommended Water Quality Criteria" will result in very low water quality criteria for toxic constituents.
- There are limited "proven" technologies available for dischargers to meet required effluent quality limits that would be derived from revised HHWQC.
    - Current secondary wastewater treatment facilities provide high degrees of removal for toxic constituents; however, they are not capable of compliance with water quality-based National Pollutant Discharge Elimination System (NPDES) permit effluent limits derived from the revised HHWQC.
    - Advanced treatment technologies have been investigated and candidate process trains have been conceptualized for toxics removal.
        - Advanced wastewater treatment technologies may enhance toxics removal rates; however, they will not be capable of compliance with HHWQC-based effluent limits for PCBs. The lowest levels achieved based on the literature review were between <0.00001 and 0.00004 micrograms per liter (µg/L), as compared to a HHWQC of 0.0000064 µg/L.
        - Based on very limited performance data for arsenic and mercury from advanced treatment information available in the technical literature, compliance with revised criteria may or may not be possible, depending upon site specific circumstances.
            - Compliance with a HHWQC for arsenic of 0.018 µg/L appears unlikely. Most treatment technology performance information available in the literature is based on drinking water treatment applications targeting a much higher Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 10 µg/L.
            - Compliance with a HHWQC for mercury of 0.005 µg/L appears to be potentially attainable on an average basis, but perhaps not if effluent limits are structured on a maximum monthly, maximum weekly or maximum daily basis. Some secondary treatment facilities attain average effluent mercury levels of 0.009 to 0.066 µg/L. Some treatment facilities with effluent filters attain average effluent mercury levels of 0.002 to 0.010 µg/L. Additional

advanced treatment processes are expected to enhance these removal rates, but little mercury performance data is available for a definitive assessment.

- Little information is available to assess the potential for advanced technologies to comply with revised BAP criteria. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

- Some technologies may be effective at treating identified constituents of concern to meet revised limits while others may not. It is therefore even more challenging to identify a technology that can meet all constituent limits simultaneously.
- A HHWQC that is one order-of-magnitude less stringent could likely be met for mercury and BAP; however, it appears PCB and arsenic limits would not be met.

- Advanced treatment processes incur significant capital and operating costs.
  - Advanced treatment process to remove additional arsenic, BAP, mercury, and PCBs would combine enhancements to secondary treatment with microfiltration membranes and reverse osmosis or granular activated carbon and increase the estimated capital cost of treatment from $17 to $29 in dollars per gallon per day of capacity (based on a 5.0-million-gallon-per-day (mgd) facility).
  - The annual operation and maintenance costs for the advanced treatment process train will be substantially higher (approximately $5 million - $15 million increase for a 5.0 mgd capacity facility) than the current secondary treatment level.
- Implementation of additional treatment will result in additional collateral impacts.
  - High energy consumption.
  - Increased greenhouse gas emissions.
  - Increase in solids production from chemical addition to the primaries. Additionally, the membrane and GAC facilities will capture more solids that require handling.
  - Increased physical space requirements at treatment plant sites for advanced treatment facilities and residuals management including reverse osmosis reject brine processing.
- It appears advanced treatment technology alone cannot meet all revised water quality limits and implementation tools are necessary for discharger compliance.
  - Implementation flexibility will be necessary to reconcile the difference between the capabilities of treatment processes and the potential for HHWQC driven water quality based effluent limits to be lower than attainable with technology

Table ES-1 indicates that the unit NPV cost for baseline conventional secondary treatment ranges from $13 to $28 per gallon per day of treatment capacity. The unit cost for the advanced treatment alternatives increases the range from the low $20s to upper $70s on a per gallon per-day of treatment capacity. The resulting unit cost for improving from secondary treatment to advanced treatment ranges between $15 and $50 per gallon per day of treatment capacity. Unit costs were also evaluated for both a 0.5 and 25 mgd facility. The range of unit costs for improving a 0.5 mgd from secondary to advanced treatment is $60 to $162 per gallon per day of treatment capacity. The range of unit costs for improving a 25 mgd from secondary to advanced treatment is $10 to $35 per gallon per day of treatment capacity.

Table ES-1. Treatment Technology Costs in 2013 Dollars for a 5-mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)***	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
Baseline (Conventional Secondary Treatment)*	59 - 127	5 - 11	65 - 138	13 - 28
Incremental Increase to Advanced Treatment - MF/RO	48 - 104	26 - 56	75 - 160	15 - 32
Advanced Treatment - MF/RO**	108 - 231	31 - 67	139 - 298	28 - 60
Incremental Increase to Advanced Treatment - MF/GAC	71 - 153	45 - 97	117 - 250	23 - 50
Advanced Treatment - MF/GAC	131 - 280	50 - 108	181 - 388	36 - 78

* Assumed existing treatment for dischargers. The additional cost to increase the SRT to upwards of 30-days is about $12 - 20 million additional dollars in total project cost for a 5 mgd design flow.

** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.

*** Does not include the cost for labor.

mgd=million gallons per day
MG=million gallons
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
O&M=operations and maintenance
Net Present Value = total financed cost assuming a 5% nominal discount rate over an assumed 25 year equipment life.

Costs presented above are based on a treatment capacity of 5.0 mgd, however, existing treatment facilities range dramatically across Washington in size and flow treated. The key differences in cost between the baseline and the advanced treatment MF/RO are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (>8 days versus <8 days).
- Additional pumping stations to pass water through the membrane facilities and granulated activated carbon facilities. These are based on peak flows.
- Membrane facilities (equipment, tanks chemical feed facilities, pumping, etc.) and replacement membrane equipment.
- Granulated activated carbon facilities (equipment, contact tanks, pumping, granulated activated carbon media, etc.)
- Additional energy and chemical demand to operate the membrane and granulated activated carbon facilities
- Additional energy to feed and backwash the granulated activated carbon facilities.
- Zero liquid discharge facilities to further concentrate the brine reject.
    - Zero liquid discharge facilities are energy/chemically intensive and they require membrane replacement every few years due to the brine reject water quality.
- Membrane and granulated activated carbon media replacement represent a significant maintenance cost.

- Additional hauling and fees to regenerate granulated activated carbon off-site.

The mass of pollutant removal by implementing advanced treatment was calculated based on reducing current secondary effluent discharges to revised effluent limits for the four pollutants of concern. These results are provided in Table ES-2 as well as a median estimated unit cost basis for the mass of pollutants removed.

Table ES-2. Unit Cost by Contaminant for a 5-mgd Facility Implementing Advanced Treatment using Membrane Filtration/Reverse Osmosis

Component	PCBs	Mercury	Arsenic	BAPs
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)	0.002	0.025	7.5	0.006
Total Mass Removed (lbs) over 25 year Period	0.76	7.6	2,800	1.8
Median Estimated Unit Cost (NPV per total mass removed in pounds over 25 years)	$290,000,000	$29,000,000	$77,000	$120,000,000

µg/L=micrograms per liter
lbs=pounds
NPV=net present value

Collateral adverse environmental impacts associated with implementing advanced treatment were evaluated. The key impacts from this evaluation include increased energy use, greenhouse gas production, land requirements and treatment residuals disposal. Operation of advanced treatment technologies could increase electrical energy by a factor of 2.3 to 4.1 over the baseline secondary treatment system. Direct and indirect greenhouse gas emission increases are related to the operation of advanced treatment technologies and electrical power sourcing, with increases of at least 50 to 100 percent above the baseline technology. The energy and air emission implications of advanced treatment employing granulated activated carbon construction of advanced treatment facilities will require additional land area. The availability and cost of land adjacent to existing treatment facilities has not been included in cost estimates, but could be very substantial. It is worthwhile noting residual materials from treatment may potentially be hazardous and their disposal may be challenging to permit. Costs assume zero liquid discharge from the facilities.

1.0 Introduction

Washington's Department of Ecology (Ecology) has an obligation to periodically review waterbody "designated uses" and to modify, as appropriate, water quality standards to ensure those uses are protected. Ecology initiated this regulatory process in 2009 for the human health-based water quality criteria (HHWQC) in Washington's *Surface Water Quality Standards* (Washington Administrative Code [WAC] 173-201A). HHWQC are also commonly referred to as "toxic pollutant water quality standards." Numerous factors will influence Ecology's development of HHWQC. The expectation is that the adopted HHWQC will be more stringent than current adopted criteria. National Pollutant Discharge Elimination System (NPDES) effluent limits for permitted dischargers to surface waters are based on U.S. Environmental Protection Agency (EPA) and state guidance. Effluent limits are determined primarily from reasonable potential analyses and waste load allocations (WLAs) from total maximum daily loads (TMDLs), although the permit writer may use other water quality data. Water quality-based effluent limits are set to be protective of factors, including human health, aquatic uses, and recreational uses. Therefore, HHWQC can serve as a basis for effluent limits. The presumption is that more stringent HHWQC will, in time, drive lower effluent limits. The lower effluent limits will require advanced treatment technologies and will have a consequent financial impact on NPDES permittees. Ecology anticipates that a proposed revision to the water quality standards regulation will be issued in first quarter 2014, with adoption in late 2014.

The Association of Washington Businesses (AWB) is recognized as the state's chamber of commerce, manufacturing and technology association. AWB members, along with the Association of Washington Cities and Washington State Association of Counties (collectively referred to as Study Partners), hold NPDES permits authorizing wastewater discharges. The prospect of more stringent HHWQC, and the resulting needs for advanced treatment technologies to achieve lower effluent discharge limits, has led this consortium to sponsor a study to assess technology availability and capability, capital and operations and maintenance (O&M) costs, pollutant removal effectiveness, and collateral environmental impacts of candidate technologies.

The "base case" for the study began with the identification of four nearly ubiquitous toxic pollutants present in many industrial and municipal wastewater discharges, and the specification of pollutant concentrations in well-treated secondary effluent. The pollutants are arsenic, benzo(a)pyrene (BAP), mercury and polychlorinated biphenyls (PCBs), which were selected for review based on available monitoring data and abundant presence in the environment. The purpose of this study is to review the potential water quality standards and associated treatment technologies able to meet those standards for four pollutants.

A general wastewater treatment process and wastewater characteristics were used as the common baseline for comparison with all of the potential future treatment technologies considered. An existing secondary treatment process with disinfection at a flow of 5 million gallons per day (mgd) was used to represent existing conditions. Typical effluent biochemical oxygen demand (BOD) and total suspended solids (TSS) were assumed between 10 and 30 milligrams per liter (mg/L) for such a facility and no designed nutrient or toxics removal was assumed for the baseline existing treatment process.

Following a literature review of technologies, two advanced treatment process options for toxics removal were selected for further evaluation based on the characterization of removal effectiveness from the technical literature review and Study Partners' preferences. The two tertiary treatment options are microfiltration membrane filtration (MF) followed by either reverse osmosis (RO) or granular activated carbon (GAC) as an addition to an existing secondary treatment facility.

The advanced treatment technologies are evaluated for their efficacy and cost to achieve the effluent limitations implied by the more stringent HHWQC. Various sensitivities are examined, including for less stringent adopted HHWQC, and for a size range of treatment systems. Collateral environmental impacts associated with the operation of advanced technologies are also qualitatively described.

2.0 Derivation of the Baseline Study Conditions and Rationale for Selection of Effluent Limitations

2.1 Summary of Water Quality Criteria

Surface water quality standards for toxics in the State of Washington are being updated based on revised human fish consumption rates (FCRs). The revised water quality standards could drive very low effluent limitations for industrial and municipal wastewater dischargers. Four pollutants were selected for study based on available monitoring data and abundant presence in the environment. The four toxic constituents are arsenic, BAP, mercury, and PCBs.

2.2 Background

Ecology is in the process of updating the HHWQC in the state water quality standards regulation. Toxics include metals, pesticides, and organic compounds. The human health criteria for toxics are intended to protect people who consume water, fish, and shellfish. FCRs are an important factor in the derivation of water quality criteria for toxics.

The AWB/City/County consortium (hereafter "Study Partners") has selected four pollutants for which more stringent HHWQC are expected to be promulgated. The Study Partners recognize that Ecology probably will not adopt more stringent arsenic HHWQC so the evaluation here is based on the current arsenic HHWQC imposed by the National Toxics Rule. Available monitoring information indicates these pollutants are ubiquitous in the environment and are expected to be present in many NPDES discharges. The four pollutants include the following:

- Arsenic
  - Elemental metalloid that occurs naturally and enters the environment through erosion processes. Also widely used in batteries, pesticides, wood preservatives, and semiconductors. Other current uses and legacy sources in fungicides/herbicides, copper smelting, paints/dyes, and personal care products.

- Benzo(a)pyrene (BAP)
  - Benzo(a)pyrene is a polycyclic aromatic hydrocarbon formed by a benzene ring fused to pyrene as the result of incomplete combustion. Its metabolites are highly carcinogenic. Sources include wood burning, coal tar, automobile exhaust, cigarette smoke, and char-broiled food.

- Mercury
  - Naturally occurring element with wide legacy uses in thermometers, electrical switches, fluorescent lamps, and dental amalgam. Also enters the environment through erosion processes, combustion (especially coal), and legacy industrial/commercial uses. Methylmercury is an organometallic that is a bioaccumulative toxic. In aquatic systems, an anaerobic methylation process converts inorganic mercury to methylmercury.

- Polychlorinated Biphenyls (PCBs)
  - Persistent organic compounds historically used as a dielectric and coolant in electrical equipment and banned from production in the U.S. in 1979. Available information indicates continued pollutant loadings to the environment as a byproduct from the use of some pigments, paints, caulking, motor oil, and coal combustion.

2.3 Assumptions Supporting Selected Ambient Water Quality Criteria and Effluent Limitations

Clean Water Act regulations require NPDES permittees to demonstrate their discharge will "not cause or contribute to a violation of water quality criteria." If a "reasonable potential analysis" reveals the possibility of a standards violation, the permitting authority is obliged to develop "water quality-based effluent limits" to ensure standards achievement. In addition, if ambient water quality monitoring or fish tissue assessments reveal toxic pollutant concentrations above HHWQC levels, Ecology is required to identify that impairment ("303(d) listing") and develop corrective action plans to force reduction in the toxic pollutant discharge or loading of the pollutant into the impaired water body segment. These plans, referred to as total maximum daily loads (TMDLs) or water cleanup plans, establish discharge allocations and are implemented for point discharge sources through NPDES permit effluent limits and other conditions.

The effect of more stringent HHWQC will intuitively result in more NPDES permittees "causing or contributing" to a water quality standards exceedance, and/or more waterbodies being determined to be impaired, thus requiring 303(d) listing, the development of TMDL/water cleanup plans, and more stringent effluent limitations to NPDES permittees whose treated wastewater contains the listed toxic pollutant.

The study design necessarily required certain assumptions to create a "baseline effluent scenario" against which the evaluation of advanced treatment technologies could occur. The Study Partners and HDR Engineering, Inc (HDR) developed the scenario. Details of the baseline effluent scenario are presented in Table 1. The essential assumptions and rationale for selection are presented below:

- Ecology has indicated proposed HHWQC revisions will be provided in first quarter 2014. A Study Partners objective was to gain an early view on the treatment technology and cost implications. Ecology typically allows 30 or 45 days for the submission of public comments on proposed regulations. To wait for the proposed HHWQC revisions would not allow sufficient time to complete a timely technology/cost evaluation and then to share the study results in the timeframe allowed for public involvement/public comments.
- Coincident with the issuance of the proposed regulation, Ecology has a statutory obligation to provide a Significant Legislative Rule evaluation, one element of which is a "determination whether the probable benefits of the rule are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs and the specific directives of the statute being implemented" (RCW 34.05.328(1)(d)). A statutory requirement also exists to assess the impact of the proposed regulation to small businesses. The implication is that Ecology will be conducting these economic evaluations in fourth quarter 2013 and early 2014. The Study Partners wanted to have a completed technology/cost study available to share with Ecology for their significant legislative rule/small business evaluations.
- The EPA, Indian tribes located in Washington, and various special interest groups have promoted the recently promulgated state of Oregon HHWQC (2011) as the "model" for Washington's revisions of HHWQC. The Oregon HHWQC are generally based on a increased FCR of 175 grams per day (g/day) and an excess cancer risk of 10^{-6}. While the Study Partners do not concede the wisdom or appropriateness of the Oregon criteria, or the selection of scientific/technical elements used to derive those criteria, the Study Partners nevertheless have selected the Oregon HHWQC as a viable "starting point" upon which this study could be based.

- The scenario assumes generally that Oregon's HHWQC for ambient waters will, for some parameters in fact, become effluent limitations for Washington NPDES permittees. The reasoning for this important assumption includes:
  - The state of Washington's NPDES permitting program is bound by the *Friends of Pinto Creek vs. EPA* decision in the United States Court of Appeals for the Ninth Circuit (October 4, 2007). This decision held that no NPDES permits authorizing new or expanded discharges of a pollutant into a waterbody identified as impaired; i.e., listed on CWA section 303(d), for that pollutant, may be issued until such time as "existing dischargers" into the waterbody are "subject to compliance schedules designed to bring the (waterbody) into compliance with applicable water quality standards." In essence, any new/expanded discharge of a pollutant causing impairment must achieve the HHWQC at the point of discharge into the waterbody.
  - If a waterbody segment is identified as "impaired" (i.e., not achieving a HHWQC), then Ecology will eventually need to produce a TMDL or water cleanup plan. For an existing NPDES permittee with a discharge of the pollutant for which the receiving water is impaired, the logical assumption is that any waste load allocation granted to the discharger will be at or lower than the numeric HHWQC (to facilitate recovery of the waterbody to HHWQC attainment). As a practical matter, this equates to an effluent limit established at the HHWQC.
  - Acceptance of Oregon HHWQC as the baseline for technology/cost review also means acceptance of practical implementation tools used by Oregon. The HHWQC for mercury is presented as a fish tissue methyl mercury concentration. For the purposes of NPDES permitting, however, Oregon has developed an implementation management directive which states that any confirmed detection of mercury is considered to represent a "reasonable potential" to cause or contribute to a water quality standards violation of the methyl mercury criteria. The minimum quantification level for total mercury is presented as 0.005 micrograms per liter (µg/L) (5.0 nanograms per liter (ng/L)).
  - The assumed effluent limit for arsenic is taken from EPA's *National Recommended Water Quality Criteria* (2012) (inorganic, water and organisms, 10^{-6} excess cancer risk). Oregon's 2011 criterion is actually based on a less protective excess cancer risk (10^{-4}). This, however, is the result of a state-specific risk management choice and it is unclear if Washington's Department of Ecology would mimic the Oregon approach.
  - The assumption is that no mixing zone is granted such that HHWQC will effectively serve as NPDES permit effluent limits. Prior discussion on the impact of the Pinto Creek decision, 303(d) impairment and TMDL Waste Load Allocations processes, all lend support to this "no mixing zone" condition for the parameters evaluated in this study.
- Consistent with Ecology practice in the evaluation of proposed regulations, the HHWQC are assumed to be in effect for a 20-year period. It is assumed that analytical measurement technology and capability will continue to improve over this time frame and this will result in the detection and lower quantification of additional HHWQC in ambient water and NPDES dischargers. This knowledge will trigger the Pinto Creek/303(d)/TMDL issues identified above and tend to pressure NPDES permittees to evaluate and install advanced treatment technologies. The costs and efficacy of treatment for these additional HHWQC is unknown at this time.

Other elements of the Study Partners work scope, as presented to HDR, must be noted:

- The selection of four toxic pollutants and development of a baseline effluent scenario is not meant to imply that each NPDES permittee wastewater discharge will include those pollutants at the assumed concentrations. Rather, the scenario was intended to represent a composite of many NPDES permittees and to facilitate evaluation of advanced treatment technologies relying on mechanical, biological, physical, chemical processes.
- The scalability of advanced treatment technologies to wastewater treatment systems with different flow capacities, and the resulting unit costs for capital and O&M, is evaluated.
- Similarly, a sensitivity analysis on the unit costs for capital and O&M was evaluated on the assumption the adopted HHWQC (and effectively, NPDES effluent limits) are one order-of-magnitude less stringent than the Table 1 values.

Table 1: Summary of Effluent Discharge Toxics Limits

Constituent	Human Health Criteria based Limits to be met with no Mixing Zone (µg/L)	Basis for Criteria	Typical Concentration in Municipal Secondary Effluent (µg/L)	Typical Concentration in Industrial Secondary Effluent (µg/L)	Existing Washington HHC (water + org.), NTR (µg/L)
PCBs	0.0000064	Oregon Table 40 Criterion (water + organisms) at FCR of 175 grams/day	0.0005 to 0.0025[b,c,d,e,f]	0.002 to 0.005[i]	0.0017
Mercury	0.005	DEQ IMD[a]	0.003 to 0.050[h]	0.010 to 0.050[h]	0.140
Arsenic	0.018	EPA National Toxics Rule (water + organisms)[k]	0.500 to 5.0[j]	10 to 40[j]	0.018
Benzo(a)Pyrene	0.0013	Oregon Table 40 Criterion (water + organisms) at FCR of 175 grams/day	0.00028 to 0.006[b,g]	0.006 to1.9	0.0028

[a] Oregon Department of Environmental Quality (ODEQ). Internal Management Directive: Implementation of Methylmercury Criterion in NPDES Permits. January 8, 2013.
[b] Control of Toxic Chemicals in Puget Sound, Summary Technical Report for Phase 3: Loadings from POTW Discharge of Treated Wastewater, Washington Department of Ecology, Publication Number 10-10-057, December 2010.
[c] Spokane River PCB Source Assessment 2003-2007, Washington Department of Ecology, Publication No. 11-03-013, April 2011.
[d] Lower Okanogan River Basin DDT and PCBs Total Maximum Daily Load, Submittal Report, Washington Department of Ecology, Publication Number 04-10-043, October 2004.
[e] Palouse River Watershed PCB and Dieldrin Monitoring, 2007-2008, Wastewater Treatment Plants and Abandoned Landfills, Washington Department of Ecology, Publication No. 09-03-004, January 2009
[f] A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River, Washington Department of Ecology, Publication No. 04-03-032, October 2004.
[g] Removal of Polycyclic Aromatic Hydrocarbons and Heterocyclic Nitrogenous Compounds by A POTW Receiving Industrial Discharges, Melcer, H., Steel, P. and Bedford, W.K., Water Environment Federation, 66th Annual Conference and Exposition, October 1993.
[h] Data provided by Lincoln Loehr's summary of WDOE Puget Sound Loading data in emails from July 19, 2013.
[i] NCASI memo from Larry Lefleur, NCASI, to Llewellyn Matthews, NWPPA, revised June 17, 2011, summarizing available PCB monitoring data results from various sources.
[j] Professional judgment, discussed in August 6, 2013 team call.
[k] The applicable Washington Human Health Criteria cross-reference the EPA National Toxics Rule, 40 CFR 131.36. The EPA arsenic HHC is 0.018 ug/L for water and organisms.

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3.0 Wastewater Characterization Description

This section describes the wastewater treatment discharge considered in this technology evaluation. Treated wastewater characteristics are described, including average and peak flow, effluent concentrations, and toxic compounds of concern.

3.1 Summary of Wastewater Characterization

A general wastewater treatment process and wastewater characteristics were developed as the common baseline to represent the existing conditions as a starting point for comparison with potential future advanced treatment technologies and improvements. A secondary treatment process with disinfection at a flow of 5 mgd as the current, baseline treatment system for existing dischargers was also developed. Typical effluent biochemical oxygen demand (BOD) and total suspended solids (TSS) were assumed between 10 to 30 mg/L from such a facility and no nutrient or toxics removal was assumed to be accomplished in the existing baseline treatment process.

3.2 Existing Wastewater Treatment Facility

The first step in the process is to characterize the existing wastewater treatment plant to be evaluated in this study. The goal is to identify the necessary technology that would need to be added to an existing treatment facility to comply with revised toxic pollutant effluent limits. Rather than evaluating the technologies and costs to upgrade multiple actual operating facilities, the Study Partners specified that a generalized municipal/industrial wastewater treatment facility would be characterized and used as the basis for developing toxic removal approaches. General characteristics of the facility's discharge are described in Table 2.

Table 2. General Wastewater Treatment Facility Characteristics

Average Annual Wastewater Flow, mgd	Maximum Month Wastewater Flow, mgd	Peak Hourly Wastewater Flow, mgd	Effluent BOD, mg/L	Effluent TSS, mg/L
5.0	6.25	15.0	10 to 30	10 to 30

mgd=million gallons per day
mg/L=milligrams per liter
BOD=biochemical oxygen demand
TSS=total suspended solids

In the development of the advanced treatment technologies presented below, the capacity of major treatment elements are generally sized to accommodate the maximum month average wastewater flow. Hydraulic elements, such as pumps and pipelines, were selected to accommodate the peak hourly wastewater flow.

The general treatment facility incorporates a baseline treatment processes including influent screening, grit removal, primary sedimentation, suspended growth biological treatment (activated sludge), secondary clarification, and disinfection using chlorine. Solids removed during primary treatment and secondary clarification are assumed to be thickened, stabilized, dewatered, and land applied to agricultural land. The biological treatment process is assumed to be activated sludge with a relatively short (less than 10-day) solids retention time. The baseline secondary treatment facility is assumed not to have processes dedicated to removing nutrients or toxics. However, some coincident removal of toxics will occur during conventional treatment.

3.3 Toxic Constituents

As described in Section 2.3, the expectation of more stringent HHWQC will eventually trigger regulatory demands for NPDES permittees to install advanced treatment technologies. The Study Group and HDR selected four specific toxic pollutants reflecting a range of toxic constituents as the basis for this study to limit the constituents and technologies to be evaluated to a manageable level.

The four toxic pollutants selected were PCBs, mercury, arsenic, and BAP, a polycyclic aromatic hydrocarbon (PAH). Mercury and arsenic are metals, and PCBs and PAHs are organic compounds. Technologies for removing metals and organic compounds are in some cases different. Key information on each of the compounds, including a description of the constituent, the significance of each constituent, proposed HHWQC, basis for the proposed criteria, typical concentration in both municipal and industrial secondary effluent, and current Washington state water quality criteria, are shown in Table 1. It is assumed that compliance with the proposed criteria in the table would need to be achieved at the “end of pipe” and Ecology would not permit a mixing zone for toxic constituents. This represents a “worst–case,” but a plausible assumption about discharge conditions.

4.0 Treatment Approaches and Costs

4.1 Summary of Treatment Approach and Costs

Two advanced treatment process options for toxics removal for further evaluation based on the characterization of removal effectiveness from the technical literature review and Study Group preferences. The two tertiary treatment options are microfiltration MF followed by either RO or GAC as an addition to an existing secondary treatment facility. Based on the literature review, it is not anticipated that any of the treatment options will be effective in reducing all of the selected pollutants to below the anticipated water quality criteria. A summary of the capital and operations and maintenance costs for tertiary treatment is provided, as well as a comparison of the adverse environmental impacts for each alternative.

4.2 Constituent Removal – Literature Review

The evaluation of treatment technologies relevant to the constituents of concern was initiated with a literature review. The literature review included a desktop search using typical web-based search engines, and search engines dedicated to technical and research journal databases. At the same time, HDR's experience with the performance of existing treatment technologies specifically related to the four constituents of concern, was used in evaluating candidate technologies. A summary of the constituents of concern and relevant treatment technologies is provided in the following literature review section.

4.2.1 Polychlorinated Biphenyls

PCBs are persistent organic pollutants that can be difficult to remove in treatment. PCB treatment in wastewater can be achieved using oxidation with peroxide, filtration, biological treatment or a combination of these technologies. There is limited information available about achieving ultra-low effluent PCB concentrations near the 0.0000064 µg/L range under consideration in the proposed rulemaking process. This review provides a summary of treatment technology options and anticipated effluent PCB concentrations.

Research on the effectiveness of ultraviolet (UV) light and peroxide on removing PCBs was tested in bench scale batch reactions (Yu, Macawile, Abella, & Gallardo 2011). The combination of UV and peroxide treatment achieved PCB removal greater than 89 percent, and in several cases exceeding 98 percent removal. The influent PCB concentration for the batch tests ranged from 50 to 100 micrograms per liter (µg/L). The final PCB concentration (for the one congener tested) was <10 µg/L (10,000 ng/L) for all tests and <5 µg/L (5,000 ng/L) for some tests. The lowest PCB concentrations in the effluent occurred at higher UV and peroxide doses.

Pilot testing was performed to determine the effectiveness of conventional activated sludge and a membrane bioreactor to remove PCBs (Bolzonella, Fatone, Pavan, & Cecchi 2010). EPA Method 1668 was used for the PCB analysis (detection limit of 0.01 ng/L per congener). Influent to the pilot system was a combination of municipal and industrial effluent. The detailed analysis was for several individual congeners. Limited testing using the Aroclor method (total PCBs) was used to compare the individual congeners and the total concentration of PCBs. Both conventional activated sludge and membrane bioreactor (MBR) systems removed PCBs. The effluent MBR concentrations ranged from <0.01 ng/L to 0.04 ng/L compared to <0.01 ng/L to 0.88 ng/L for conventional activated sludge. The pilot testing showed that increased solids retention time (SRT) and higher mixed liquor suspended solids concentrations in the MBR system led to increased removal in the liquid stream.

Bench scale studies were completed to test the effectiveness of GAC and biological activated carbon (BAC) for removing PCBs (Ghosh, Weber, Jensen, & Smith 1999). The effluent from the

GAC system was 800 ng/L. The biological film in the BAC system was presumed to support higher PCB removal with effluent concentrations of 200 ng/L. High suspended sediment in the GAC influent can affect performance. It is recommended that filtration be installed upstream of a GAC system to reduce solids and improve effectiveness.

Based on limited available data, it appears that existing municipal secondary treatment facilities in Washington state are able to reduce effluent PCBs to the range approximately 0.10 to 1.5 ng/L. It appears that the best performing existing municipal treatment facility in Washington state with a microfiltration membrane is able to reduce effluent PCBs to the range approximately 0.00019 to 0.00063 µg/L. This is based on a very limited data set and laboratory blanks covered a range that overlapped with the effluent results (blanks 0.000058 to 0.00061 µg/L).

Addition of advanced treatment processes would be expected to enhance PCB removal rates, but the technical literature does not appear to provide definitive information for guidance. A range of expected enhanced removal rates might be assumed to vary widely from level of the reference microfiltration facility of 0.19 to 0.63 ng/L.

Summary of PCB Technologies

The literature review revealed there are viable technologies available to reduce PCBs **but no research was identified with treatment technologies capable of meeting the anticipated human health criteria based limits for PCB removal**. Based on this review, a tertiary process was selected to biologically reduce PCBs and separate the solids using tertiary filtration. Alternately, GAC was investigated as an option to reduce PCBs, although it is not proven that it will meet revised effluent limits.

4.2.2 Mercury

Mercury removal from wastewater can be achieved using precipitation, adsorption, filtration, or a combination of these technologies. There is limited information available about achieving ultra-low effluent mercury concentrations near the 5 ng/L range under consideration in the proposed rulemaking process. This review provides a summary of treatment technology options and anticipated effluent mercury concentrations.

Precipitation (and co-precipitation) involves chemical addition to form a particulate and solids separation, using sedimentation or filtration. Precipitation includes the addition of a chemical precipitant and pH adjustment to optimize the precipitation reaction. Chemicals can include metal salts (ferric chloride, ferric sulfate, ferric hydroxide, or alum), pH adjustment, lime softening, or sulfide. A common precipitant for mercury removal is sulfide, with an optimal pH between 7 and 9. The dissolved mercury is precipitated with the sulfide to form an insoluble mercury sulfide that can be removed through clarification or filtration. One disadvantage of precipitation is the generation of a mercury-laden sludge that will require dewatering and disposal. The mercury sludge may be considered a hazardous waste and require additional treatment and disposal at a hazardous waste site. The presence of other compounds, such as other metals, may reduce the effectiveness of mercury precipitation/co-precipitation. For low-level mercury treatment requirements, several treatment steps will likely be required in pursuit of very low effluent targets.

EPA compiled a summary of facilities that are using precipitation/co-precipitation for mercury treatment (EPA 2007). Three of the full-scale facilities were pumping and treating groundwater and the remaining eight facilities were full-scale wastewater treatment plants. One of the pump and treat systems used precipitation, carbon adsorption, and pH adjustment to treat groundwater to effluent concentrations of 300 ng/L.

Adsorption treatment can be used to remove inorganic mercury from water. While adsorption can be used as a primary treatment step, it is frequently used for polishing after a preliminary treatment step (EPA 2007). One disadvantage of adsorption treatment is that when the adsorbent is saturated, it either needs to be regenerated or disposed of and replaced with new adsorbent. A common adsorbent is GAC. There are several patented and proprietary adsorbents on the market for mercury removal. Adsorption effectiveness can be affected by water quality characteristics, including high solids and bacterial growth, which can cause media blinding. A constant and low flow rate to the adsorption beds increases effectiveness (EPA 2007). The optimal pH for mercury adsorption on GAC is pH 4 to 5; therefore, pH adjustment may be required.

EPA compiled a summary of facilities that are using adsorption for mercury treatment (EPA 2007). Some of the facilities use precipitation and adsorption as described above. The six summarized facilities included two groundwater treatment and four wastewater treatment facilities. The reported effluent mercury concentrations were all less than 2,000 ng/L (EPA 2007).

Membrane filtration can be used in combination with a preceding treatment step. The upstream treatment is required to precipitate soluble mercury to a particulate form that can be removed through filtration. According to the EPA summary report, ultrafiltration is used to remove high-molecular weigh contaminants and solids (EPA 2007). The treatment effectiveness can depend on the source water quality since many constituents can cause membrane fouling, decreasing the effectiveness of the filters. One case study summarized in the EPA report showed that treatment of waste from a hazardous waste combustor treated with precipitation, sedimentation, and filtration achieved effluent mercury concentrations less than the detection limit of 200 ng/L.

Bench-scale research performed at the Oak Ridge Y-12 Plant in Tennessee evaluated the effectiveness of various adsorbents for removing mercury to below the NPDES limit of 12 ng/L and the potential revised limit of 51 ng/L (Hollerman et al. 1999). Several proprietary adsorbents were tested, including carbon, polyacrylate, polystyrene, and polymer adsorption materials. The adsorbents with thiol-based active sites were the most effective. Some of the adsorbents were able to achieve effluent concentrations less than 51 ng/L but none of the adsorbents achieved effluent concentrations less than 12 ng/L.

Bench-scale and pilot-scale testing performed on refinery wastewater was completed to determine treatment technology effectiveness for meeting very low mercury levels (Urgun-Demirtas, Benda, Gillenwater, Negri, Xiong & Snyder 2012) (Urgun-Demirtas, Negri, Gillenwater, Agwu Nnanna & Yu 2013). The Great Lakes Initiative water quality criterion for mercury is less than 1.3 ng/L for municipal and industrial wastewater plants in the Great Lakes region. This research included an initial bench scale test including membrane filtration, ultrafiltration, nanofiltration, and reverse osmosis to meet the mercury water quality criterion. The nanofiltration and reverse osmosis required increased pressures for filtration and resulted in increased mercury concentrations in the permeate. Based on this information and the cost difference between the filtration technologies, a pilot-scale test was performed. The 0.04 um PVDF GE ZeeWeed 500 series membranes were tested. The 1.3 ng/L water quality criterion was met under all pilot study operating conditions. The mercury in the refinery effluent was predominantly in particulate form which was well-suited for removal using membrane filtration.

Based on available data, it appears that existing municipal treatment facilities are capable of reducing effluent mercury to near the range of the proposed HHWQC on an average basis. Average effluent mercury in the range of 1.2 to 6.6 ng/L for existing facilities with secondary treatment and enhanced treatment with cloth filters and membranes. The Spokane County plant data range is an average of 1.2 ng/L to a maximum day of 3 ng/L. Addition of

advanced treatment processes such as GAC or RO would be expected to enhance removal rates. Data from the West Basin treatment facility in California suggests that at a detection limit of 7.99 ng/L mercury is not detected in the effluent from this advanced process train. A range of expected enhanced removal rates from the advanced treatment process trains might be expected to ranged from meeting the proposed standard at 5 ng/L to lower concentrations represented by the Spokane County performance level (membrane filtration) in the range of 1 to 3 ng/L, to perhaps even lower levels with additional treatment. For municipal plants in Washington, this would suggest that effluent mercury values from the two advanced treatment process alternatives might range from 1 to 5 ng/L (0.001 to 0.005 µg/L) and perhaps substantially better, depending upon RO and GAC removals. It is important to note that industrial plants may have higher existing mercury levels and thus the effluent quality that is achievable at an industrial facility would be of lower quality.

Summary of Mercury Technologies

The literature search revealed limited research on mercury removal technologies at the revised effluent limit of 0.005 µg/L. Tertiary filtration with membrane filters or reverse osmosis showed the best ability to achieve effluent criteria less than 0.005 µg/L.

4.2.3 Arsenic

A variety of treatment technologies can be applied to capture arsenic (Table 3). Most of the information in the technical literature and from the treatment technology vendors is focused on potable water treatment for compliance with a Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 10 µg/L. The most commonly used arsenic removal method for a wastewater application (tertiary treatment) is coagulation/ flocculation plus filtration. This method by itself could remove more than 90 to 95 percent of arsenic. Additional post-treatment through adsorption, ion exchange, or reverse osmosis is required for ultra-low arsenic limits in the 0.018 µg/L range under consideration in the proposed rulemaking process. In each case it is recommended to perform pilot-testing of each selected technology.

Table 3: Summary of Arsenic Removal Technologies[1]

Technology	Advantages	Disadvantages
Coagulation/filtration	• Simple, proven technology • Widely accepted • Moderate operator training	• pH sensitive • Potential disposal issues of backwash waste • As^{+3} and As^{+5} must be fully oxidized
Lime softening	• High level arsenic treatment • Simple operation change for existing lime softening facilities	• pH sensitive (requires post treatment adjustment) • Requires filtration • Significant sludge operation
Adsorptive media	• High As^{+5} selectivity • Effectively treats water with high total dissolved solids (TDS)	• Highly pH sensitive • Hazardous chemical use in media regeneration • High concentration SeO_4^{-2}, F^-, Cl^-, and SO_4^{-2} may limit arsenic removal

Table 3: Summary of Arsenic Removal Technologies[1]

Technology	Advantages	Disadvantages
Ion exchange	• Low contact times • Removal of multiple anions, including arsenic, chromium, and uranium	• Requires removal of iron, manganese, sulfides, etc. to prevent fouling • Brine waste disposal
Membrane filtration	• High arsenic removal efficiency • Removal of multiple contaminants	• Reject water disposal • Poor production efficiency • Requires pretreatment

[1]Adapted from WesTech

The removal of arsenic in activated sludge is minimal (less than 20 percent) (Andrianisa et al. 2006), but biological treatment can control arsenic speciation. During aerobic biological process As (III) is oxidized to As (V). Coagulation/flocculation/filtration removal, as well as adsorption removal methods, are more effective in removal of As(V) vs. As (III). A combination of activated sludge and post-activated sludge precipitation with ferric chloride (addition to MLSS and effluent) results in a removal efficiency of greater than 95 percent. This combination could decrease As levels from 200 µg/L to less than 5 µg/L (5,000 ng/L) (Andrianisa et al. 2008) compared to the 0.018 µg/L range under consideration in the proposed rulemaking process.

Data from the West Basin facility (using MF/RO/AOP) suggests effluent performance in the range of 0.1 to 0.2 µg/L, but it could also be lower since a detection limit used there of 0.15 µg/l is an order of magnitude higher than the proposed HHWQC. A range of expected enhanced removal rates might be assumed to equivalent to that achieved at West Basin in 0.1 to 0.2 µg/L range.

Review of Specific Technologies for Arsenic Removal

Coagulation plus Settling or Filtration

Coagulation may remove more than 95 percent of arsenic through the creation of particulate metal hydroxides. Ferric sulfite is typically more efficient and applicable to most wastewater sources compared to alum. The applicability and extent of removal should be pilot-tested, since removal efficiency is highly dependent on the water constituents and water characteristics (i.e., pH, temperature, solids).

Filtration can be added after or instead of settling to increase arsenic removal. Example treatment trains with filtration are shown in Figures 1 and 2, respectively.

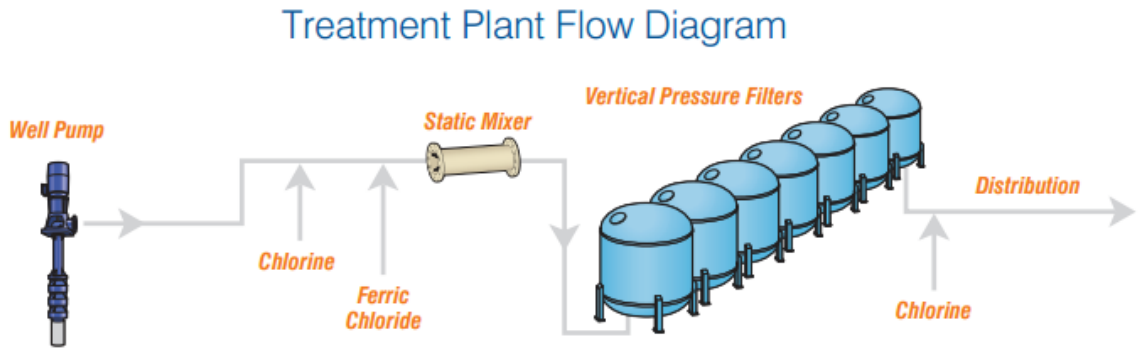

Figure 1. Water Treatment Configuration for Arsenic Removal (WesTech)

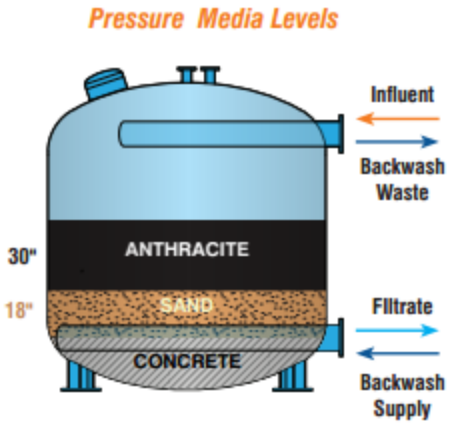

Figure 2. WesTech Pressure Filters for Arsenic Removal

One system for treatment of potable water with high levels of arsenic in Colorado (110 parts per million [ppm]) consists of enhanced coagulation followed by granular media pressure filters that include anthracite/silica sand/garnet media (WesTech). The arsenic levels were reduced to less than the drinking water MCL, which is 10 µg/L (10,000 ng/L). The plant achieves treatment by reducing the pH of the raw water to 6.8 using sulfuric acid, and then adding approximately 12 to 14 mg/L ferric sulfate. The water is filtered through 16 deep bed vertical pressure filters, the pH is elevated with hydrated lime and is subsequently chlorinated and fed into the distribution system.
(http://www.westechinc.com/public/uploads/global/2011/3/Fallon%20NV%20Installation%20ReportPressureFilter.pdf).

Softening (with lime)

Removes up to 90 percent arsenic through co-precipitation, but requires pH to be higher than 10.2.

Adsorption processes

Activated alumina is considered an adsorptive media, although the chemical reaction is an exchange of arsenic ions with the surface hydroxides on the alumina. When all the surface hydroxides on the alumina have been exchanged, the media must be regenerated. Regeneration consists of backwashing, followed by sodium hydroxide, flushing with water and neutralization with a strong acid. Effective arsenic removal requires sufficient empty bed contact time. Removal efficiency can also be impacted by the water pH, with neutral or slightly acidic conditions being considered optimum. If As (III) is present, it is generally advisable to increase empty bed contact time, as As (III) is adsorbed more slowly than As (V). Alumina dissolves slowly over time due to contact with the chemicals used for regeneration. As a result, the media bed is likely to become compacted if it is not backwashed periodically.

Granular ferric hydroxide works by adsorption, but when the media is spent it cannot be regenerated and must be replaced. The life of the media depends upon pH of the raw water, the concentrations of arsenic and heavy metals, and the volume of water treated daily. Periodic backwashing is required to prevent the media bed from becoming compacted and pH may need to be adjusted if it is high, in order to extend media life. For maximum arsenic removal, filters operate in series. For less stringent removal, filters can operate in parallel.

One type of adsorption media has been developed for application to non-drinking water processes for arsenic, phosphate and for heavy metals removal by sorption (Severent Trent Bayoxide® E IN-20). This granular ferric oxide media has been used for arsenic removal from

mining and industrial wastewaters, selenium removal from refinery wastes and for phosphate polishing of municipal wastewaters. Valley Vista drinking water treatment with Bayoxide® E IN-20 media achieves removal from 31-39 µg/L (31,000-39,000 ng/L) to below 10 µg/L MCL (http://www.severntrentservices.com/News/Successful_Drinking_Water_Treatment_in_an_Arsenic__Hot_Spot__nwMFT_452.aspx).

Another adsorptive filter media is greensand. Greensand is available in two forms: as glauconite with manganese dioxide bound ionically to the granules and as silica sand with manganese dioxide fused to the granules. Both forms operate in pressure filters and both are effective. Greensand with the silica sand core operates at higher water temperatures and higher differential pressures than does greensand with the glauconite core. Arsenic removal requires a minimum concentration of iron. If a sufficient concentration of iron is not present in the raw water, ferric chloride is added.

WesTech filters with greensand and permanganate addition for drinking water systems can reduce As from 15-25 µg/L to non-detect. Sodium hypochlorite and/or potassium permanganate are added to the raw water prior to the filters. Chemical addition may be done continuously or intermittently, depending on raw water characteristics. These chemicals oxidize the iron in the raw water and also maintain the active properties of the greensand itself. Arsenic removal is via co-precipitation with the iron.

Ion Exchange

Siemens offers a potable ion exchange (PIX) arsenic water filtration system. PIX uses ion exchange resin canisters for the removal of organic and inorganic contaminants, in surface and groundwater sources to meet drinking water standards.

Filtronics also uses ion exchange to treat arsenic. The technology allows removal for below the SWDA MCL for potable water of 10 µg/L (10,000 ng/L).

Reverse osmosis

Arsenic is effectively removed by RO when it is in oxidative state As(V) to approximately 1,000 ng/L or less (Ning 2002).

Summary of Arsenic Technologies

The current state of the technology for arsenic removal is at the point where all the processes target the SWDA MCL for arsenic in potable water. Current EPA maximum concentration level for drinking water is 10 ug/l; much higher than 0.0018 µg/L target for arsenic in this study. The majority of the methods discussed above are able to remove arsenic to either EPA maximum contaminant level or to the level of detection. The lowest detection limit of one of the EPA approved methods of arsenic measurements is 20 ng/l (0.020 µg/l) (Grosser, 2010), which is comparable to the 0.018 µg/L limit targeted in this study.

4.2.1 Polycyclic Aromatic Hydrocarbons

BAP During Biological Treatment

During wastewater treatment process, BAP tends to partition into sludge organic matter (Melcer et al. 1993). Primary and secondary processing could remove up to 60 percent of incoming PAHs and BAP in particular, mostly due to adsorption to sludge (Kindaichi et al., NA, Wayne et al. 2009). Biodegradation of BAP is expected to be very low since there are more than five benzene rings which are resistant to biological degradation. Biosurfactant addition to biological process could partially improve biodegradation, but only up to removal rates of 50 percent (Sponza et al. 2010). Existing data from municipal treatment facilities in Washington state have

influent and effluent concentrations of BAP of approximately 0.30 ng/L indicating that current secondary treatment has limited effectiveness at BAP removal.

Methods to Enhance Biological Treatment of BAP

Ozonation prior to biological treatment could potentially improve biodegradability of BAP (Zeng et al. 2000). In the case of soil remediation, ozonation before biotreatment improved biodegradation by 70 percent (Russo et al. 2012). The overall removal of BAP increased from 23 to 91 percent after exposure of water to 0.5 mg/L ozone for 30 minutes during the simultaneous treatment process and further to 100 percent following exposure to 2.5 mg/L ozone for 60 minutes during the sequential treatment mode (Yerushalmi et al. 2006). In general, to improve biodegradability of BAP, long exposure to ozone might be required (Haapea et al. 2006).

Sonication pre-treatment or electronic beam irradiation before biological treatment might also make PAHs more bioavailable for biological degradation..

Recent studies reported that a MBR is capable of removing PAHs from wastewater (Rodrigue and Reilly 2009; Gonzaleza et al. 2012). None of the studies listed the specific PAHs constituents removed.

Removal of BAP from Drinking Water

Activated Carbon

Since BAP has an affinity to particulate matter, it is removed from the drinking water sources by means of adsorption, such as granular activated carbon (EPA). Similarly, Oleszczuk et al. (2012) showed that addition of 5 percent activated carbon could remove 90 percent of PAHs from the wastewater.

Reverse Osmosis

Light (1981) (referenced by Williams, 2003) studied dilute solutions of PAHs, aromatic amines, and nitrosamines and found rejections of these compounds in reverse osmosis to be over 99 percent for polyamide membranes. Bhattacharyya et al. (1987) (referenced by Williams, 2003) investigated rejection and flux characteristics of FT30 membranes for separating various pollutants (PAHs, chlorophenols, nitrophenols) and found membrane rejections were high (>98 percent) for the organics under ionized conditions.

Summary of BAP Technologies

Current technologies show that BAP removal may be 90 percent or greater. The lowest detection limit for BAP measurements is 0.006 µg/L, which is also the assumed secondary effluent BAP concentration assumed for this study. If this assumption is accurate, it appears technologies may exist to remove BAP to a level below the proposed criteria applied as an effluent limit of 0.0013 µg/L; however, detection limits exceed this value and it is impossible to know this for certain. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

4.3 Unit Processes Evaluated

Based on the results of the literature review, a wide range of technologies were evaluated for toxic constituent removal. A listing of the technologies is as follows:

- Chemically enhanced primary treatment (CEPT): this physical and chemical technology is based on the addition of a metal salt to precipitate particles prior to primary treatment, followed by sedimentation of particles in the primary clarifiers. This technology has been

shown to effectively remove arsenic but there is little data supporting the claims. As a result, the chemical facilities are listed as optional.

- Activated sludge treatment (with a short SRT of approximately 8 days or less): this biological technology is commonly referred to as secondary treatment. It relies on converting dissolved organics into solids using biomass. Having a short SRT is effective at removing degradable organics referred to as BOD compounds for meeting existing discharge limits. Dissolved constituents with a high affinity to adsorb to biomass (e.g., metals, high molecular weight organics, and others) will be better removed compared to smaller molecular weight organics and recalcitrant compounds which will have minimal removal at a short SRT.
- Enhanced activated sludge treatment (with a long SRT of approximately 8 days or more): this technology builds on secondary treatment by providing a longer SRT, which enhances sorption and biodegradation. The improved performance is based on having more biomass coupled with a more diverse biomass community, especially nitrifiers, which have been shown to assist in removal of some of the more recalcitrant constituents not removed with a shorter SRT (e.g., lower molecular weight PAHs). There is little or no data available on the effectiveness of this treatment for removing BAP.

  Additional benefits associated with having a longer SRT are as follows:

  - Lower BOD/TSS discharge load to receiving water
  - Improved water quality and benefit to downstream users
  - Lower effluent nutrient concentrations which reduce algal growth potential in receiving waters
  - Reduced receiving water dissolved oxygen demand due to ammonia removal
  - Reduced ammonia discharge, which is toxic to aquatic species
  - Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
  - Secondary clarifier effluent more conditioned for filtration and disinfection
  - Greater process stability from the anaerobic/anoxic zones serving as biological selectors
- Coagulation/Flocculation and Filtration: this two-stage chemical and physical process relies on the addition of a metal salt to precipitate particles in the first stage, followed by the physical removal of particles in filtration. This technology lends itself to constituents prone to precipitation (e.g., arsenic).
- Lime Softening: this chemical process relies on increasing the pH as a means to either volatilize dissolved constituents or inactivate pathogens. Given that none of the constituents being studied are expected to volatilize, this technology was not carried forward.
- Adsorptive Media: this physical and chemical process adsorbs constituents to a combination of media and/or biomass/chemicals on the media. There are several types of media, with the most proven and common being GAC. GAC can also serve as a coarse roughing filter.
- Ion Exchange: this chemical technology exchanges targeted constituents with a resin. This technology is common with water softeners where the hard divalent cations are

exchanged for monovalent cations to soften the water. Recently, resins that target arsenic and mercury removal include activated alumina and granular ferric hydroxides have been developed. The resin needs to be cleaned and regenerated, which produces a waste slurry that requires subsequent treatment and disposal. As a result, ion exchange was not considered for further.

- Membrane Filtration: This physical treatment relies on the removal of particles larger than the membranes pore size. There are several different membrane pore sizes as categorized below.
  - Microfiltration (MF): nominal pore size range of typically between 0.1 to 1 micron. This pore size targets particles, both inert and biological, and bacteria. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution and bacteria can be removed by the MF membrane.
  - Ultrafiltration (UF): nominal pore size range of typically between 0.01 to 0.1 micron. This pore size targets those solids removed with MF (particles and bacteria) plus viruses and some colloidal material. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution can be removed by the UF membrane.
  - Nanofiltration (NF): nominal pore size range of typically between 0.001 to 0.010 micron. This pore size targets those removed with UF (particles, bacteria, viruses) plus colloidal material. If placed in series with coagulation/flocculation upstream, dissolved constituents precipitated out of solution can be removed by the NF membrane.
- MBR (with a long SRT): this technology builds on secondary treatment whereby the membrane (microfiltration) replaces the secondary clarifier for solids separation. As a result, the footprint is smaller, the mixed liquor suspended solids concentration can be increased to about 5,000 – 10,000 mg/L, and the physical space required for the facility reduced when compared to conventional activated sludge. As with the activated sludge option operated at a longer SRT, the sorption and biodegradation of organic compounds are enhanced in the MBR process. The improved performance is based on having more biomass coupled with a more diverse biomass community, especially nitrifiers which have been shown to assist in removal of persistent dissolved compounds (e.g., some PAHs). There is little or no data available on effectiveness at removing BAP. Although a proven technology, MBRs were not carried further in this technology review since they are less likely to be selected as a retrofit for an existing activated sludge (with a short SRT) secondary treatment facility. The MBR was considered to represent a treatment process approach more likely to be selected for a new, greenfield treatment facility. Retrofits to existing secondary treatment facilities can accomplish similar process enhancement by extending the SRT in the activated sludge process followed by the addition of tertiary membrane filtration units.
- RO: This physical treatment method relies on the use of sufficient pressure to osmotically displace water across the membrane surface while simultaneously rejecting most salts. RO is very effective at removing material smaller than the size ranges for the membrane filtration list above, as well as salts and other organic compounds. As a result, it is expected to be more effective than filtration and MBR methods described above at removing dissolved constituents. Although effective, RO produces a brine reject water that must be managed and disposed.

- Advanced Oxidation Processes (AOPs): this broad term considers all chemical and physical technologies that create strong hydroxyl-radicals. Examples of AOPs include Fenton's oxidation, ozonation, ultraviolet/hydrogen peroxide (UV-H2O2), and others. The radicals produced are rapid and highly reactive at breaking down recalcitrant compounds. Although effective at removing many complex compounds such as those evaluated in this study, AOPs does not typically have as many installations as membranes and activated carbon technologies. As a result, AOPs were not carried forward.

Based on the technical literature review discussed above, a summary of estimated contaminant removal rated by unit treatment process is presented in Table 4.

Table 4. Contaminants Removal Breakdown by Unit Process

Unit Process	Arsenic	BAP	Mercury	Polychlorinated Biphenyls
Activated Sludge Short SRT	No removal	Partial Removal by partitioning		80% removal; effluent <0.88 ng/L
Activated Sludge Long SRT	No removal	Partial removal by partitioning and/or partially biodegradation; MBR could potentially remove most of BAP		>90% removal with a membrane bioreactor, <0.04 ng/L (includes membrane filtration)
Membrane Filtration (MF)	More than 90 % removal (rejection of bound arsenic)	No removal	<1.3 ng/L	>90% removal with a membrane bioreactor, <0.04 ng/L (includes membrane filtration)
Reverse Osmosis (RO)	More than 90% removal (rejection of bound arsenic and removal of soluble arsenic)	More than 98% removal		
Granular Activated Carbon (GAC)	No removal, removal only when carbon is impregnated with iron	90 % removal	<300 ng/L (precipitation and carbon adsorption) <51 ng/L (GAC)	<800 ng/L Likely requires upstream filtration
Disinfection	--	--	--	--

4.4 Unit Processes Selected

The key conclusion from the literature review was that there is limited, to no evidence, that existing treatment technologies are capable of simultaneously meeting all four of the revised discharge limits for the toxics under consideration. Advanced treatment using RO or GAC is expected to provide the best overall removal of the constituents of concern. It is unclear whether these advanced technologies are able to meet revised effluent limits, however these processes may achieve the best effluent quality of the technologies reviewed. This limitation in the findings is based on a lack of an extensive dataset on treatment removal effectiveness in the technical literature for the constituents of interest at the low levels relevant to the proposed criteria, which

approach the limits of reliable removal performance for the technologies. As Table 4 highlights, certain unit processes are capable of removing a portion, or all, of the removal requirements for each technology. The removal performance for each constituent will vary from facility to facility and require a site-specific, detailed evaluation because the proposed criteria are such low concentrations. In some cases, a facility may only have elevated concentrations of a single constituent of concern identified in this study. In other cases, a discharger may have elevated concentrations of the four constituents identified in this study, as well as others not identified in this study but subject to revised water quality criteria. This effort is intended to describe a planning level concept of what treatment processes are required to comply with discharge limits for all four constituents. Based on the literature review of unit processes above, two different treatment trains were developed for the analysis that are compared against a baseline of secondary treatment as follows:

- Baseline: represents conventional secondary treatment that is most commonly employed nationwide at wastewater treatment plants. A distinguishing feature for this treatment is the short solids residence time (SRT) (<8 days) is intended for removal of BOD with minimal removal for the toxic constituents of concern.
- Advanced Treatment – MF/RO: builds on baseline with the implementation of a longer SRT (>8 days) and the addition of MF and RO. The longer SRT not only removes BOD, but it also has the capacity to remove nutrients and a portion of the constituents of concern. This alternative requires a RO brine management strategy which will be discussed in sub-sections below.
- Advanced Treatment – MF/GAC: this alternative provides a different approach to advanced treatment with MF/RO by using GAC and avoiding the RO reject brine water management concern. Similar to the MF/RO process, this alternative has the longer SRT (>8 days) with the capacity to remove BOD, nutrients, and a portion of the toxic constituents of concern. As a result, the decision was made to develop costs for both advanced treatment options.

A description of each alternative is provided in Table 5. The process flowsheets for each alternative are presented in Figure 3 to Figure 5.

4.4.1 Baseline Treatment Process

A flowsheet of the baseline treatment process is provided in Figure 3. The baseline treatment process assumes the current method of treatment commonly employed by dischargers. For this process, water enters the headworks and undergoes primary treatment, followed by conventional activated sludge (short SRT) and disinfection. The solids wasted in the activated sludge process are thickened, followed by mixing with primary solids prior to entering the anaerobic digestion process for solids stabilization. The digested biosolids are dewatered to produce a cake and hauled off-site. Since the exact process for each interested facility in Washington is unique, this baseline treatment process was used to establish the baseline capital and O&M costs. The baseline costs will be compared against the advanced treatment alternatives to illustrate the magnitude of the increased costs and environmental impacts.

Table 5. Unit Processes Description for Each Alternative

Unit Process	Baseline	Advanced Treatment – MF/RO	Advanced Treatment - GAC
Influent Flow	5 mgd	5 mgd	5 mgd
Chemically Enhanced Primary Treatment (CEPT); Optional	--	• Metal salt addition (alum) upstream of primaries	• Metal salt addition (alum) upstream of primaries
Activated Sludge	• Hydraulic Residence Time (HRT): 6 hrs • Short Solids Residence Time (SRT): <8 days	• Hydraulic Residence Time (HRT): 12 hrs (Requires more tankage than the Baseline) • Long Solids Residence Time (SRT): >8 days (Requires more tankage than the Baseline)	• Hydraulic Residence Time (HRT): 12 hrs (Requires more tankage than the Baseline) • Long Solids Residence Time (SRT): >8 days (Requires more tankage than the Baseline)
Secondary Clarifiers	Hydraulically Limited	Solids Loading Limited (Larger clarifiers than Baseline)	Solids Loading Limited (Larger clarifiers than Baseline)
Microfiltration (MF)	--	Membrane Filtration to Remove Particles and Bacteria	Membrane Filtration to Remove Particles and Bacteria
Reverse Osmosis (RO)	--	Treat 50% of the Flow by RO to Remove Metals and Dissolved Constituents. Sending a portion of flow through the RO and blending it with the balance of plant flows ensures a stable non-corrosive, non-toxic discharge.	--
Reverse Osmosis Brine Reject Mgmt	--	Several Options (All Energy or Land Intensive)	--
Granular Activated Carbon (GAC)	--	--	Removes Dissolved Constituents
Disinfection	Not shown to remove any of the constituents	Not shown to remove any of the constituents	Not shown to remove any of the constituents

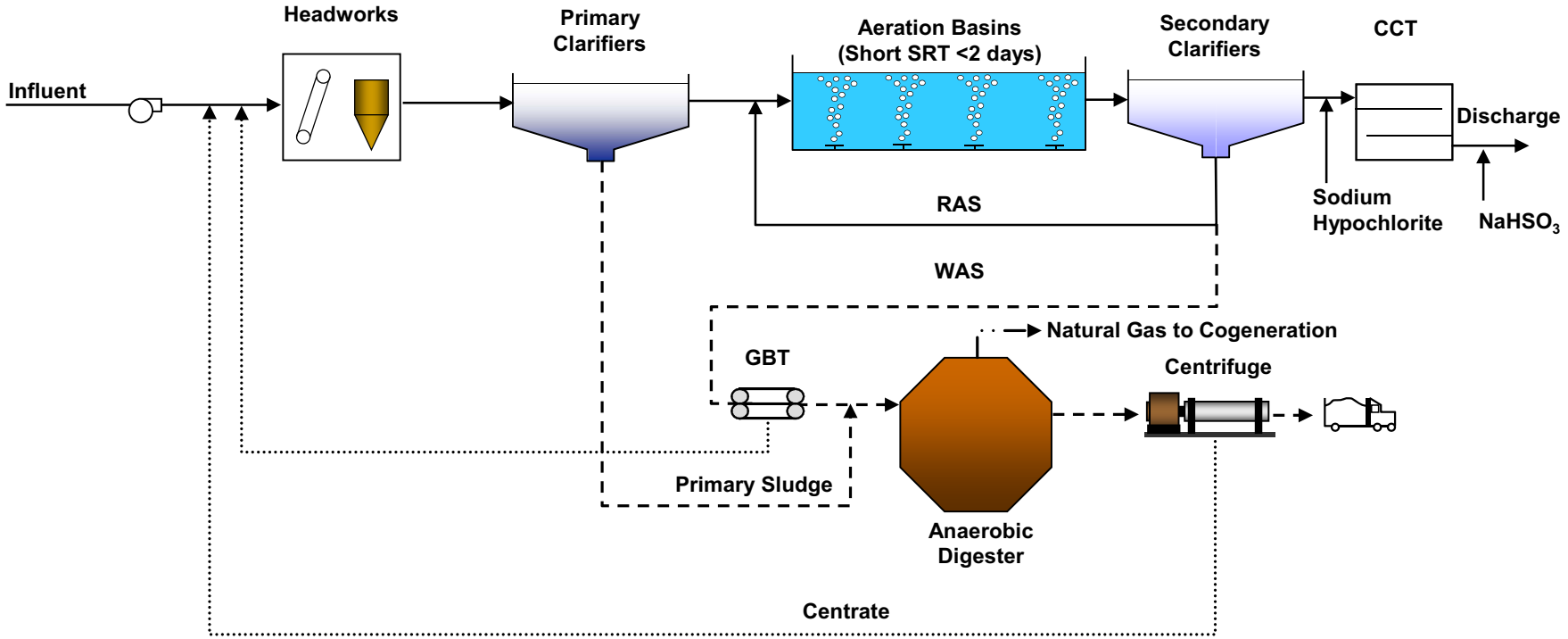

Figure 3. Baseline Flowsheet – Conventional Secondary Treatment

4.4.2 Advanced Treatment – MF/RO Alternative

A flowsheet of the advanced treatment – MF/RO alternative is provided in Figure 4. This alternative builds on the baseline secondary treatment facility, whereby the SRT is increased in the activated sludge process, and MF and RO are added prior to disinfection. The solids treatment train does not change with respect to the baseline. Additionally, a brine management strategy must be considered.

The RO process concentrates contaminants into a smaller volume reject stream. Disposing of the RO reject stream can be a problem because of the potentially large volume of water involved and the concentration of contaminants contained in the brine. For reference, a 5 mgd process wastewater flow might result in 1 mgd of brine reject requiring further management. The primary treatment/handling options for RO reject are as follows:

- Zero liquid discharge
- Surface water discharge
- Ocean discharge
- Haul and discharge to coastal location for ocean discharge
- Sewer discharge
- Deep well injection
- Evaporate in a pond
- Solar pond concentrator

Many of the RO brine reject management options above result in returning the dissolved solids to a “water of the state” such as surface water, groundwater, or marine waters. Past rulings in Washington State have indicated that once pollutants are removed from during treatment they are not to be re-introduced to a water of the state. As a result, technologies with this means for disposal were not considered viable options for management of RO reject water in Washington.

Zero Liquid Discharge

Zero liquid discharge (ZLD) is a treatment process that produces a little or no liquid brine discharge but rather a dried residual salt material. This process improves the water recovery of the RO system by reducing the volume of brine that must be treated and disposed of in some manner. ZLD options include intermediate treatment, thermal-based technologies, pressure driven membrane technologies, electric potential driven membrane technologies, and other alternative technologies.

Summary

There are many techniques which can be used to manage reject brine water associated with RO treatment. The appropriate alternative is primarily governed by geographic and local constraints. A comparison of the various brine management methods and potential costs are provided in Table 6.

Of the listed options, ZLD was considered for this analysis as the most viable approach to RO reject water management. An evaporation pond was used following ZLD. The strength in this combination is ZLD reduces the brine reject volume to treat, which in turn reduces the required evaporation pond footprint. The disadvantage is that evaporation ponds require a substantial amount of physical space which may not be available at existing treatment plant sites. It is also important to recognize that the greenhouse gas (GHG) emissions vary widely for the eight brine management options listed above based on energy and chemical intensity.

Table 6. Brine Disposal Method Relative Cost Comparison

Disposal Method	Description	Relative Capital Cost	Relative O&M Cost	Comments
Zero Liquid Discharge (ZLD)	Further concentrates brine reject for further downstream processing	High	High	This option is preferred as an intermediate step. This rationale is based on the reduction in volume to handle following ZLD. For example, RO reject stream volume is reduced on the order of 50-90%.
Surface Water Discharge	Brine discharge directly to surface water. Requires an NPDES permit.	Lowest	Lowest	Both capital and O&M costs heavily dependent on the distance from brine generation point to discharge. Not an option for nutrient removal.
Ocean Discharge	Discharge through a deep ocean outfall.	Medium	Low	Capital cost depends on location and availability of existing deep water outfall.
Sewer Discharge	Discharge to an existing sewer pipeline for treatment at a wastewater treatment plant.	Low	Low	Both capital and O&M costs heavily dependent on the brine generation point to discharge distance. Higher cost than surface water discharge due to ongoing sewer connection charge. Not an option for wastewater treatment.
Deep Well Injection	Brine is pumped underground to an area that is isolated from drinking water aquifers.	Medium	Medium	Technically sophisticated discharge and monitoring wells required. O&M cost highly variable based on injection pumping energy.
Evaporation Ponds	Large, lined ponds are filled with brine. The water evaporates and a concentrated salt remains.	Low – High	Low	Capital cost highly dependent on the amount and cost of land.
Salinity Gradient Solar Ponds (SGSP)	SGSPs harness solar power from pond to power an evaporative unit.	Low – High	Lowest	Same as evaporation ponds plus added cost of heat exchanger and pumps. Lower O&M cost due to electricity production.
Advanced Thermal Evaporation	Requires a two-step process consisting of a brine concentrator followed by crystallizer	High	Highest	Extremely small footprint, but the energy from H_2O removal is by far the most energy intensive unless waste heat is used.

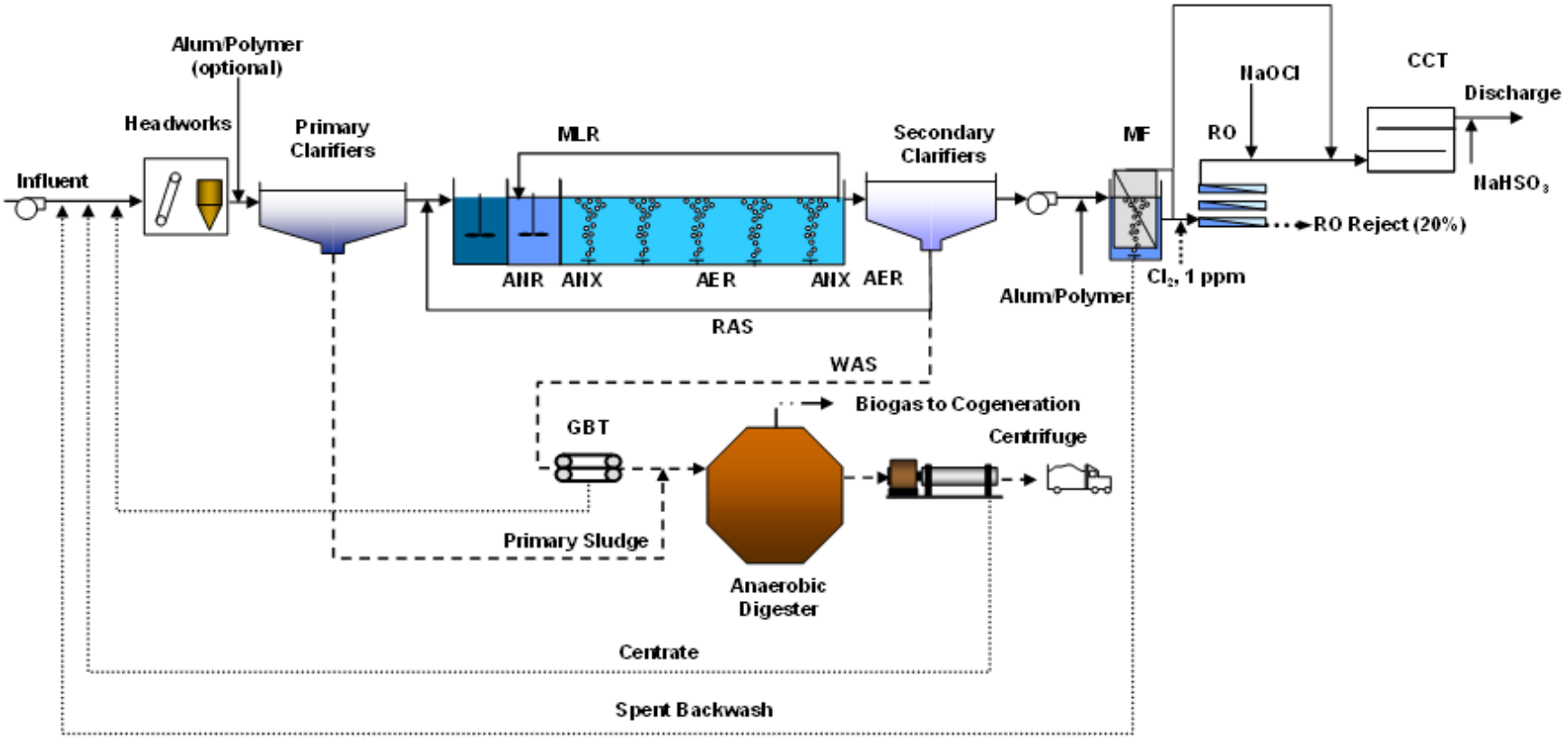

Figure 4. Advanced Treatment Flowsheet – Tertiary Microfiltration and Reverse Osmosis

4.4.3 Advanced Treatment – MF/GAC Alternative

A flowsheet of the advanced treatment – MF/GAC alternative is provided in Figure 5. Following the MF technology, a GAC contactor and media are required.

This alternative was developed as an option that does not require a brine management technology (e.g., ZLD) for comparison to the MF/RO advanced treatment alternative. However, this treatment alternative does require that the GAC be regenerated. A baseline secondary treatment facility can be retrofitted for MF/GAC. If an existing treatment facility has an extended aeration lagoon, the secondary effluent can be fed to the MF/GAC. The longer SRT in the extended aeration lagoon provides all the benefits associated with the long SRT in an activated sludge plant as previously stated:

- Lower BOD/TSS discharge load
- Higher removal of recalcitrant constituents and heavy metals
- Improved water quality and benefit to downstream users
- Less downstream algal growth
- Reduced receiving water dissolved oxygen demand due to ammonia removal
- Reduced ammonia discharge loads, which is toxic to several aquatic species
- Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
- Secondary clarifier effluent more conditioned for filtration and disinfection
- Greater process stability from the anaerobic/anoxic zones serving as a selector

If an existing treatment facility employs a high rate activated sludge process (short SRT) similar to the baseline, it is recommended that the activated sludge process SRT be increased prior to the MF/GAC unit processes. The longer SRT upstream of the MF is preferred to enhance the membrane flux rate, reduce membrane biofouling, increase membrane life, and reduce the chemicals needed for membrane cleaning.

The key technical and operational challenges associated with the tertiary add-on membrane filtration units are as follows:

- The membrane filtration technology is a proven and reliable technology. With over 30 years of experience, it has made the transition in recent years from an emerging technology to a proven and reliable technology.
- Membrane durability dependent on feed water quality. The water quality is individual facility specific.
- Membranes are sensitive to particles, so upstream screening is critical. The newer generations of membranes have technical specifications that require a particular screen size.
- Membrane area requirements based on peak flows as water must pass through the membrane pores. Additionally, membranes struggle with variable hydraulic loading. Flow equalization upstream can greatly reduce the required membrane surface area and provide uniform membrane loading.

- Membrane tanks can exacerbate any foam related issues from the upstream biological process. Foam entrapment in the membrane tank from the upstream process can reduce membrane filtration capacity and in turn result in a plant-wide foam problem.
- Reliable access to the membrane modules is key to operation and maintenance. Once PLC is functionary properly, overall maintenance requirements for sustained operation of the system are relatively modest.
- The membranes go through frequent membrane relaxing or back pulse and a periodic deep chemical clean in place (CIP) process.
- Sizing of membrane filtration facilities governed by hydraulic flux. Municipal wastewaters have flux values that range from about 20 to 40 gallons per square foot per day (gfd) under average annual conditions. The flux associated with industrial applications is wastewater specific.

Following the MF is the activated carbon facilities. There are two kinds of activated carbon used in treating water: powdered activated carbon (PAC) and GAC. PAC is finely-ground, loose carbon that is added to water, mixed for a short period of time, and removed. GAC is larger than PAC, is generally used in beds or tanks that permit higher adsorption and easier process control than PAC allows, and is replaced periodically. PAC is not selective, and therefore, will adsorb all active organic substances making it an impractical solution for a wastewater treatment plant. As a result, GAC was considered for this analysis. The type of GAC (e.g., bituminous and subbituminous coal, wood, walnut shells, lignite or peat), gradation, and adsorption capacity are determined by the size of the largest molecule/ contaminant that is being filtered (AWWA, 1990).

As water flows through the carbon bed, contaminants are captured by the surfaces of the pores until the carbon is no longer able to adsorb new molecules. The concentration of the contaminant in the treated effluent starts to increase. Once the contaminant concentration in the treated water reaches an unacceptable level (called the breakthrough concentration), the carbon is considered "spent" and must be replaced by virgin or reactivated GAC.

The capacity of spent GAC can be restored by thermal reactivation. Some systems have the ability to regenerate GAC on-site, but in general, small systems haul away the spent GAC for off-site regeneration (EPA 1993). For this study, off-site regeneration was assumed.

The basic facilities and their potential unit processes included in this chapter are as follows:

- GAC supply and delivery
- Influent pumping
  - Low head feed pumping
  - High head feed pumping (assumed for this study as we have low limits so require high beds)
- Contactors and backwash facilities
  - Custom gravity GAC contactor
  - Pre-engineered pressure GAC contactor (Used for this study)
  - Backwash pumping
- GAC transport facilities
  - Slurry pumps
  - Eductors (Used for this study)

- Storage facilities
  - Steel tanks
  - Concrete tanks (Used for this study; larger plants would typically select concrete tanks)
- Spent carbon regeneration
  - On-site GAC regeneration
  - Off-Site GAC regeneration

Following the MF is the GAC facility. The GAC contactor provides about a 12-min hydraulic residence time for average annual conditions. The GAC media must be regenerated about twice per year in a furnace. The constituents sorbed to the GAC media are removed during the regeneration process. A typical design has full redundancy and additional storage tankage for spent and virgin GAC. Facilities that use GAC need to decide whether they will regenerate GAC on-site or off-site. Due to challenges associated with receiving air emission permits for new furnaces, it was assumed that off-site regeneration would be evaluated.

The key technical and operational challenges associated with the tertiary add-on GAC units are as follows:

- Nearest vendor to acquire virgin GAC – How frequently can they deliver virgin GAC and what are the hauling costs?
- Contactor selection is typically based on unit cost and flow variation. The concrete contactor is typically more cost effective at higher flows so it was used for this evaluation. The pre-engineered pressure contactor can handle a wider range of flows than a concrete contactor. Additionally, a pressure system requires little maintenance as they are essentially automated
- Periodical contactor backwashing is critical for maintaining the desired hydraulics and control biological growth
- Eductors are preferred over slurry pumps because they have fewer mechanical components. Additionally, the pump with eductors is not in contact with the carbon, which reduces wear.
- Off-site GAC regeneration seems more likely due to the challenges with obtaining an air emissions permit.

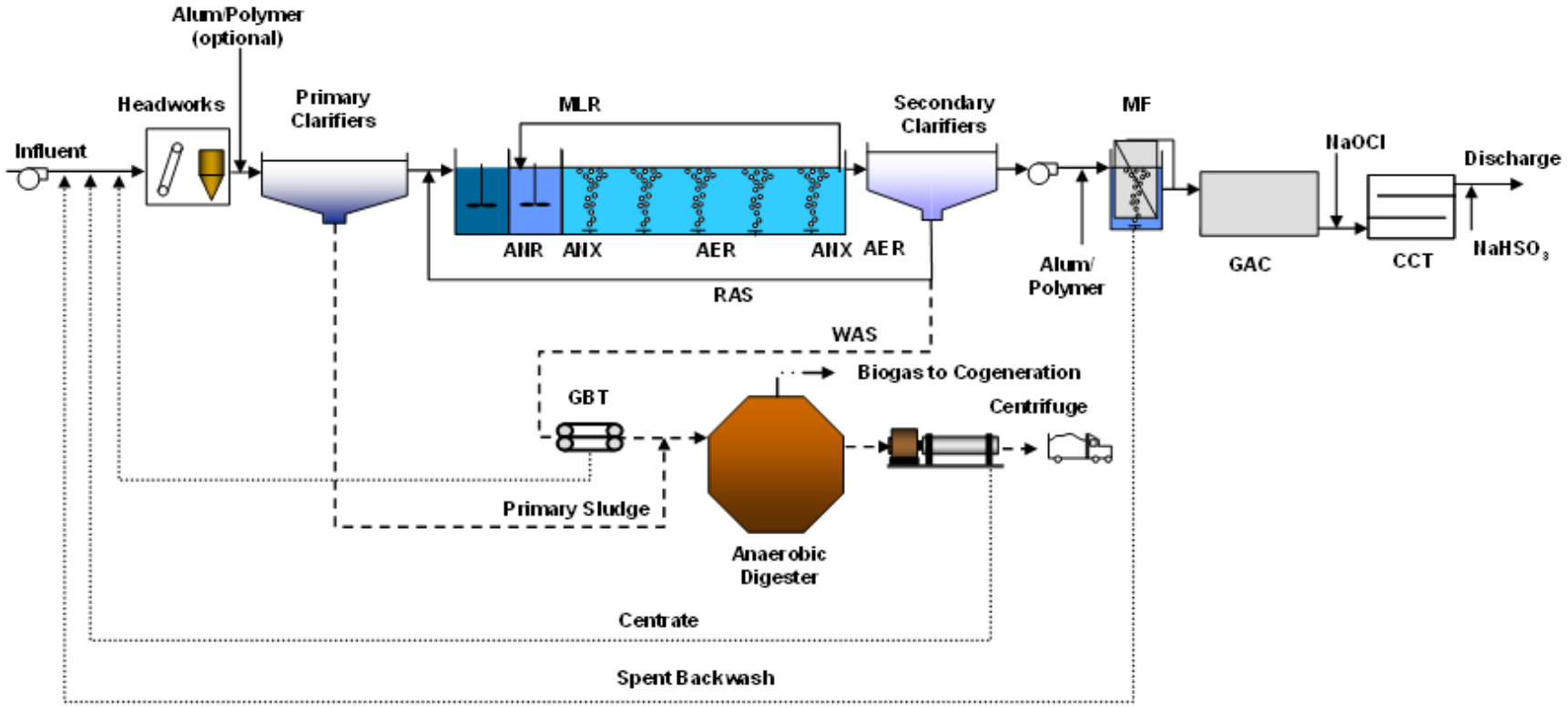

Figure 5. Advanced Treatment Flowsheet – Tertiary Microfiltration and Granular Activated Carbon

4.5 Steady-State Mass Balance

HDR used its steady-state mass balance program to calculate the flows and loads within the candidate advanced treatment processes as a means to size facilities. The design of wastewater treatment facilities are generally governed by steady-state mass balances. For a steady-state mass balance, the conservation of mass is calculated throughout the entire wastewater treatment facility for defined inputs. Dynamic mass balance programs exist for designing wastewater facilities, but for a planning level study such as this, a steady state mass balance program is adequate. A dynamic program is generally used for detailed design and is site-specific with associated requirements for more detailed wastewater characterization.

The set of model equations used to perform a steady-state mass balance are referred to as the model. The model equations provide a mathematical description of various wastewater treatment processes, such as an activated sludge process, that can be used to predict unit performance. The program relies on equations for each unit process to determine the flow, load, and concentration entering and leaving each unit process.

An example of how the model calculates the flow, load, and concentration for primary clarifiers is provided below. The steady-state mass balance equation for primary clarifiers has a single input and two outputs as shown in the simplified Figure 6. The primary clarifier feed can exit the primary clarifiers as either effluent or sludge. Solids not removed across the primaries leave as primary effluent, whereas solids captured leave as primary sludge. Scum is not accounted for.

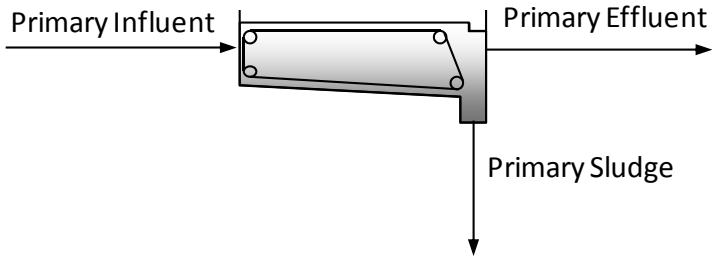

Figure 6. Primary Clarifier Inputs/Outputs

The mass balance calculation requires the following input:

- Solids removal percentage across the primaries (based on average industry accepted performance)
- Primary solids thickness (i.e., percent solids) (based on average industry accepted performance)

The steady-state mass balance program provides a reasonable first estimate for the process performance, and an accurate measure of the flows and mass balances at various points throughout the plant. The mass balance results were used for sizing the facility needs for each alternative. A listing of the unit process sizing criterion for each unit process is provided in Appendix A. By listing the unit process sizing criteria, a third-party user could redo the analysis and end up with comparable results. The key sizing criteria that differ between the baseline and treatment alternatives are as follows:

- Aeration basin mixed liquor is greater for the advanced treatment alternatives which in turn requires a larger volume
- The secondary clarifiers are sized based on hydraulic loading for the baseline versus solids loading for the advanced treatment alternatives

- The MF/GAC and MF/RO sizing is only required for the respective advanced treatment alternatives.

4.6 Adverse Environmental Impacts Associated with Advanced Treatment Technologies

The transition from the baseline (conventional secondary treatment) to either advanced treatment alternatives has some environmental impacts that merit consideration, including the following:

- Land area for additional system components (which for constrained facility sites, may necessitate land acquisition and encroachment into neighboring properties with associated issues and challenges, etc.).
- Increased energy use and atmospheric emissions of greenhouse gases and criteria air contaminants associated with power generation to meet new pumping requirements across the membrane filter systems (MF and RO) and GAC.
- Increased chemical demand associated with membrane filters (MF and RO).
- Energy and atmospheric emissions associated with granulated charcoal regeneration.
- RO brine reject disposal. The zero liquid discharge systems are energy intensive energy and increase atmospheric emissions as a consequence of the electrical power generation required for removing water content from brine reject.
- Increase in sludge generation while transitioning from the baseline to the advanced treatment alternatives. There will be additional sludge captured with the chemical addition to the primaries and membrane filters (MF and RO). Additionally, the GAC units will capture more solids.
- Benefits to receiving water quality by transitioning from a short SRT (<2 days) in the baseline to a long SRT (>8 days) for the advanced treatment alternatives (as previously stated):
    - Lower BOD/TSS discharge load
    - Higher removal of recalcitrant constituents and heavy metals
    - Improved water quality and benefit to downstream users
    - Reduced nutrient loadings to receiving waters and lower algal growth potential
    - Reduced receiving water dissolved oxygen demand due to ammonia removal
    - Reduced ammonia discharge loads, which is toxic to aquatic species
    - Improved water quality for habitat, especially as it relates to biodiversity and eutrophication
    - Secondary clarifier effluent better conditioned for subsequent filtration and disinfection
    - Greater process stability from the anaerobic/anoxic zones serving as a biological selectors

HDR calculated GHG emissions for the baseline and advanced treatment alternatives. The use of GHG emissions is a tool to normalize the role of energy, chemicals, biosolids hauling, and fugitive emissions (e.g., methane) in a single unit. The mass balance results were used to quantify energy demand and the corresponding GHG emissions for each alterative. Energy

demand was estimated from preliminary process calculations. A listing of the energy demand for each process stream, the daily energy demand, and the unit energy demand is provided in Table 7. The advanced treatment options range from 2.3 to 4.1 times greater than the baseline. This large increase in energy demand is attributed to the energy required to pass water through the membrane barriers and/or the granular activated carbon. Additionally, there is energy required to handle the constituents removed as either regenerating the GAC or handling the RO brine reject water. This additional energy required to treat the removed constituents is presented in Table 7.

Table 7. Energy Breakdown for Each Alternative (5 mgd design flow)

Parameter	Units	Baseline	Advanced Treatment – MF/GAC	Advanced Treatment – MF/RO
Daily Liquid Stream Energy Demand	MWh/d	11.6	23.8	40.8
Daily Solids Stream Energy Demand	MWh/d	-1.6	-1.1	-1.1
Daily Energy Demand	MWh/d	10.0	22.7	39.7
Unit Energy Demand	kWh/MG Treated	2,000	4,500	7,900

MWh/d = megawatt hours per day
kWh/MG = kilowatt hours per million gallons

Details on the assumptions used to convert between energy demand, chemical demand and production, as well as biologically-mediated gases (i.e., CH4 and N2O) and GHG emissions are provided in Appendix B.

A plot of the GHG emissions for each alternative is shown in Figure 7. The GHG emissions increase from the baseline to the two advanced treatment alternatives. The GHG emissions increase about 50 percent with respect to baseline when MF/GAC is used and the GHG emissions increase over 100 percent with respect to baseline with the MF/RO advanced treatment alternative.

The MF/GAC energy demand would be larger if GAC regeneration was performed on-site. The GHG emissions do not include the energy or air emissions that result from off-site GAC regeneration. Only the hauling associated with moving spent GAC is included. The energy associated with operating the furnace would exceed the GHG emissions from hauling spent GAC.

The zero liquid discharge in the MF/RO alternative alone is comparable to the Baseline. This contribution to increased GHG emissions by zero liquid discharge brine system highlights the importance of the challenges associated with managing brine reject.

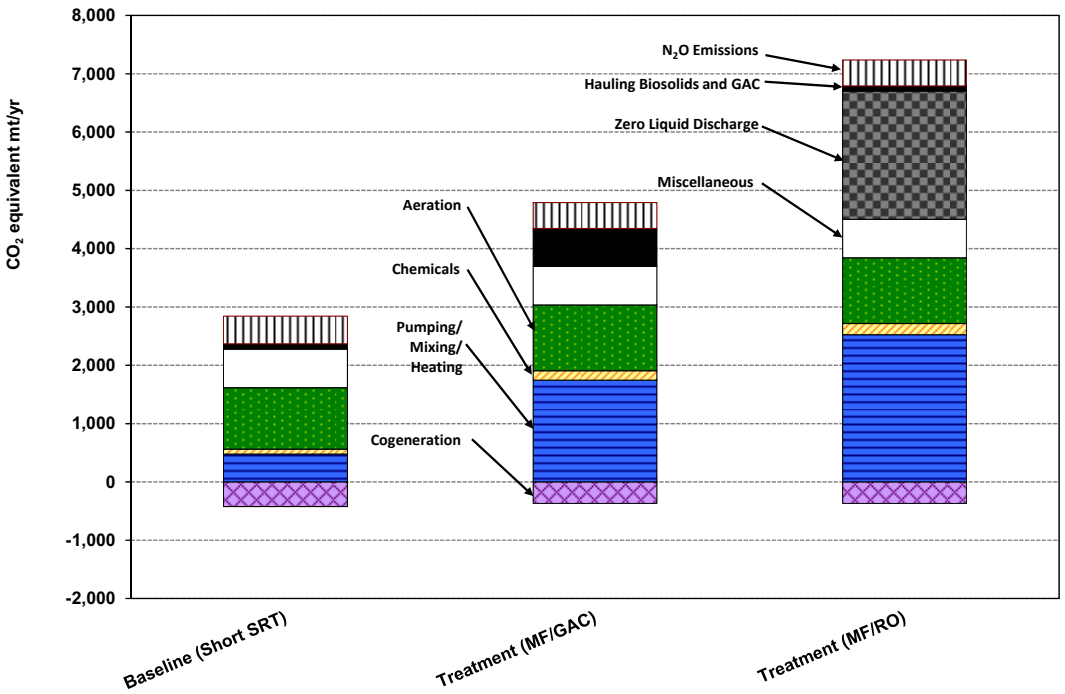

Figure 7. Greenhouse Gas Emissions for Each Alternative

The use of GHG emissions as a measure of sustainability does not constitute a complete comparison between the baseline and advanced treatment alternatives. Rather, it is one metric that captures the impacts of energy, chemical demand and production, as well as biologically-mediated gases (i.e., CH_4 and N_2O). The other environmental impacts of advanced treatment summarized in the list above should also be considered in decision making beyond cost analysis.

4.7 Costs

Total project costs along with the operations and maintenance costs were developed for each advanced treatment alternative for a comparison with baseline secondary treatment.

4.7.1 Approach

The cost estimates presented in this report are planning level opinions of probable construction costs for a nominal 5 mgd treatment plant design flow representing a typical facility without site specific details about local wastewater characteristics, physical site constraints, existing infrastructure, etc. The cost estimates are based on wastewater industry cost references, technical studies, actual project cost histories, and professional experience. The costs presented in this report are considered planning level estimates. A more detailed development of the advanced treatment process alternatives and site specific information would be required to further refine the cost estimates. Commonly this is accomplished in the preliminary design phase of project development for specific facilities following planning.

The cost opinion includes a range of costs associated with the level of detail used in this analysis. Cost opinions based on preliminary engineering can be expected to follow the Association for the Advancement of Cost Engineering (AACE International) Recommended Practice No. 17R-97 Cost Estimate Classification System estimate Class 4. A Class 4 estimate is based upon a 5 to 10 percent project definition and has an expected accuracy range of -30 to +50 percent and typical end usage of budget authorization and cost control. It is considered an

"order-of-magnitude estimate." The life-cycle costs were prepared using the net present value (NPV) method.

The cost associated for each new unit process is based on a unit variable, such as required footprint, volume, demand (e.g., lb O_2/hr), and others. This approach is consistent with the approach developed for the EPA document titled "Estimating Water Treatment Costs: Volume 2-Cost Curves Applicable to 1 to 200 mgd Treatment Plants" dated August 1979. The approach has been updated since 1979 to account for inflation and competition, but the philosophy for estimating costs for unit processes has not changed. For example, the aeration system sizing/cost is governed by the maximum month airflow demand. Additionally, the cost associated constructing an aeration basin is based on the volume. The cost considers economies of scale.

The O&M cost estimates were calculated from preliminary process calculations. The operations cost includes energy and chemical demand. For example, a chemical dose was assumed based on industry accepted dosing rates and the corresponding annual chemical cost for that particular chemical was accounted for. The maintenance values only considered replacement equipment, specifically membrane replacement for the Advanced Treatment Alternatives.

4.7.2 Unit Cost Values

The life-cycle cost evaluation was based on using the economic assumptions shown in Table 8. The chemical costs were based on actual values from other projects. To perform detailed cost evaluations per industry, each selected technology would need to be laid out on their respective site plan based on the location of the existing piping, channels, and other necessary facilities.

Table 8. Economic Evaluation Variables

Item	Value
Nominal Discount Rate	5%
Inflation Rate:	
General	3.5%
Labor	3.5%
Energy	3.5%
Chemical	3.5%
Base Year	2013
Project Life	25 years
Energy	$0.06/kWh
Natural Gas	$0.60/therm
Chemicals:	
Alum	$1.1/gal
Polymer	$1.5/gal
Hypochlorite	$1.5/gal
Salt	$0.125/lb
Antiscalant	$12.5/lb
Acid	$0.35/lb
Deionized Water	$3.75/1,000 gal
Hauling:	

Table 8. Economic Evaluation Variables

Item	Value
Biosolids Hauling Distance	100 miles (one way)
Biosolids Truck Volume	6,000 gal/truck
Biosolids Truck Hauling	$250/truck trip
GAC Regeneration Hauling Distance	250 miles (round trip)
GAC Regeneration Truck Volume	$20,000 lb GAC/truck
GAC Regeneration Truck Hauling	Included in cost of Virgin GAC

kWh= kilowatt hours; lbs=pounds; GAC=granulated activated carbon; gal=gallon

4.7.3 Net Present Value of Total Project Costs and Operations and Maintenance Cost in 2013 Dollars

An estimate of the net present value for the baseline treatment process and the incremental cost to implement the advanced treatment alternatives is shown in Table 9. The cost for the existing baseline treatment process was estimated based on new construction for the entire conventional secondary treatment process (Figure 3). The incremental cost to expand from existing baseline secondary treatment to advanced treatment was calculated by taking the difference between the baseline and the advanced treatment alternatives. These values serve as a benchmark for understanding the prospective cost for constructing advanced treatment at the planning level of process development.

Table 9. Treatment Technology Total Project Costs in 2013 Dollars for a 5 mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)*	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
Baseline (Conventional Secondary Treatment)*	59 - 127	5 - 11	65 – 138	13 - 28
Advanced Treatment – MF/RO**	108 - 231	31 - 67	139 - 298	28 - 60
Advanced Treatment – MF/GAC	131 - 280	50 - 108	181 - 388	36 - 78
Incremental Increase to Advanced Treatment MF/RO	48 - 104	26 - 56	75 - 160	15 - 32
Incremental Increase to Advanced Treatment MF/GAC	71 - 153	45 - 97	117 - 250	23 - 50

* The additional cost to increase the SRT to upwards of 30-days is about $12 - 20 million additional dollars in total project cost for a 5 mgd design flow

** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.

O&M=operations and maintenance; MF/RO=membrane filtration/reverse osmosis; MF/GAC=membrane filtration/granulated activated carbon; gpd=gallons per day

4.7.4 Unit Cost Assessment

Costs presented above are based on a treatment capacity of 5.0 mgd, however, existing treatment facilities range dramatically across Washington in size and flow treated. Table 9 indicates that the unit capital cost for baseline conventional secondary treatment for 5.0 mgd ranges between $13 to 28 per gallon per day of treatment capacity. The unit cost for the advanced treatment alternatives increases the range from the low $20s to upper $70s on a per-gallon per-day of capacity. The increase in cost for the advanced treatment alternatives is discussed in the sub-sections below.

Advanced Treatment MF/RO

The advanced treatment MF/RO alternative has a total present worth unit cost range of $28 to $60 million in per gallon per day of capacity. This translates to an incremental cost increase with respect to the baseline of $15 to $32 million dollars in per gallon per day treatment capacity. The key differences in cost between the baseline and the advanced treatment MF/RO are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (<8 days versus >8 days).
- Additional pumping stations to pass water through the membrane facilities (MF and RO). These are based on peak flows.
- Membrane facilities (MF and RO; equipment, tanks chemical feed facilities, pumping, etc.) and replacement membrane equipment.
- Additional energy and chemical demand to operate the membrane facilities (MF and RO) and GAC.
- Zero liquid discharge facilities to further concentrate the brine reject.
- Zero liquid discharge facilities are energy/chemically intensive and they require membrane replacement every few years due to the brine reject water quality.
- An evaporation pond to handle the brine reject that has undergone further concentration by zero liquid discharge.

The advanced treatment MF/RO assumes that 100 percent of the flow is treated by MF, followed by 50 percent of the flow treated with RO. Sending a portion of flow through the RO and blending it with the balance of plant flows ensures a stable water to discharge. The RO brine reject (about 1.0 mgd) undergoes ZLD pre-treatment that further concentrates the brine reject to about 0.1-0.5 mgd. The recovery for both RO and ZLD processes is highly dependent on water quality (e.g., silicate levels).

ZLD technologies are effective at concentrating brine reject, but it comes at a substantial cost ($17.5 per gallon per day of ZLD treatment capacity of brine reject). The zero liquid discharge estimate was similar in approach to the demonstration study by Burbano and Brandhuber (2012) for La Junta, Colorado. The ability to further concentrate brine reject was critical from a management standpoint. Although 8 different options were presented for managing brine reject in Section 4.4.2, none of them is an attractive approach for handling brine reject. ZLD provides a viable pre-treatment step that requires subsequent downstream treatment. Evaporation ponds following ZLD were used for this study. Without ZLD, the footprint would be 3-5 times greater.

Roughly 30 acres of evaporation ponds, or more, may be required to handle the ZLD concentrate, depending upon concentrator effectiveness, local climate conditions, residuals

accumulation, residual removal, etc. Precipitation throughout Washington is highly variable which can greatly influence evaporation pond footprint. The approach for costing the evaporation pond was in accordance with Mickley et al. (2006) and the cost was about $2.6 million.

Recent discussions with an industry installing evaporation ponds revealed that they will use mechanical evaporators to enhance evaporation rates. The use of mechanical evaporators was not included in this study, but merits consideration if a facility is performing a preliminary design that involves evaporation ponds. The mechanical evaporators have both a capital costs and annual energy costs.

Advanced Treatment MF/GAC

The advanced treatment MF/GAC alternative has a total present worth unit cost range of $36 to $78 million in per gallon per day capacity. This translates to an incremental cost increase with respect to the baseline of $23 to $50 million dollars on a per gallon per day of treatment capacity basis. The key differences in cost between the baseline and the advanced treatment MF/GAC are as follows:

- Larger aeration basins than the baseline to account for the longer SRT (<8 days versus >8 days).
- Additional pumping stations to pass water through the MF membrane and GAC facilities. These are based on peak flows.
- GAC facilities (equipment, contact tanks, pumping, GAC media, etc.)
- Additional energy to feed and backwash the GAC facilities.
- GAC media replacement was the largest contributor of any of the costs.
- Additional hauling and fees to regenerate GAC off-site.

The advanced treatment MF/GAC assumes that 100 percent of the flow is treated by MF, followed by 100 percent of the flow treated with GAC. The GAC technology is an established technology. The costing approach was in accordance with EPA guidelines developed in 1998.

The critical issue while costing the GAC technology is whether a GAC vendor/regeneration facility is located within the region. On-site regeneration is an established technology with a furnace.

However, there are several concerns as listed in Section 4.4.3:

- Ability to obtain an air emissions permit
- Additional equipment to operate and maintain
- Energy and air emissions to operate a furnace on-site
- Operational planning to ensure that furnace is operating 90-95 percent of the time. Otherwise, operations is constantly starting/stopping the furnace which is energy intensive and deleterious to equipment
- If not operated properly, the facility has the potential to create hazardous/toxic waste to be disposed

If located within a couple hundred miles, off-site regeneration is preferred. For this study, off-site regeneration was assumed with a 250-mile (one-way) distance to the nearest vendor that can provide virgin GAC and a regeneration facility.

Incremental Treatment Cost

The difference in costs between the baseline and the advanced treatment alternatives is listed in Table 10. The incremental cost to retrofit the baseline facility to the advanced treatment was calculated by taking the difference between the two alternatives. These values should serve as a planning level benchmark for understanding the potential cost for retrofitting a particular facility. The incremental cost is unique to a particular facility. Several reasons for the wide range in cost in retrofitting a baseline facility to advanced treatment are summarized as follows:

- Physical plant site constraints. A particular treatment technology may or may not fit within the constrained particular plant site. A more expensive technology solution that is more compact may be required. Alternately, land acquisition may be necessary to enlarge a plant site to allow the addition of advanced treatment facilities. An example of the former is stacking treatment processes vertically to account for footprint constraints. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.
- Yard piping. Site specific conditions may prevent the most efficient layout and piping arrangement for an individual facility. This could lead to additional piping and pumping to convey the wastewater through the plant. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.
- Pumping stations. Each facility has unique hydraulic challenges that might require additional pumping stations not captured in this planning level analysis. This is an additional financial burden that would not be captured in the incremental costs presented in Table 10.

A cursory unit cost assessment was completed to evaluate how costs would compare for facilities with lower (0.5 mgd) and higher capacity (25 mgd), as presented in Table 10. Capital costs were also evaluated for a 0.5 mgd and 25 mgd facility using non-linear scaling equations with scaling exponents. The unit capital cost for baseline conventional secondary treatment for 0.5 mgd and 25 mgd is approximately $44 and $10 per gallon per day of treatment capacity, respectively. The incremental unit costs to implement an advanced treatment retrofit for 0.5 mgd would range between $30 to $96 per gallon per day of treatment capacity and would be site and discharger specific. The incremental unit costs to implement an advanced treatment retrofit for 25 mgd would range between $10 to 35 per gallon per day of treatment capacity and would be site and discharger specific. The larger flow, 25 mgd, is not as expensive on a per gallon per day of treatment capacity. This discrepancy for the 0.5 and 25 mgd cost per gallon per day of treatment capacity is attributed to economies of scale. Cost curve comparisons (potential total construction cost and total net present value) for the baseline and the two tertiary treatment options (MF/RO and MF/GAC) are shown in Figure 8 and Figure 9 between the flows of 0.5 and 25 mgd. It is important to note that while the economies of scale suggest lower incremental costs for the larger size facilities, some aspects of the advanced treatment processes may become infeasible at larger capacities due to factors such as physical space limitations and the large size requirements for components such as RO reject brine management.

Table 10. Treatment Technology Total Project Costs in 2013 Dollars for a 0.5 mgd Facility and a 25 mgd Facility

Alternative	Total Construction Cost, 2013 dollars ($ Million)	O&M Net Present Value, 2013 dollars ($ Million)*	Total Net Present Value, 2013 dollars ($ Million)	NPV Unit Cost, 2013 dollars ($/gpd)
0.5 mgd:				
Baseline (Conventional Secondary Treatment)	15 - 32	0.5 - 1.1	15 - 33	31 - 66
Advanced Treatment – MF/RO**	27 - 58	3.2 - 6.8	30 - 65	60 - 130
Advanced Treatment – MF/GAC	33 - 70	5 - 10.8	38 - 81	76 - 162
Incremental Increase to Advanced Treatment MF/RO	12 - 26	2.7 - 5.7	15 - 32	30 - 64
Incremental Increase to Advanced Treatment MF/GAC	18 - 38	4.6 - 9.8	22 - 48	45 - 96
25 mgd:				
Baseline (Conventional Secondary Treatment)	156 - 335	25 - 54	182 - 389	7 - 16
Advanced Treatment – MF/RO**	283 - 606	157 - 336	440 - 942	18 - 38
Advanced Treatment – MF/GAC	343 - 735	252 - 541	595 - 1276	24 - 51
Incremental Increase to Advanced Treatment MF/RO	127 - 272	131 - 281	258 - 553	10 - 22
Incremental Increase to Advanced Treatment MF/GAC	187 - 401	226.9 - 486	414 - 887	17 - 35

* Does not include the cost for labor.
** Assumes zero liquid discharge for RO brine management, followed by evaporation ponds. Other options are available as listed in Section 4.4.2.
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
O&M=operations and maintenance
gpd=gallons per day

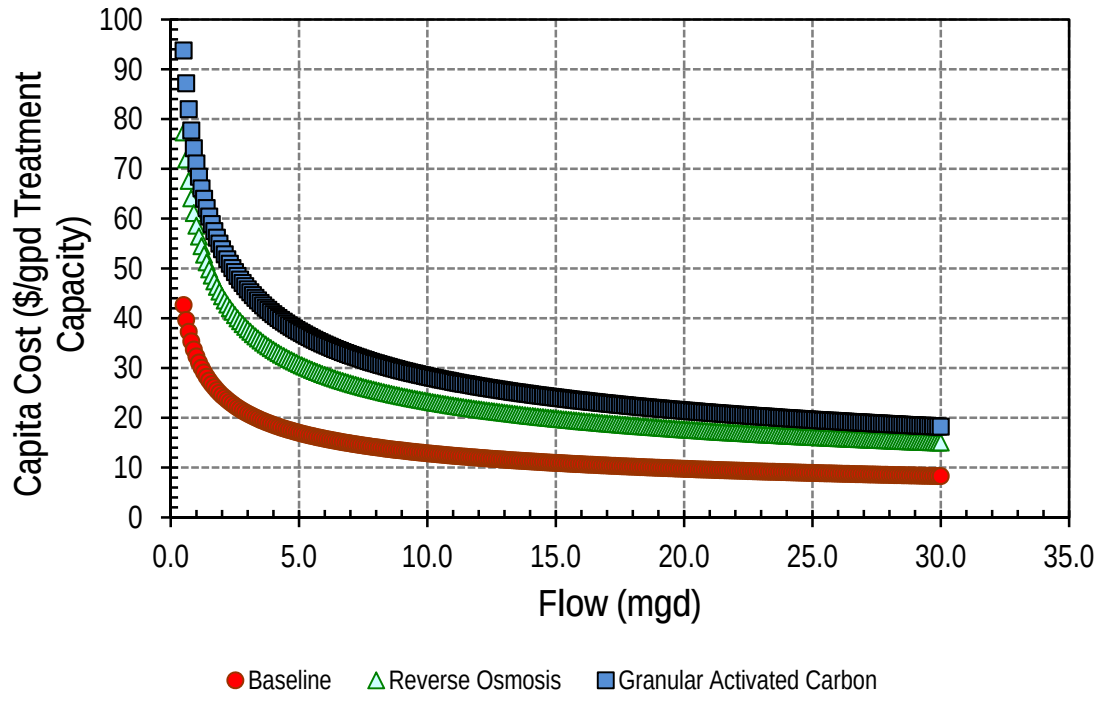

Figure 8: Capital Cost Curve Comparison for Baseline Treatment, MF/RO, and MF/GAC

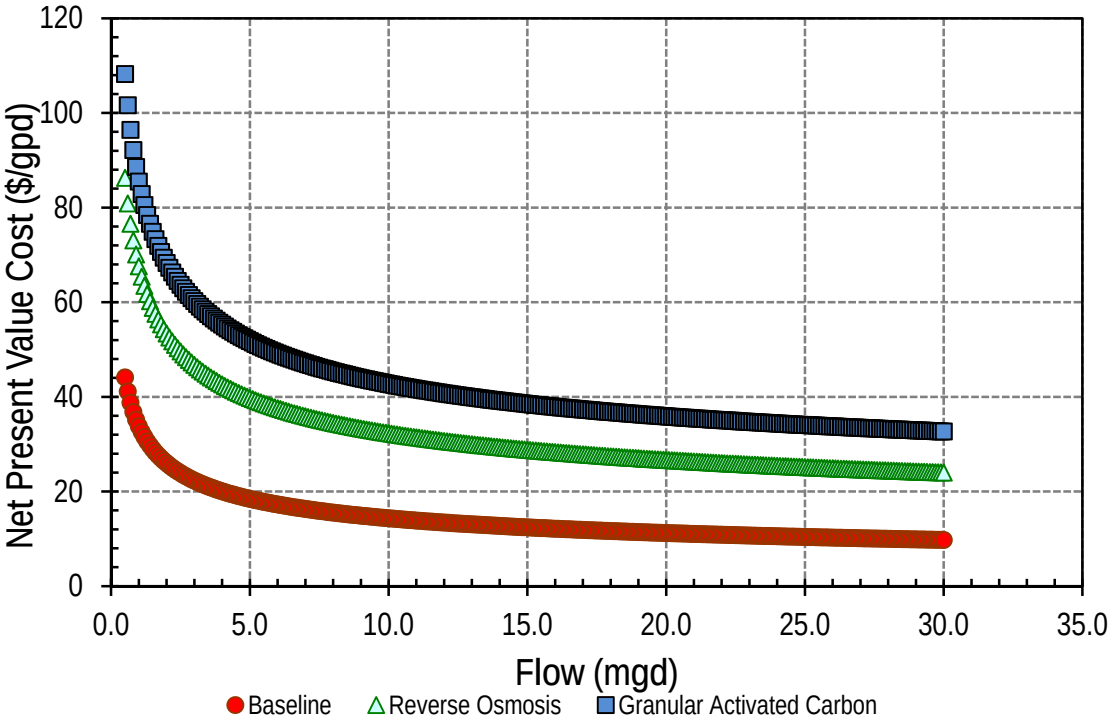

Figure 9: NPV Cost Curve Comparison for Baseline Treatment, MF/RO, and MF/GAC

4.8 Pollutant Mass Removal

An estimate of the projected load removal for the four constituents of concern was developed and is presented in Table 11. The current secondary effluent and advanced treatment effluent data is based on the only available data to HDR and is from municipal treatment plant facilities. Data is not available for advanced treatment facilities such as MF/RO or MF/GAC. Due to this lack of data, advanced treatment using MF/RO or MF/GAC was assumed to remove an additional zero to 90 percent of the constituents presented resulting in the range presented in Table 11. It is critical to note these estimates are based on limited data and are presented here simply for calculating mass removals. Current secondary effluent for industrial facilities would likely be greater than the data presented here and as a result, the projected effluent quality for industrial facilities would likely be higher as well. Based on the limited actual data from municipal treatment facilities, Table 11 indicates that mercury and BAP effluent limits may potentially be met using advanced treatment at facilities with similar existing secondary effluent quality.

Table 11. Pollutant Mass Removal by Contaminant for a 5 mgd Facility

Component	PCBs	Mercury	Arsenic	BAP
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)*	0.0015	0.025	7.5	0.00031
Projected Effluent Quality (µg/L) from Advanced Treatment (MF/RO or MF/GAC)*	0.000041 – 0.00041	0.00012 – 0.0012	0.38 – 3.8	0.000029 - 0.00029
Mass Removed (mg/d)**	21 - 28	451 - 471	71,000 – 135,000	0.4 – 5.0
Mass Removed (lb/d)**	0.000045 – 0.000061	0.00099 – 0.0010	0.16 – 0.30	0.0000010 – 0.0000012

* Based on or estimated for actual treatment plant data from municipal facilities. Data sets are limited and current secondary effluent for industrial facilities would likely be greater than the data presented here.
** 1 lb = 454,000 mg
HHWQC=human health-based water quality criteria
MF/RO=membrane filtration/reverse osmosis
MF/GAC=membrane filtration/granulated activated carbon
µg/L=micrograms per liter
mg/d=milligrams per day
lb/d=pounds per day

Unit costs were developed based on required mass removal from a 5 mgd facility for each of the four constituents of concern to reduce discharges from current secondary effluent quality to the assumed required effluent quality (HHWQC). It important to note that this study concludes it is unclear if existing technology can meet the required effluent quality, however, the information presented in Table 12 assumes HHWQC would be met for developing unit costs. The unit costs are expressed as dollars in NPV (over a 25 year period) per pound of constituent removed over the same 25 year period using advanced treatment with MF/RO. The current secondary effluent quality data presented are based on typical secondary effluent quality expected for a municipal/industrial discharger. Table 12 suggests unit costs are most significant in meeting the PCB, mercury, and PAH required effluent quality.

Table 12. Unit Cost by Contaminant for a 5 mgd Facility Implementing Advanced Treatment using MF/RO

Component	PCBs	Mercury	Arsenic	PAHs
Required HHWQC based Effluent Quality (µg/L)	0.0000064	0.005	0.018	0.0013
Current Secondary Effluent Concentration (µg/L)*	0.002	0.025	7.5	0.006
Total Mass Removed (lbs) over 25-year Period	0.76	7.6	2,800	1.8
Unit Cost (NPV per total mass removed in pounds over 25 years)	$290,000,000	$29,000,000	$77,000	$120,000,000

*Derived from data presented in Table 3.
**Based on assumed 25-year NPV of $219,000,000 (average of the range presented in Table 10) and advanced treatment using MF/RO.
NPV=net present value
HHWQC=human health-based water quality criteria
µg/l=micrograms per liter

4.9 Sensitivity Analysis

The ability of dischargers to meet a HHWQC one order of magnitude less stringent (than HHWQC presented in Table 3 and used in this report) was considered. The same advanced treatment technologies using MF/RO or MF/GAC would still be applied to meet revised effluent quality one order-of-magnitude less stringent despite still not being able to meet less stringent effluent limits. As a result, this less stringent effluent quality would not impact costs. Based on available data, it appears the mercury and BAP limits would be met at a less stringent HHWQC. PCB effluent quality could potentially be met if advanced treatment with RO or GAC performed at the upper range of their projected treatment efficiency. It does not appear the less stringent arsenic HHWQC would be met with advanced treatment. It is important to note that a discharger's ability to meet these less stringent limits depends on existing secondary effluent characteristics and is facility specific. Facilities with higher secondary effluent constituent concentrations will have greater difficulty meeting HHWQC.

5.0 Summary and Conclusions

This study evaluated treatment technologies potentially capable of meeting revised effluent discharge limits associated with revised HHWQC. HDR completed a literature review of potential technologies and engineering review of their capabilities to evaluate and screen treatment methods for meeting revised effluent limits for four constituents of concern: arsenic, BAP, mercury, and PCBs. HDR selected two alternatives to compare against a baseline, including enhanced secondary treatment, enhanced secondary treatment with MF/RO, and enhanced secondary treatment with MF/GAC. HDR developed capital costs, operating costs, and a NPV for each alternative, including the incremental cost to implement from an existing secondary treatment facility.

The following conclusions can be made from this study.

- Revised HHWQC based on state of Oregon HHWQC (2001) and EPA "National Recommended Water Quality Criteria" will result in very low water quality criteria for toxic constituents.
- There are limited "proven" technologies available for dischargers to meet required effluent quality limits that would be derived from revised HHWQC.
    - Current secondary wastewater treatment facilities provide high degrees of removal for toxic constituents; however, they will not be capable of compliance with water quality-based NPDES permit effluent limits derived from revised HHWQC.
    - Advanced treatment technologies have been investigated and candidate process trains have been conceptualized for toxics removal.
        - Advanced wastewater treatment technologies may enhance toxics removal rates, however they will not be capable of compliance with HHWQC based effluent limits for PCBs. The lowest levels achieved based on the literature review were between <0.00001 and 0.00004 µg/L, as compared to a HHWQC of 0.0000064 µg/L.
        - Based on very limited performance data for arsenic and mercury from advanced treatment information available in the technical literature, compliance with revised criteria may or may not be possible, depending upon site specific circumstances.
            - Compliance with a HHWQC for arsenic of 0.018 µg/L appears unlikely. Most treatment technology performance information available in the literature is based on drinking water treatment applications targeting a much higher SDWA MCL of 10 µg/L.
            - Compliance with a HHWQC for mercury of 0.005 µg/L appears to be potentially attainable on an average basis but perhaps not if effluent limits are structured on a maximum monthly, weekly or daily basis. Some secondary treatment facilities attain average effluent mercury levels of 0.009 to 0.066 µg/L. Some treatment facilities with effluent filters attain average effluent mercury levels of 0.002 to 0.010 µg/L. Additional advanced treatment processes are expected to enhance these removal rates, but little mercury performance data is available for a definitive assessment.
        - Little information is available to assess the potential for advanced technologies to comply with revised benzo(a)pyrene criteria. A municipal wastewater treatment plant study reported both influent and effluent BAP concentrations less than the HHWQC of 0.0013 ug/L (Ecology, 2010).

  - Some technologies may be effective at treating identified constituents of concern to meet revised limits while others may not. It is therefore even more challenging to identify a technology that can meet all constituent limits simultaneously.
  - A HHWQC that is one order-of-magnitude less stringent could likely be met for mercury and PAHs however it appears PCB and arsenic limits would not be met.
- Advanced treatment processes incur significant capital and operating costs.
  - Advanced treatment process to remove additional arsenic, benzo(a)pyrene, mercury, and PCBs would combine enhancements to secondary treatment with microfiltration membranes, reverse osmosis, and granular activated carbon and increase the estimated capital cost of treatment from $17 to $29 in dollars per gallon per day of capacity (based on a 5.0 mgd facility).
  - The annual operation and maintenance costs for the advanced treatment process train will be substantially higher (approximately $5 million - $15 million increase for a 5.0 mgd capacity facility) than the current secondary treatment level.
- Implementation of additional treatment will result in additional collateral impacts.
  - High energy consumption.
  - Increased greenhouse gas emissions.
  - Increase in solids production from chemical addition to the primaries. Additionally, the membrane and GAC facilities will capture more solids that require handling.
  - Increased physical space requirements at treatment plant sites for advanced treatment facilities and residuals management including reverse osmosis reject brine processing.
- It appears advanced treatment technology alone cannot meet all revised water quality limits and implementation tools are necessary for discharger compliance.
  - Implementation flexibility will be necessary to reconcile the difference between the capabilities of treatment processes and the potential for HHWQC driven water quality based effluent limits to be lower than attainable with technology

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7.0 Appendices

- Appendix A - Unit Process Sizing Criteria
- Appendix B - Greenhouse Gas Emissions Calculation Assumptions

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APPENDIX A - UNIT PROCESS SIZING CRITERIA

Table A-1. Unit Processes Sizing Criteria for Each Alternative

Unit Process	Units	Baseline Treatment	Advanced Treatment	Comment
Influent Pumping Station	unitless	3 Times Ave Flow	3 Times Ave Flow	This is peaking factor used to size the pumps (peak flow:average flow)
Alum Dose for CEPT (optional)	mg/L	20	20	This is the metal salt upstream of the primaries
Primary Clarifiers	gpd/sf	1000	1000	This is for average annual flows
Primary Solids Pumping Station	unitless	1.25 Times Ave Flow	1.25 Times Ave Flow	This is peaking factor used to size the pumps (maximum month flow:average flow)
Aeration System Oxygen Uptake Rate (OUR)	mg/L/hr	25	25	Average annual OUR is used in tandem with mixed liquor to determine the required aeration basin volume (the limiting parameter governs the activated sludge basin volume)
Aeration Basin Mixed Liquor	mg/L	1250	2500	Average annual mixed liquor is used in tandem with OUR (see next row) to determine the required aeration basin volume (the limiting parameter governs the activated sludge basin volume)
Secondary Clarifiers Hydraulic Loading	gpd/sf	650	--	Only use for Baseline as clarifiers governed hydraulically with short SRT (<2 days)
Secondary Clarifiers Solids Loading	lb/d/sf	--	24	Only use for Advanced Treatment as clarifiers governed by solids with long SRT (>8 days)
Return Activated Sludge (RAS) Pumping Station	unitless	1.25 Times Ave Flow	1.25 Times Ave Flow	RAS must have capacity to meet 100% influent max month Flow. The influent flow is multiplied by this peaking factor to determine RAS pumping station capacity.
Waste Activated Sludge (WAS) Pumping Station	gpm	1.25 Times Ave Flow	1.25 Times Ave Flow	WAS must have capacity to meet max month WAS flows. The average annual WAS flow is multiplied by this peaking factor to determine WAS pumping station capacity.
Microfiltration (MF) Flux	gfd	--	25	Based on average annual pilot experience in Coeur D'Alene, ID
MF Backwash Storage Tank	unitless	--	1.25	Storage tanks must have capacity to meet maximum month MF backwash flows. The average annual MF backwash volume is multiplied by this peaking factor to determine required volume.

Table A-1. Unit Processes Sizing Criteria for Each Alternative

Unit Process	Units	Baseline Treatment	Advanced Treatment	Comment
MF Backwash Pumps	unitless	--	1.25	Backwash pumps must have capacity to meet maximum month MF backwash flows. The average annual MF backwash flow is multiplied by this peaking factor to determine required flows.
Reverse Osmosis (RO)	gallon per square foot per day (gfd)	--	10	
RO Reject	%	--	20	This represents the percentage of feed flow that is rejected as brine
Chlorination Dose	mg/L	15	15	
Chlorination Storage Capacity	days	14	14	
Chlorine Contact Tank	min	30	30	This is for average annual conditions.
Dechlorination Dose	mg/L	15	15	
Dechlorination Storage Capacity	days	14	14	
Gravity Belt Thickener	gpm/m	200	200	This is for maximum month conditions using the 1.25 peaking factor from average annual to maximum month
Anaerobic Digestion	Hydraulic residence time (HRT)	18	18	This is for average annual conditions
Dewatering Centrifuge	gpm	120	120	This is for maximum month conditions using the 1.25 peaking factor from average annual to maximum month

gpd=gallons per day; sf=square feet; gpm=gallons per minute

Appendix B – Greenhouse Gas Emissions Calculation Assumptions

The steady state mass balance results were used to calculate GHG emissions. The assumptions used to convert between energy demand, chemical demand and production, as well as biologically-mediated gases (i.e., CH4 and N2O) and GHG emissions are provided in Table B-1. The assumptions are based on EPA (2007) values for energy production, an adaptation of the database provided in Ahn et al. (2010) for N2O emissions contribution, Intergovernmental Panel on Climate Change (IPCC) (2006) for fugitive CH4 emissions, and various resources for chemical production and hauling from production to the wastewater treatment plant (WWTP). Additionally, the biogas produced during anaerobic digestion that is used as a fuel source is converted to energy with MOP8 (2009) recommended waste-to-energy values.

Table B-1. Greenhouse Gas Emissions Assumptions

Parameters	Units	Value	Source
N_2O to CO_2 Conversion	lb CO_2/lb N_2O	296	IPCC, 2006
CH_4 to CO_2 Conversion	lb CO_2/lb CH_4	23	IPCC, 2006
Energy Production			
CO_2	lb CO_2/MWh	1,329	USEPA (2007)
N_2O	lb N_2O/GWh	20.6	USEPA (2007)
CH_4	lb CO_2/GWh	27.3	USEPA (2007)
Sum Energy Production	lb CO_2/MWh	1336	USEPA (2007)
GHGs per BTU Natural Gas			
CO_2	lb CO_2/MMBTU Natural Gas	52.9	CA Climate Action Registry Reporting Tool
N_2O	lb N_2O/MMBTU Natural Gas	0.0001	CA Climate Action Registry Reporting Tool
CH_4	lb CO_2/MMBTU Natural Gas	0.0059	CA Climate Action Registry Reporting Tool
Sum Natural Gas		53.1	CA Climate Action Registry Reporting Tool
Non-BNR N_2O Emissions	g N_2O/PE/yr	32	Ahn et al. (2010)
BNR N_2O Emissions	g N_2O/PE/yr	30	Ahn et al. (2010)
Biogas Purity	% Methane	65	WEF, 2009
Biogas to Energy	BTU/cf CH4	550	WEF, 2009
Digester Gas to Electrical Energy Transfer Efficiency	%	32	HDR Data

Table B-1. Greenhouse Gas Emissions Assumptions

Parameters	Units	Value	Source
Chemical Production			
Alum	lb CO_2/lb Alum	0.28	SimaPro 6.0 - BUWAL250, Eco-indicator 95
Polymer	lb CO_2/lb Polymer	1.18	Owen (1982)
Sodium Hypochlorite	lb CO_2/lb Sodium Hypochlorite	1.07	Owen (1982)
Building Energy Efficiency	kBTU/sf/yr	60	Calif. Commercial End-Use Survey (2006)
Hauling Distance		-	
Local	miles	100	-
Hauling Emissions			
Fuel Efficiency	miles per gallon	8	
CO_2	kg CO_2/gal diesel	10.2	CA Climate Action Registry Reporting Tool
N_2O	kg N_2O/gal diesel	0.0001	CA Climate Action Registry Reporting Tool
CH_4	kg CH_4/gal diesel	0.003	CA Climate Action Registry Reporting Tool
Sum Hauling Fuel	kg CO_2/gal diesel	10.2	CA Climate Action Registry Reporting Tool

GWh = Giga Watt Hours
MWh = Mega Watt Hours
MMBTU = Million British Thermal Units
BTU = British Thermal Unit
PE = Population Equivalents
kBTU/sf/yr = 1,000 British Thermal Units per Square Foot per Year
cf = cubic feet
lb = pound
kg = kilogram
gal = gallon

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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Staff Report

FINAL

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A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley

Staff Report

FINAL

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EXECUTIVE SUMMARY

Fish in the Sacramento-San Joaquin River Delta Estuary (Delta) have elevated levels of methylmercury that pose a risk for human and wildlife consumers. As a result, the Delta is on the Clean Water Act Section 303(d) List of Impaired Water Bodies. Section 303(d)(1)(A) of the Clean Water Act requires the Central Valley Water Board to develop a water quality management strategy – a.k.a. total maximum daily load (TMDL) – to lower fish mercury levels in the Delta so that the beneficial uses of fishing and wildlife habitat are attained.

Although methylmercury is less than 1% of all mercury discharged to the Delta, methylmercury is the chemical that accumulates in the food web. Available science indicates that reducing methylmercury in ambient water is the most direct way to reduce methylmercury in biota. The need for methylmercury effluent data for facilities permitted by the National Pollutant Discharge Elimination System (NPDES) program arose during the development of the TMDL source analysis for the Delta. There was a substantial amount of concentration and load data for inorganic mercury; however, there was limited information about methylmercury. Although inorganic mercury in effluent is a concern because of the potential for it to be methylated in downstream aquatic ecosystems, methylmercury also is a concern because it is immediately available for uptake by aquatic biota.

The Central Valley Water Board issued a California Water Code Section 13267 Order (13267 Order) in 2004 that required municipal wastewater treatment plants (WWTPs) and other non-municipal NPDES-permitted dischargers located in the Delta and its source region to monitor their methylmercury discharges. Effluent methylmercury data were submitted by 111 facilities. Although not required by the 13267 Order, thirty-six of those facilities also submitted influent methylmercury data. In addition, the Sacramento Regional Count Sanitation District submitted influent and effluent methylmercury concentration data for a six-year period.

This report provides a literature review and summary of NPDES influent and effluent methylmercury and inorganic mercury data along with available treatment process information for municipal WWTPs. No policy or regulation is either expressed or intended. This report is not a required element of the Delta methylmercury TMDL. However, this report includes a wealth of effluent and influent data and treatment process information that may be useful for future characterization and control studies in the Central Valley and elsewhere nationwide.

Overall, NPDES facilities account for about 4% of the methylmercury load to the Delta; NPDES facilities within the Delta contribute about 205 grams per year (g/year) while facilities in upstream watersheds that are downstream of major dams contribute about 24 g/year. The Delta TMDL divides the Delta into hydrologically-defined subwatershed

areas; different sources supply the different areas. For example, NPDES facilities within the San Joaquin River and Sacramento River subareas contribute about 7-9% of all methylmercury loading to those subareas, while NPDES facilities within the Central Delta, West Delta, and Yolo Bypass subareas contribute less than 0.2% of all methylmercury loading to these subareas. This report evaluates how the different NPDES categories contribute to methylmercury loading to the Delta.

Twelve categories of non-municipal facilities submitted effluent data: aggregate, aquaculture, drinking water treatment, food processing, groundwater remediation, heating/cooling, manufacturing, mines, paper/saw mill, power generation, power generation/domestic WWTP and a miscellaneous category. A few of the aquaculture and power generation facilities were neither significant sources nor sinks of methylmercury. More influent and effluent data are necessary to determine if other facilities in these two categories and heating/cooling facilities are net methylmercury sources or sinks. Aggregate, drinking water treatment, groundwater remediation, paper/saw mills and the other non-municipal facilities were sources of methylmercury but typically had low effluent methylmercury concentrations (average of 0.05 nanograms per liter [ng/l]). Eight of the twelve categories of non-municipal facilities had average effluent methylmercury concentrations less than or equal to 0.05 ng/l (the lowest calibration standard for methylmercury). Of the 198 effluent methylmercury samples submitted by all non-municipal facilities, 134 were less than or equal to 0.05 ng/l, and 80 of those were below the method detection limit (typically < 0.025 ng/l). The highest effluent methylmercury concentration observed at a non-municipal facility was 1.19 ng/l from a stormwater detention pond at the Sierra Pacific Industries Shasta Lake Mill, which is in the paper/saw mill category; all other samples from the paper/saw mills and other non-municipal facilities were less than 0.2 ng/l.

In contrast, municipal WWTPs contribute the most discharge (by discharge volume and methylmercury load) to the Delta source region of any one of the NPDES discharger categories monitored and have the most variability in effluent methylmercury concentrations. Individual effluent samples collected from WWTPs had methylmercury concentrations that ranged from below the detection limit to 4 ng/l, a 200-fold difference. Twenty of the 61 WWTPs that submitted effluent data had an average concentration less than or equal to 0.05 ng/l, and 13 of the WWTPs had an average concentration less than 0.03 ng/l. In contrast, 18 WWTPs had an average effluent methylmercury concentration greater than 0.2 ng/l, and seven had mean concentrations greater than 1 ng/l.

Staff grouped the municipal WWTPs into mutually exclusive treatment categories based on their secondary, tertiary and disinfection treatment types to determine if trends existed between treatment processes and effluent methylmercury concentrations. The facilities that use treatment pond systems (oxidation, facilitative, settling or stabilization ponds) had the highest effluent methylmercury concentrations. The median effluent

methylmercury values of all pond treatment categories were statistically higher than all other treatment categories, with one exception; the “Pond + Filtration + Chlorination/Decholorination” category did not have significantly higher effluent methylmercury concentrations than the “Secondary + Chlorination/Decholorination” (secondary treatment without nitrification/denitrification and filtration) category. WWTPs that use one or more of the following treatment processes generally had lower effluent methylmercury concentrations: nitrification/denitrification, filtration, and ultraviolet (UV) disinfection. Treatment categories that include one or more of these processes had statistically lower effluent methylmercury concentrations than both the pond and “Secondary + Chlorination/Dechlorination” categories.

Seasonal variability was observed in effluent methylmercury concentrations at several municipal WWTPs in the Central Valley and elsewhere. Studies were conducted at the City of Winnipeg WWTP (Canada) and Onondaga County WWTP (New York); both WWTP studies demonstrated that effluent methylmercury concentrations increase as ambient temperatures increase, particularly when treatment ponds are used. Effluent methylmercury concentrations were also higher in the warm season (e.g., May through November) than the cool season at several of the Central Valley WWTPs. The Central Valley WWTPs that showed seasonal patterns in their effluent methylmercury concentrations had many different types of treatment processes, indicating that there was no trend between the type of treatment process and seasonality.

These and other possible trends between treatment processes and effluent methylmercury concentrations identified by the Central Valley facility data and literature reviews merit additional investigation. There are many factors that affect the concentrations of methylmercury in effluent and subsequent methylation/demethylation processes in the receiving waters. Additional studies are required to understand the mercury/methylmercury relationships between different treatment processes and mercury methylation/demethylation processes in the receiving water. Chapter 5 of this report suggests preliminary ideas for future analyses and key questions to be addressed by treatment plant analyses.

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ACRONYMS

Basin Plan	Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
CTR	California Toxics Rule
CVRWQCB	Central Valley Regional Water Quality Control Board (a.k.a. Central Valley Water Board)
CWA	Federal Clean Water Act
EC	Electrical conductivity
GIS	Geographic Information System
GW	Groundwater
Hg	Mercury
ID	Irrigation District
mgd	Million gallons per day
MeHg	Monomethyl mercury (also referred to as methylmercury in this report)
NPDES	National Pollutant Discharge Elimination System
O	Oxygen
PUD	Public Utilities District
SD	Sanitation District
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board (a.k.a. San Francisco Bay Water Board)
SFEI	San Francisco Estuary Institute
SRCSD	Sacramento Regional County Sanitation District
TMDL	Total maximum daily load
TSS	Total suspended solids
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet radiation
WTP	Water treatment plant (drinking water filtration or groundwater treatment)
WWTP	Wastewater treatment plant
WY	Water Year[1]

[1] A "water year" (WY) is defined as the period between 1 October and 30 September of the following year; for example, WY2001 is the period between 1 October 2000 and 30 September 2001. The California Department of Water Resources (DWR) developed the Hydrologic Classification Index (HCI) to evaluate the distribution of wet and dry years in the Central Valley. DWR classifies water year types according to the natural water production of the major basins. See the following website for more information about the HCI: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

UNITS OF MEASURE

μg	microgram
μg/g	microgram per gram
μg/l	microgram per liter
μm	micrometer
cfs	cubic feet per second
cm	centimeter
g	Gram
g/day	gram per day
g/l	gram per liter
in/yr	inches per year
kg	kilogram
L	Liter
m	Meter
mg	milligram
mg/g	milligram per gram
ml	milliliter
mm	millimeter
ng	nanograms
ng/l	nanograms per liter
o/oo	parts per thousand (salinity)
ppb	parts per billion; usually µg/kg
ppm	parts per million; usually mg/kg or μg/g
ppt	parts per trillion; usually ng/kg

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1 INTRODUCTION

In 1990, the Central Valley Regional Water Quality Control Board (Central Valley Water Board) identified the Delta as impaired by mercury because fish had elevated levels that posed a risk for human and wildlife consumers. This is a concern because fishing is a popular activity in the Delta. About 300,000 licensed sport and subsistence anglers fish in the Delta each year, along with an unknown number of unlicensed anglers. Wildlife species of concern that consume Delta fish include California least tern, bald eagle, and river otter. Eating fish with high levels of mercury is a problem, especially for the young, because mercury is a potent neurotoxicant that impairs nervous systems in both humans and wildlife (National Research Council (NRC), 2000). In addition, it affects their reproductive and immune system function; examples of negative effects include deficits in memory and motor control in humans and reductions in physical abilities in wildlife (Wolfe *et al.*, 1998; Whitney, 1991 in Huber, 1997; Dansereau *et al*., 1999; Huber, 1997; Wiener and Spry, 1996).

As stated in CalFed's 2003 Mercury Strategy: "The problem with mercury in the Delta's aquatic ecosystems can be defined as biotic exposure to methylmercury." Methylmercury is the most toxic and bioaccumulated form of mercury. Methylmercury concentrations in aquatic ecosystems are the result of two competing processes: methylation and demethylation. Methylation is the addition of a methyl group to an inorganic mercury molecule. Sulfate reducing bacteria in sediment are the primary agents responsible for the methylation of mercury in aquatic ecosystems. Maximum methylmercury production occurs at the oxic-anoxic boundary in sediment, usually several centimeters below the surface. Although less common, methylmercury also may be formed in anaerobic water (Regnell *et al.*, 1996 and 2001).

Demethylation is both a biotic and abiotic process. Both sulfate reducing and methanogen-type bacteria have been reported to demethylate mercury in sediment with maximum demethylation co-occurring in the same zone where maximum methylmercury production is located (Marvin-DiPasquale *et al*., 2000). Photodegradation of methylmercury in the water column also has been observed (Sellers *et al*., 1996; Byington *et al*., 2005; Gill, 2008). The rate of both biotic and abiotic demethylation appear quantitatively important in controlling net methylmercury concentrations in aquatic ecosystems (Sellers and Kelly, 2001; Marvin-DiPasquale *et al*., 2000; Foe *et al*., 2008).Several published papers provide comprehensive reviews of the methylmercury cycle in the Delta and elsewhere (e.g., Wiener *et al.*, 2003a and 2003b; Tetra Tech, Inc., 2005; Larry Walker Associates (LWA), 2002). Board staff and others have found that in some waterways, processes of methylmercury production and transport downstream in the water column are dominant (e.g., in the lower Sacramento and San Joaquin Rivers upstream of the Delta) and in others, processes that remove

methylmercury from the water column such as photodegradation and sedimentation are dominant (e.g., in the Central Delta) (Stephenson *et al.*, 2008).

Once in the water column, methylmercury bioaccumulates in the food web. That is, very low methylmercury levels in water lead to high methylmercury levels in fish. For example, largemouth bass in the Delta have more than 6 million times the methylmercury as the water in which they swim. As a result, human and wildlife exposure to methylmercury is primarily through consumption of fish and shellfish, rather than drinking water.

Although processes that remove methylmercury from the water column may be dominant in some water bodies, there is no information that suggests that methylmercury discharged into a water body would disappear so rapidly that none of it would be accumulated, at least in part, into the food chain immediately downstream of the discharge. For example, in its Localized Mercury Bioaccumulation Study, SRCSD concluded that SRCSD WWTP effluent contributes about the same percentage of methylmercury to Sacramento River biota downstream of its discharge as it does to the methylmercury loading in the river. SRCSD found that four out of six fish and clams species sampled had methylmercury concentrations about 10% greater downstream from the discharge than upstream. The ratio of SRSCD WWTP methylmercury loads to river methylmercury loads was also about 10% during the study period. Also, as demonstrated by extensive spatial and temporal sampling of large and small fish in the Delta and its tributary watersheds (e.g., Slotton *et al*., 2003 and 2007; Davis *et al*., 2000, 2003 and 2008), methylmercury persists long enough in tributary and Delta waters to be reflected in fish uptake with regional patterns that stay consistent over years.

Although methylmercury is less than 1% of the inorganic mercury input to the Delta (Wood *et al*., 2010b), methylmercury is the form of mercury that accumulates in the food web. Available science indicates that reducing methylmercury in ambient water is the most direct way to reduce methylmercury in biota. Methylmercury produced by many modern-day activities may potentially be managed so that less methylmercury is discharged. Chapters 3 and 5 in the February 2008 draft staff TMDL report (Wood *et al*., 2010b) provides information about the relationship between methylmercury in Delta fish and water and potentially controllable methylation processes in the Delta region. Methylmercury in Delta waterways comes from many sources, such as wetlands, agricultural drains, urban runoff, wastewater treatment plant effluent and tributary inflows, in addition to methylmercury production in and flux from open-water sediments in Delta waterways.

Section 303(d)(1)(A) of the federal Clean Water Act requires States to establish a “Total Maximum Daily Load” (TMDL) for each impaired water body to attain water quality standards. Section 13240 of the State of California Porter-Cologne Water Quality

Control Act requires Regional Boards to develop water quality control plans to meet reasonable protection of beneficial uses, including establishing water quality objectives and a program of implementation to achieve the water quality objectives. A TMDL represents the maximum load (usually expressed as a rate, such as kilograms per day (kg/day) or other appropriate measure) of a pollutant that a water body can receive and still meet water quality objectives. A TMDL describes the reductions needed to meet water quality objectives and allocates those reductions among the sources in the watershed. Central Valley Water Board staff has proposed a mercury TMDL control program for the Delta that addresses sources of both inorganic mercury and methylmercury (Wood *et al.*, 2010a and 2010b). The proposed program focuses on methylmercury source reduction because available information indicates that methylmercury levels in water may be a primary factor determining methylmercury concentrations in fish. A inorganic mercury load reduction strategy also is part of the proposed program for several reasons: to reduce sediment mercury levels and associated water methylmercury levels in the Delta; to maintain compliance with the USEPA's criterion of 50 ng/l; and to comply with the San Francisco Bay mercury control program adopted by the San Francisco Bay Regional Water Quality Control Board.

The need for methylmercury data for discharges permitted by the National Pollutant Discharge Elimination System (NPDES) arose during the development of the source analysis for the Delta methylmercury TMDL. At the beginning of the TMDL development, only one NPDES-permitted facility in the Central Valley had collected effluent methylmercury data. Between December 2000 and June 2003, the Sacramento Regional County Sanitation District (SRCSD) collected 60 samples to characterize its effluent methylmercury levels. In February and March 2004, Central Valley Water Board staff conducted two sampling events at four other municipal facilities to determine whether the SRCSD data are representative of other WWTPs. The 2004 sampling results, along with data available in the published literature, indicated that the effluent methylmercury data for the SRCSD facility might not be representative of all facilities in the Delta. Therefore, the Central Valley Water Board issued a California Water Code Section 13267 Order (13267 Order) in 2004 that required NPDES dischargers, including municipal WWTPs and non-municipal facilities to monitor methylmercury discharges for one year.

Specifically, the 13267 Order required the following:

- Instantaneous, unfiltered grab samples collected from the facilities effluent for one year (generally September 2004 to August 2005) at a monthly, quarterly or biannual frequency, depending on facility size and whether there was a discharge to surface water;
- Use of clean hands/dirty hands sampling procedures and U.S. Environmental Protection Agency (USEPA) Method 1630/1631 (Revision E) with a method detection limit of 0.02 ng/l;

- Analysis of a matrix spike and matrix spike duplicate with either the first or second set of samples to ensure an acceptable methylmercury recovery rate; and
- Analysis of a travel blank with every other set of samples.

The 13267 Order did not require the collection of inorganic mercury data. However, if the facility was already collecting samples for inorganic mercury analysis, then it was required to collect the methylmercury samples concurrently. Also all inorganic mercury data and any other methylmercury monitoring data collected by a facility must be reported to the Central Valley Water Board. While not required by the 13267 Order, collection of instantaneous grab samples from the facilities' upstream receiving water and main influent were recommended to calculate methylmercury treatment efficiency. Appendix A provides an example of the 13267 Order letter and a list of facilities that received the Order.

This technical staff report presents a summary of the methylmercury data submitted by the NPDES dischargers. Because of the file size, data for individual facilities are not attached to this report; a Microsoft Excel file containing all data is available upon request. This report also includes an evaluation of the quality assurance/quality control results, a literature review, a description of the treatment processes in place at the municipal WWTPs when their methylmercury data were collected, a discussion of treatment processes and their possible relation to effluent methylmercury levels, and recommendations for further research. An administrative draft report was sent in December 2008 to all of the NPDES facilities whose data was summarized in this report. Staff addressed comments submitted for the December 2008 draft report and made the revised draft report available for public review in May 2009. Staff incorporated corrections and comments on the December 2008 and May 2009 draft reports into this final version of the report. Comments submitted by facilities and staff responses are in Appendix D.

As part of the proposed Delta mercury control program (Wood *et al.*, 2010a), Central Valley Water Board staff is currently recommending that methylmercury dischargers in the Delta and its source region conduct collaborative methylmercury control studies to develop methods to reduce their methylmercury discharges. This report and the associated database are a first step in that process, particularly for the municipal WWTPs.

The literature review of studies that investigated methylmercury in WWTPs is presented in Chapter 2. The quality assurance/quality control evaluation is presented in Chapter 3. The summary of effluent and influent methylmercury data is provided in Chapter 4. In response to comments from the Sacramento Regional County Sanitation District on the May 2009 draft report, an additional chapter (Chapter 5) was added to this report to assess the relative contribution of methylmercury load to the Delta by NPDES facilities in and upstream of the Delta. The discussion of treatment processes

and their possible relation to effluent methylmercury levels and recommendations for further research are provided in Chapter 6.

In this report, mercury, inorganic mercury, and total mercury are used synonymously.

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2 LITERATURE REVIEW

Several published reports have evaluated wastewater treatment plant mercury fate and transport. Results and conclusions from these studies are summarized below and in Table 1.

2.1 San Jose / Santa Clara Water Pollution Control Plant

From October 2004 to March 2006, the City of San Jose conducted a sampling program to study the fate and transport of mercury within its wastewater treatment facility in compliance with its NPDES waste discharge permit (SJ/SC, 2007). The treatment process of the San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP) consists of screening and grit removal, primary sedimentation, secondary treatment (activated sludge with nitrification/denitrification), secondary clarification, filtration, chlorination, and dechlorination before the wastewater is discharged. During the secondary treatment process the waste stream is split between two parallel units, which are identical in function. Aqueous samples were collected from the raw influent after grit removal, primary effluent, settled sewage influent to nitrification units (secondary influent), secondary effluent, tertiary filter influent and effluent, and final effluent. City staff collected and analyzed over 140 aqueous samples for total and dissolved mercury, methylmercury, and parallel samples for total suspended solids (TSS), sulfide, chloride, and sulfate. Total and dissolved mercury and methylmercury results for the aqueous sampling are summarized in Table 2.

In addition, City staff collected and analyzed 32 biosolids samples for inorganic mercury, methylmercury, sulfide, sulfate, pH and moisture content. Sludge samples were collected from the primary sludge, waste activated sludge from secondary units, returned activated sludge, thickened activated sludge and digested sludge. Inorganic mercury concentrations in sludge were higher than in the water due to the strong particle association of mercury. Inorganic mercury and methylmercury concentrations in sludge were roughly uniform throughout the treatment process.

In this study, the removal of TSS corresponded with the removal of inorganic mercury. Raw influent contained approximately 190 mg/l TSS and 168 ng/l inorganic mercury. After primary settling, the TSS concentration was approximately 85 mg/l and the inorganic mercury concentration was 92 ng/l. Secondary effluent, which is a combined flow from identical and parallel activated sludge units, continued to show a close correlation between TSS and inorganic mercury removal with concentrations of about 5 mg/l and 5.2 ng/l, respectively. The TSS was reduced to approximately 2 mg/l in the treated tertiary effluent, but increased to 3 mg/l in the final effluent. The corresponding inorganic mercury concentration for the tertiary treated effluent was 1.6 ng/l, and for the final effluent was 2.0 ng/l. The study states that this slight increase in inorganic mercury

and TSS in the final effluent may be attributed to the addition of the filter backwash water, treated by flocculation and clarification, to the filter effluent prior to disinfection. The final effluent represented an overall removal of 99% of the inorganic mercury.

The secondary treatment process proved to be a catalyst for the removal of methylmercury, indicated by a primary effluent concentration of 1.5 ng/l and a reduction to 0.05 ng/l in the secondary effluent. Although anoxic conditions are present during some process steps of secondary treatment, the conditions were not sufficient to promote methylation of mercury. The authors of the study noted that little apparent sulfate reduction occurred within the treatment process, which could explain why significant methylation did not occur. Final effluent concentrations of methylmercury showed a decrease to 0.04 ng/l, representing an overall removal efficiency of 97%.

The study found no significant seasonal trend in influent inorganic mercury concentrations; however, the study observed a diurnal trend, with higher concentrations in the afternoon and early evening. There were no observed diurnal patterns for methylmercury in the influent. The study concluded that methylmercury concentrations in the influent were relatively uniform over the course of a day. The study did not discuss seasonal or diurnal patterns or variability in effluent inorganic mercury and methylmercury concentrations.

2.2 Sacramento Regional County Sanitation District Wastewater Treatment Plant

The Sacramento Regional County Sanitation District (SRCSD) WWTP is a 181 mgd pure oxygen activated sludge secondary treatment plant (Parmer *et al.*, 2005). The SRCSD also operates a 5 mgd tertiary treatment plant for water recycling. The SRCSD study investigated both inorganic mercury and methylmercury fate and transport for the wastewater and solids treatment trains. The tertiary effluent (recycled water) was not tested. This study used a two-phased approach, identified as Phase 1A and 1B.

Phase 1A included nine sampling days that occurred from October to November 2004. Samples were taken from the influent, primary effluent, secondary effluent prior to chlorination, dechlorinated final effluent, and solids storage basin return flow to the plant influent structure. The liquid supernatant from the digested sludge and three different solids storage basins (SSB) named green, black and harvest were also sampled. The parameters measured in Phase 1A were inorganic mercury (total and dissolved), methylmercury (total and dissolved), total dissolved solids, TSS, pH and dissolved oxygen.

Phase 1B involved more extensive sampling of the treatment process from the end of Phase 1A to May 2005. Phase 1B sampling locations included all locations sampled in Phase 1A, except for the supernatant from the SSB Ponds. In addition, the mixed liquor (mixture of the influent flow to the secondary clarifiers and the return activated sludge),

the waste activated sludge from the secondary clarifiers, the biosolids recycling facility (BRF) influent from the sludge digesters and the BRF return flow to the plant influent structure were sampled during Phase 1B. The same analytes were measured in both Phases 1A and 1B. The concentrations, mass loads and particulate concentrations for the inorganic mercury and methylmercury samples collected during both phases of the study are summarized in Tables 3 and 4.

There was a strong correlation between solids removal and inorganic mercury removal. The inorganic mercury concentration was reduced by an average of 94% from the influent to the secondary effluent, and 95% from the influent to the final dechlorinated effluent. The TSS was reduced by an average of 95% from the influent to the secondary effluent, and 96% from the influent to the final effluent. Overall, it appeared that the treatment process removed inorganic mercury more efficiently than methylmercury. The methylmercury concentration was reduced by an average of 75% from the influent to the secondary effluent, and 70% from the influent to the dechlorinated final effluent.

The highest methylmercury loading in the liquid train of the plant occurred in the mixed liquor channel, which comprises primary effluent and 40% return activated sludge. The highest methylmercury concentration (not including digested sludge and return flows) of about 31 ng/l occurred in the return activated sludge stream, which is recycled to the mixed liquor (activated sludge unit process). The secondary process achieved the greatest reduction of methylmercury concentrations and loads in the liquid train as observed from the primary and secondary effluents; however, it also had the greatest methylmercury concentration (in the waste activated sludge stream) of all the liquid train unit processes in this study.

An increase in methylmercury concentration occurred between the secondary effluent (0.38 ng/l) and the dechlorinated final effluent (0.55 ng/l). The study authors noted the increase was consistent with the slightly increased TSS concentration in the final effluent. According to the authors, no backwash or other return flow is added to the waste stream between the secondary effluent and the dechlorinated final effluent. The report authors concluded that both inorganic mercury and methylmercury removals correlated with TSS removal due to strong particle affinity.

2.3 Concentrations and Fluxes of Inorganic mercury and Methylmercury within the Onondaga County Metropolitan Wastewater Treatment Plant

The Onondaga County Metropolitan Wastewater Treatment Plant discharges its effluent to Onondaga Lake, a mercury-contaminated lake in Syracuse, New York (McAlear, 1996). A study at the Onondaga County Metropolitan WWTP investigated the concentrations and fluxes of inorganic mercury and methylmercury within the plant and in its discharge. The WWTP treatment processes consist of screening and grit removal,

primary clarification, conventional activated sludge, secondary clarification, chlorination, and phosphorous removal (coagulation by addition of iron salts followed by clarification) before the wastewater is discharged.

Monthly samples were collected from the plant influent, primary effluent, secondary effluent, “tertiary” effluent from the phosphorous removal clarifiers and final plant effluent between October 1995 and September 1996 and analyzed for inorganic mercury and methylmercury. Daily composite total dissolved solids concentrations and daily inorganic mercury concentrations in sludge also were evaluated. The average concentrations of inorganic mercury, methylmercury and TSS at each treatment process are summarized in Table 5.

The authors determined that seasonal conditions play an important role in the methylation process, and in particular, that warm temperatures may be a catalyst for methylation. The influent methylmercury concentrations were much lower during cold weather (November through April) than during warm weather (May through October), and further, methylmercury concentrations remained relatively constant throughout the treatment process during cold weather (Table 6). However, during the warm weather months, an increase in the average methylmercury concentrations occurred between primary effluent and secondary effluent (from 1.8 ng/l to 3.5 ng/l), followed by a decrease in the “tertiary” and final effluents (2.9 ng/l and 1.6 ng/l, respectively). Despite this apparent methylation during secondary treatment in warm weather months, the study found that the average final effluent methylmercury concentration in the warm weather months was only slightly higher than during the cold weather months (1.6 ng/l compared to 1.4 ng/l).

There was a strong correlation between the mean concentrations of inorganic mercury and TSS throughout the treatment processes. In contrast, a weak correlation was evident between the mean methylmercury and TSS concentrations. The ratios of methylmercury versus inorganic mercury concentrations for the entire study period (includes warm and cold weather months) were highest during secondary treatment at 20.5%, decreasing to 8.3% in the final effluent.

During the cold weather months, November through April, the influent and final effluent methylmercury averaged 2.3 and 1.4 ng/l, respectively. Primary and secondary treatment effluent had concentrations near 2.0 ng/l. The highest methylmercury concentration during the cold weather months was in the “tertiary” effluent (2.4 ng/l). The percentage of inorganic mercury as methylmercury during the same period increased gradually throughout the treatment process from about 1% (influent), 2% (primary), 6% (secondary), and 12% (“tertiary”), before decreasing in the outfall to 3%.

The influent and final plant effluent methylmercury averaged 7.8 and 1.6 ng/l, respectively, in the warm weather months. The percentage of inorganic mercury as

methylmercury during warm weather months varied from approximately 2 to 3% in the influent and primary effluent, to a high of 35% in secondary treatment, and then decreasing to 15% in tertiary treatment and 13% in the final effluent measured at the outfall. Although activated sludge is an aerobic treatment process, the study author hypothesized that methylation of mercury likely occurred during secondary treatment in anaerobic microenvironments.

2.4 City of Winnipeg, Manitoba, Canada

The City of Winnipeg, Manitoba operates three secondary treatment plants that discharge to two local rivers, the Red and Assiniboine Rivers (Bodaly *et al.*, 1998). Two of the plants (the North End and South End plants) use pure oxygen activated sludge in their secondary treatment process. The West End plant, in contrast, uses conventional activated sludge with diffusers. The West End facility also is the only WWTP of the three to use lagoons after secondary treatment and before final effluent discharge.

Samples were collected from the influent and effluent of the three plants. Five sampling events took place from early summer to autumn 1994 and one event took place in spring 1995, for a total of six sampling events. The unfiltered water samples were analyzed for inorganic mercury and methylmercury.

Influent methylmercury concentrations observed at the three treatment plants ranged from 0.5 to greater than 4 ng/l and averaged 2.2 ng/l. Effluent methylmercury concentrations observed at the North and South End plants ranged from 0.13 to 0.56 ng/l. However, effluent methylmercury concentrations observed at the West End Plant, which utilizes conventional activated sludge and lagoons after secondary treatment, were significantly higher, varying from about 0.2 to greater than 2 ng/l. A seasonal trend was apparent only in the West End facility; effluent methylmercury concentrations increased as ambient temperatures increased, with the highest concentration occurring in August. The authors noted that the high concentrations of methylmercury in 1994 may have been related to the fact that the West End facility had begun operations within the year and experienced start-up problems. Also, this facility was the only one of the three plants to use final polishing lagoons, which could be sites of substantial methylmercury production, especially if anoxic conditions exist.

Overall removal rates for the three treatment plants were 88% of inorganic mercury and 90% of methylmercury. However, this methylmercury removal rate does not include the summer period at the West End Plant when methylmercury concentrations in the effluent were elevated. The study authors did not observe a seasonal pattern in the concentration of inorganic mercury in effluent from any of the plants.

2.5 Fritz Island Wastewater Treatment Plant

The City of Reading signed a consent decree with the State of Pennsylvania agreeing to remove three mercury-filled trickling filter center column seals used in the Fritz Island WWTP (Gilmour and Bloom, 1995). This allowed researchers to examine the extent of inorganic mercury and methylmercury contamination within the plant and its receiving water body, the Schuylkill River. Each filter seal initially contained 340 kg of mercury, some of which was lost from the seals due to excessive pressure and equipment failures and escaped to the rock media and underbed of the trickling filters. The mobility and fate of the mercury contaminating the Fritz Island WWTP was determined by evaluating inorganic mercury and methylmercury concentrations of the inflow to and outflow from a number of individual treatment components in the WWTP.

The Fritz Island WWTP is a secondary treatment facility that employs trickling filters (TFs) for secondary treatment. The treatment process consists of primary settling before the 1st stage TFs, 1st stage trickling filters (TF# 1-3), intermediate settling before the 2nd stage TFs, 2nd stage trickling filters (TF# 4-6), settling after the 2nd stage TFs, aeration and then a final settling process. There are six trickling filters involved in the treatment process. Four of these (TF# 1, 3, 5 and 6) originally used mercury-containing center seals. The contaminated seal in trickling filter #5 was replaced with a mechanical seal in 1984, and the rock media and underbed was cleaned or replaced.

Researchers collected aqueous samples from the plant influent and effluent, and sludge samples from the belt press, from July to December 1993. The aqueous and sludge samples were analyzed for inorganic mercury and methylmercury. A summary of the inorganic mercury and methylmercury concentration data and calculated mass balances are presented in Tables 7 and 8, respectively. During a one-time sampling event in August 1993, researchers collected inorganic mercury and methylmercury samples from the inputs and outputs from each treatment process within the WWTP. A summary of those results is provided in Table 9.

With the exception of TF# 5, all of the trickling filters were measurable sources of both inorganic mercury and methylmercury, demonstrated by greater concentrations in the effluent than in the influent of the contaminated trickling filters. In TF# 1, the inorganic mercury concentration of the effluent was 25 times higher than the influent, and the methylmercury concentration was four times higher. Inorganic mercury in the wastewater was lost to the sludge during the settling steps. More than 90% of the inorganic mercury in the effluent of the first stage trickling filters was removed to the sludge during the intermediate settling process. A similar trend was observed in the post 2nd stage and final settling processes.

An average of 157 grams of inorganic mercury was released from the plant per day, with less than 10% in the effluent and more than 90% released in the sludge. Only

about 20 grams of the 157 grams was derived from the plant influent, with the remainder generated inside the plant. However, the WWTP was an overall sink for inorganic mercury in the wastewater, demonstrated by lower inorganic mercury concentrations and loads in the plant effluent than in the plant influent.

Methylmercury production was closely related to the mercury concentration in each of the trickling filters. The contaminated trickling filters were the main sites of methylmercury production. Methylmercury concentrations decreased during aeration, which the study authors hypothesized was attributed to chemical or microbial demethylation of methylmercury to inorganic mercury during this process. Overall, about 0.4 g/day of methylmercury was released from the plant, with about 25% of this amount introduced from the plant influent and the rest generated inside the plant. Of the 0.4 g/day of methylmercury released from the plant, 30% was in the sludge, and 70% was released to the river in the effluent. The WWTP was an overall source of methylmercury in the wastewater. Both the methylmercury concentrations and loads in the effluent were higher than in the plant influent.

2.6 Whitlingham Sewage Treatment Works

Between May 1986 and June 1988, a study was conducted at Whitlingham Sewage Treatment Works in Norwich, England to evaluate the behavior of heavy metals during wastewater treatment and to investigate the occurrence of mercury methylation throughout the treatment plant (Goldstone *et al.*, 1990). The wastewater treatment processes at the Whitlingham facility consisted of primary clarification followed by secondary activated sludge treatment before discharge as effluent.

The study consisted of two sampling events, the first in May 1986 and the second in October 1987. The constituents evaluated during both sampling events were inorganic mercury, dissolved mercury, total solids and total suspended solids (TSS). Methylmercury was sampled throughout the treatment process only during the second sampling event. Raw sewage (influent), settled sewage (primary effluent), picket fence thickener overflow, returned activated sludge, and final effluent were sampled during the second event. Table 10 provides a summary of the inorganic mercury and methylmercury concentration results for the second sampling event.

Methylation of mercury within the treatment plant was observed, especially in the presence of bacterial solids. Methylmercury and inorganic mercury concentrations were highest in the return activated sludge. However, the average methylmercury concentration of the final effluent was below the 10 ng/l detection limit; the study authors assumed that the seven samples with methylmercury concentrations below the detection limit were equal to zero when they calculated the average methylmercury concentration of the final effluent.

The effects of centrifugation and filtration on additional return activated sludge samples were investigated to determine whether methylmercury has a greater affinity for the soluble or particulate phase of the return activated sludge. Results indicated that methylmercury was predominantly associated with solids. The study authors determined that the absence of detectable methylmercury in the influent and primary effluent indicates that all methylmercury in the return activated sludge had been produced by *in situ* biological methylation. However, the authors noted that the aerobic conditions of the activated sludge could be considered unfavorable to the production and accumulation of methylmercury. The authors hypothesized that the high concentrations of bacterial solids and other organic material in the waste activated sludge may have outweighed the aerobic conditions and permitted the establishment of an equilibrium concentration of methylmercury. Correlations performed on the data confirmed a relationship between high concentrations of biological solids and aerobic methylation.

2.7 Determination of Methylmercury in a Pilot-Scale Activated Sludge Wastewater Treatment Plant

Pavlogeorgatos and others (2006) investigated methylation in a pilot-scale activated sludge plant supplied with synthetic wastewater enriched with mercury. The wastewater was spiked with mercury concentrations of 10, 100 and 500 µg/l. The initial methylmercury concentration of the synthetic wastewater was not evaluated. Duplicate samples from the aeration tank, treatment plant effluent, and sludge were analyzed for inorganic mercury and methylmercury. The results indicated that all of the samples had methylmercury concentrations below the detection limit of 0.07 µg/l. The highest inorganic mercury concentration of 17.8 mg/l was found in the sludge sample associated with the 500 µg/l mercury spike. On average, 82.8% of the mercury entering the treatment plant was adsorbed to the particulate matter in the aeration tank.

While no conclusion could be drawn regarding methylation because of the high method detection limit (0.7 µg/l, compared to the MDL of 0.02 ng/l required for the 13267 Order monitoring), this investigation confirmed that the reduction and volatilization of mercury is the primary pathway to its removal. In the aeration tank, this pathway becomes secondary when the microorganisms and mercury reach equilibrium. Adsorption of mercury onto the biosolid flocs becomes the primary removal mechanism. The study theorized that methylmercury was not detectable because the conditions were aerobic, or because demethylation predominated. Methylation may have occurred but was not detectable given the method detection limit used in the study. The authors also discovered that spiking the wastewater with increased mercury concentrations reduced the removal effectiveness of organic matter in the treatment process.

3 QUALITY ASSURANCE AND QUALITY CONTROL

The 13267 Order required NPDES facilities to submit effluent methylmercury monitoring data collected using the clean hands/dirty hands technique described in USEPA Method 1669 and analyzed using USEPA Method 1630/1631 (Revision E) with a method detection limit (MDL) of 0.02 ng/l. In addition, the facilities were required to have a matrix spike/matrix spike duplicate (MS/MSD) performed on their first or second set of effluent samples, and travel blanks performed with every other set of samples. The MS/MSD is designed to determine if the effluent matrix causes interferences in methylmercury recovery and to provide an estimate of analytical precision. The travel blank is used to determine if there is any contamination during transport. Other quality assurance/quality control (QA/QC) parameters not required by the 13267 Order but evaluated by some of the facilities include field duplicates, MS/MSD of other matrixes, and field blanks. Staff used guidelines described in the CALFED Mercury Program Quality Assurance Project Plan (Puckett, 2000) to assess the quality of the data presented in this report.

3.1 Method Detection Limit

Since Frontier GeoSciences laboratory has a minimum reporting limit of 0.025 ng/l and Frontier conducted many of the analyses for the facilities, staff considered non-detects to be reported as less than 0.025 ng/l or lower. Only on six occasions were MDLs greater than 0.025 ng/l; the maximum MDL reported was 0.05 ng/l. The concentration data submitted by the dischargers overall appear to be of high quality and analyzed by laboratories able to perform the latest methods for analyzing methylmercury.

3.2 Sample Handling and Preservation

USEPA Method 1630 requires samples to be preserved with acid within 48 hours to a pH of less than two. The analytical laboratories verify the pH of the samples upon receipt, and the laboratories acid-preserve the samples if the pH is found to be greater than two. The laboratories flag samples when the samples are preserved after the 48-hour hold time. Thirty-four percent of the samples analyzed for methylmercury were preserved before being received by the analytical laboratories (field), 37% were preserved at the laboratories, and 29% of the samples had no acid preservation information provided (unknown). All data from samples known to have pH hold time exceedences were flagged so. Data for samples whose hold times exceeded 60 hours were flagged and excluded from calculations made in this report. Table 11 shows the data for these excluded samples. All samples with no preservation information provided were assumed to meet their pH hold times and their data were accepted.

Twenty-two samples exceeded the 48-hour hold time, and of those, 21 samples exceeded 60 hours (Table 11). Acid preservation stops the bacterial activity in the water that produces methylmercury from inorganic mercury. Samples without preservation may not be representative of the conditions at the time of sampling if bacterial activity continues after sampling. However, because bacterial activity is believed to be minimal in samples that are kept cold (0 to 4°C), data from samples with minimal hold time exceedences (<60 hours) were considered acceptable.

The USEPA Method 1630 states that unpreserved samples should be kept at 0 to 4°C until preserved, after which samples can be stored at cool temperatures. The analytical laboratory reports state the optimal temperature is 4 ±2°C for unpreserved samples; as a result, all data derived from samples received by the laboratories above 6°C and unpreserved were flagged for being out of optimal temperature range. A review of the data indicated that temperature did not likely affect the samples; therefore, staff incorporated the flagged data in this report's calculations.

3.3 Matrix Spike/Matrix Spike Duplicates

MS/MSD results were submitted by 93 facilities (see Appendix C, Table C.1). The facilities were not required to submit the laboratory reports from the analysis laboratories; consequently, eight facilities submitted summaries only of their methylmercury data. Ninety-two facilities had MS/MSDs performed on their effluent at least once for a total of 161 effluent MS/MSDs performed. On eight occasions, the MS/MSDs were not within the criteria of acceptability.[2] For three events the MS/MSD had relative percent differences (RPD) greater than 25%, and the associated effluent data were flagged "not reproducible" for high variability. In addition, there were three times where the MS/MSD had recoveries below 70% and twice the recovery was greater than 130%, hence the associated effluent data were flagged "low bias" for low recoveries and "high bias" for high recoveries, respectively.

Influent and receiving water had MS/MSDs performed on 25 and 32 occasions, respectively. One of the influent MS/MSDs exhibited a recovery above 130%, and the data were flagged "high bias". Five of the influent MS/MSDs (20% of the MS/MSDs performed on influent samples) exhibited recoveries below 70%, and their data were flagged "low bias". The USEPA Method 1630 may underestimate the methylmercury concentration in wastewater influent samples. Receiving water MS/MSD experienced recoveries below 70% once and above 130% once, hence the associated data were flagged accordingly. In all instances that the MS/MSDs experienced recoveries below 70% or above 130%, the laboratories' analyses of laboratory control samples were

[2] Acceptable MS/MSD recovery per the CalFed QAPP: >70% and <130% recovery.
Acceptable MS/MSD RPD: ≤25%.

within acceptable limits, indicating that the laboratories performed the method appropriately.

One laboratory reported that high levels of chloride in effluent could interfere with recoveries, and that a special preparation of the sample could remedy the problem. However, the small occurrence of low recoveries in effluent indicates that there is little interference caused by the effluent matrix. In addition, the low occurrence of MS/MSD RPD exceedences greater than 25% indicates the high precision of the laboratory analyses and the high quality of data produced.

3.4 Travel Blanks

The facilities were required to submit travel blanks with every other set of samples submitted. Some facilities submitted trip blanks or field blanks, in addition to or instead of travel blanks. Travel blanks are bottles filled with deionized (DI) water that are transported to the site but not opened (CDFG, 2002). Travel blanks are synonymous to trip blanks, which is defined by USEPA as, "A clean sample of a matrix that is taken from the laboratory to the sampling site and transported back to the laboratory without being exposed to the sampling procedures" (USEPA, 2002). Conversely, one of the laboratories contracted to collect water samples defined trip blanks as, "…Trip blanks should be handled the same as the sample; however, they only need to be exposed to the atmosphere. Do not put sample in the bottle. Trip blanks are designed to measure the amount of methyl mercury in the air…" This suggests that this laboratory's trip blanks were performed to test parameters typically assessed with field blanks. Field blanks are considered acceptable substitutes because they assess contamination introduced by field sampling conditions in addition to all of the contamination assessed by travel blanks.

Approximately 85% of the facilities that submitted data fulfilled their requirements for blanks submittal, 4% partially fulfilled their requirements, and 11% did not submit any blank analysis. Approximately 5% of the combined number of trip and field blanks had methylmercury concentrations detected above the MDL; however, the majority of the detections were less than two times the detection limit or less than five times the sample concentration. These deviations are not considered to affect the quality of the sample concentration data. The analytical laboratories reported that concentration detections less than two times the MDL have high variability and are considered estimates. Only 3% of the blank concentration detections were greater than two times the MDL and proportionately high when compared to their respective sample concentrations. Because these data could be affected by contamination they were flagged. Blanks are designed to be used as an interactive QA/QC tool, where sources of reoccurring contaminations can be identified and eliminated. Because most of the contaminations

were isolated events, the concentration data accuracy should not be greatly affected; therefore, the flagged data were used in this report's calculations.

3.5 Field Duplicates

Field duplicates are used to examine field homogeneity and sampling handling. Though not required by the 13267 Order, field duplicates were collected on 35 occasions (Table 12). Field duplicate mean RPD was 12.7%. On four occasions the RPD was greater than 25%; however, the methylmercury concentrations for each of the samples and their duplicates were less than 10 times the MDL. Sample concentrations at or near the MDL have higher variability, suggesting that these field duplicates' high RPD cannot be completely attributed to field variability. All of the field duplicates met the criterion for data acceptability, indicating that the facilities performing field duplicates had acceptable field collection precision. Field duplicates were not incorporated into the calculations of this report.

3.6 Anomalous Values

Several anomalous values were observed in the methylmercury and inorganic mercury dataset when compared to the remainder of the values observed at a facility (Table 13). When an analytical laboratory report was available, staff was able to confirm the anomalous values. None of the available laboratory reports indicated that contamination or any other error or misreporting occurred. Otherwise, if no laboratory information was provided, staff assumed that all data including anomalous values were correct. As a result, Board staff included all anomalous values in the report calculations since staff could not conclude definitively that errors were made.

SRCSD staff identified three methylmercury results that failed their quality assurance review. Influent and effluent samples collected on 13 July 2001 had methylmercury concentrations of 1.05 and 2.93 ng/l, respectively; SRCSD staff commented in their data review notes, "highly unlikely that there is more MeHg in effluent than influent". Likewise, an effluent sample collected on 18 June 2006 had a methylmercury concentration of 0.077 ng/l; SRCSD noted, "highly unlikely that effluent concentration is this low". As a result, these three samples were not included in the calculations in this report.

There were three instances when a municipal WWTP had a higher effluent methylmercury concentration than the influent value collected on the same day. This occurred one time at each of the Colusa, SRCSD Walnut Grove and Mariposa WWTPs. Staff carefully reviewed available information to determine the likelihood of some type of data or reporting error. The influent and effluent values were confirmed by analytical

laboratory reports and chain of custody documents; hence, staff assumed that the data was correct and the data was included in the report calculations.

3.7 Summary

The data presented in this report meets the overall QA/QC requirements of the NPDES 13267 Order. Less than 1% of the analyses for methylmercury had method detection limits greater than 0.025 ng/l, with 0.05 ng/l being the highest, indicating that the samples were analyzed using the latest methods. Only 3% of the effluent matrix spikes resulted in recoveries exceeding the criterion, and less than 2% of the MS/MSD analyses resulted in RPDs greater than 25%. Wastewater treatment plant effluent appears to exhibit little to no interference with Method 1630. These results agree with Caltest Analytical Laboratory staff's review of Method 1630 performance on wastewater they have analyzed, where their last 200 matrix spikes averaged 93% recovery in matrix and MS/MSD relative percent differences averaged 9% in their last 100 MS/MSD performed (SFEI, 2007). In contrast, 20% of the MS/MSD performed on influent samples submitted by Central Valley facilities exhibited low recoveries; therefore, Method 1630 may underestimate the methylmercury concentration in wastewater influent samples. Less than 3% of the combined travel and field blanks resulted in detections above the criterion of acceptability, suggesting that there was little cross contamination between bottles and/or contamination from field procedures.

Twenty-five methylmercury samples were excluded from calculations and graphs in this report. Twenty-two of these excluded samples had acid preservation hold times that exceeded 60 hours. In addition, 6 of the samples excluded due to hold time exceedences, were also contaminated with mercury in the laboratory and were not believed to be representative of site influent or effluent. These contaminated samples were from General Electric Co. GWCS (NPDES No. CA0081833) and were collected on 18 October 2004. The three other methylmercury samples excluded from calculations in this report failed the SRCSD staff quality assurance review.

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4 REVIEW OF METHYLMERCURY CONCENTRATION DATA FROM CENTRAL VALLEY DISCHARGERS

There are currently 124 NPDES-permitted dischargers in the Delta source region[3] representing a variety of discharger types, primarily: aggregate, aquaculture, food processing, heating/cooling, manufacturing, mines, municipal WWTPs, paper/saw mills, power generation, water filtration (e.g., for drinking water), and groundwater remediation. The approximate discharge volumes of each of these NPDES categories are provided in Table 14.

A total of 134 Central Valley NPDES-permitted dischargers received the 13267 Order (see Appendix A, Table A.1). Staff did not send the 13267 Order to every NPDES-permitted discharger in the Delta source region. In addition, some of the facilities that received the Order discharge upstream of major dams, some were not discharging to surface waters during the study period, and some no longer discharge. Of the 134 dischargers that received the Order, 18 facilities discharge upstream of major dams, 22 facilities discharge directly to the Delta/Yolo Bypass, 17 discharge to other waterways that are 303(d)-listed as mercury impaired as of 2006, and 12 discharge to small waterways that, although not 303(d)-listed, drain directly to the Delta/Yolo Bypass. Table 15 summarizes the number of facilities that received the Order, categorized by discharger type and geographical region.

Effluent methylmercury data were submitted by 111 facilities as a result of the 13267 Order monitoring requirements. Although not required by the Order, thirty-six of those facilities also submitted influent methylmercury data. In addition, the Sacramento Regional County Sanitation District submitted influent and effluent methylmercury concentration data for a six-year period (December 2000 – March 2007). Central Valley Water Board staff compiled influent and effluent inorganic mercury concentration data available in SRCSD monitoring reports. The abundance of inorganic mercury and methylmercury data for the SRCSD Sacramento River WWTP influent and effluent allowed for more analysis of the SRCSD data. Figures 1, 2 and 3 illustrate the locations of the Central Valley facilities that submitted methylmercury data and Table 16 provides the map codes, receiving water information, approximate discharge volumes and facility types discussed in this report.

Tables G.3a and G.3b in Appendix G of the Delta methylmercury TMDL report summarize the number of effluent methylmercury samples collected by each facility, along with their average, minimum and maximum methylmercury concentrations. Tables in the Delta methylmercury TMDL report appendix provide average concentrations only for discharges to surface water. The graphs and calculations in this

[3] The "Delta Source Region" is a geographic area that includes the Delta and the watershed areas upstream that drain into the Delta but are downstream of major dams.

report incorporate all available data, including samples collected when facilities did not discharge to surface water. Of the approximately 700 effluent methylmercury samples collected, nine samples were taken from reclaimed effluent that was not discharged to surface water.

Available influent and effluent data are summarized by discharger type in the following sections. Summaries of effluent and influent methylmercury data for each NPDES facility are presented in Appendix B, Tables B.1 through B.4, at the end of this report.

4.1 Non-Municipal Discharges

Section 4.1 is divided into six subsections that describe non-municipal discharges:

1. Aggregate;
2. Aquaculture, power generation and heating/cooling;
3. Paper, pulp and saw mills;
4. Groundwater remediation;
5. Drinking water treatment; and
6. Food processing, manufacturing, and other non-municipal discharges.

A summary of the effluent methylmercury concentration data categorized by discharger type for the non-municipal NPDES facilities is provided in Table 17.

4.1.1 Aggregate

Discharge from aggregate plants, which process rock and gravel from quarries, is typically storm water after it is settled in sedimentation basins. These facilities were a small source of methylmercury with an average effluent concentration of 0.026 ng/l (Table 17). Five aggregate facilities submitted discharge methylmercury concentration data; one of the facilities is no longer active. Six of the eight samples collected by the active aggregate plants had methylmercury concentrations less than the method detection limit, and the other two samples had concentrations of 0.062 and 0.081 ng/l. Discharges from aggregate plants comprise about 2% of NPDES discharges (by volume) to the Delta source region.

The Oakwood Lake Subdivision Mining Reclamation NPDES permit (CA0082783; formerly known as the Brown Sand, Inc., Manteca Aggregate Sand Plant) allows for the discharge of water from Oakwood Lake to the San Joaquin River for flood control. Oakwood Lake is a former excavation pit filled primarily by groundwater. The results from discharge sampling in August and November 2004, nondetect (<0.02 ng/l) and 0.043 ng/l, respectively, are comparable to results for groundwater remediation plant discharges (Section 4.1.4). Furthermore, these effluent values are substantially lower

than the monthly average methylmercury concentrations observed in the adjacent San Joaquin River at Vernalis during August and November (0.167 and 0.130 ng/l, respectively; Wood *et al.*, 2010b).

4.1.2 Aquaculture, Power Generation & Heating/Cooling

Aquaculture, power generation, and heating/cooling facilities typically use ambient surface water, domestic water or groundwater for hatchery flow-through water or cooling water. Wastewater from these types of facilities may be untreated, filtered to remove solids and/or metals, or clarified in sedimentation basins prior to discharge. The combined discharge volume from all of these facility categories is about 50% of the total discharged by NPDES facilities to the Delta source region (Table 14).

Aquaculture, power generation and heating/cooling facilities had average effluent methylmercury concentrations of 0.041 ng/L, 0.061 ng/L and 0.11 ng/L, respectively (Table 17). The intake water of many of these facilities is taken from the same water body that the effluent is discharged to; therefore, a comparison of intake and effluent concentrations is necessary to determine whether a facility is a net source or sink of methylmercury.

Ten of the twenty-four facilities that submitted methylmercury data collected paired intake/outfall samples (Table 18). The power and heating/cooling facilities did not appear to be a source of methylmercury to the Delta. However, staff was unable to do statistical analyses of the paired influent-effluent samples of these facilities because sample sizes were too small for all facilities except for Mirant Delta CCPP (CA0004863), a power generation facility. Furthermore, many of these facilities had influent and effluent samples that were below the detection limit, making it impossible to statistically compare those paired samples. Methylmercury concentrations of outfalls 1 and 2 from Mirant Delta CCPP were not significantly different than intake 2 when compared individually (Outfall 1 vs. Intake 2: $p=0.26$; Outfall 2 vs. Intake 2: $p=0.37$, paired t-test). Therefore, outfalls 1 and 2 were neither significant sources nor sinks of methylmercury. More data is necessary to determine if the other power and heating/cooling facilities are methylmercury sources or sinks.

Effluent methylmercury concentrations of the aquaculture facilities were not significantly different than the paired influent concentrations ($p=0.21$, paired t-test). Even though the effluent concentrations typically exceeded intake concentrations (see Table 18), aquaculture facilities were neither a source nor sink of methylmercury. This comparison is based upon five paired influent-effluent samples from three facilities; therefore, more paired data is necessary to determine if aquaculture facilities are net sources or sinks. Almost all the aquaculture facilities had average effluent methylmercury concentrations equal to or less than 0.05 ng/l.

Until recently, the SMUD Rancho Seco Nuclear Generating Station (CA0004758) discharged a combination of treated liquid radioactive wastewater, secondary treated domestic wastewater, stormwater and irrigation runoff. It is the only facility in the power generation/ domestic WWTP category and was a small source of methylmercury. Methylmercury concentrations in the combined effluent ranged from nondetect (<0.025 ng/l) to 0.104 ng/l with an average of 0.040 ng/l.

4.1.3 Paper, Pulp & Saw Mills

Paper, pulp and saw mills discharge a combination of process wastewater and storm water after it is typically clarified in settling basins. These facilities were a source of methylmercury with an average effluent concentration of 0.117 ng/l (Table 17). However, 15 of the 21 effluent samples collected at these facilities were less than 0.10 ng/l. Paper, pulp and saw mills account for about 0.4% of the volume discharged by NPDES facilities to the Delta source region.

Five of the 12 effluent samples collected at the Pactiv Molded pulp mill (CA0004821) had methylmercury concentrations less than the method detection limit, and the other seven samples were between the detection limit and 0.085 ng/l. Eight of the nine samples collected at the two other mills had concentrations between the detection limit and 0.18 ng/l. The SPI Shasta Lake saw mill (CA0081400) had the highest effluent methylmercury concentration of 1.19 ng/l, collected from “Discharge 002” on 30 December 2004. The concentration of the other effluent sample collected from “Discharge 002” on 23 March 2005 at this facility was 0.023 ng/l. Discharge 002 is from a stormwater retention pond, and rainfall occurred on both sample dates and on previous days; it is conceivable that a “first flush” effect could be the cause of the highly variable results.

4.1.4 Groundwater Remediation

Groundwater remediation facilities extract contaminated groundwater for treatment prior to discharge to surface waters. These facilities had very low levels of methylmercury in their discharge. Nineteen of the 20 effluent samples collected by four facilities had methylmercury concentrations less than the method detection limit, and one sample was just slightly above the detection limit (0.033 ng/l). One plant collected nine influent samples, all of which had methylmercury concentrations less than the detection limit. Groundwater remediation plants account for about 1.4% of the volume discharged by PDES facilities to the Delta source region.

4.1.5 Drinking Water Treatment

Drinking water treatment plants account for about 0.1% of the volume discharged by NPDES facilities to the Delta source region. Drinking water treatment plants typically

discharge settled filter backwash water from their treatment process to surface waters. Six drinking water treatment facilities submitted effluent methylmercury concentration data and two of those submitted influent data. These facilities had an average effluent concentration of 0.033 ng/l (Table 17). Five of the facilities had effluent samples with methylmercury concentrations ranging from below the detection limit to 0.043 ng/l. One of these facilities collected an intake sample with a methylmercury concentration of 0.084 ng/l. The other facility had two effluent samples with methylmercury concentrations measuring 0.045 ng/l and 0.066 ng/l, and two influent samples with concentrations measuring less than the detection limit (0.02 ng/l) and 0.033 ng/l.

4.1.6 Food processing, Manufacturing, and other Non-Municipal Discharges

Food processing, manufacturing, and publishing facilities were not a substantial source of methylmercury. Fifteen of the 20 effluent samples collected by facilities in these categories had methylmercury concentrations less than the method detection limit, and the other five samples had concentrations between the detection limit and calibration standard (0.05 ng/l). One of the manufacturing facilities collected 12 influent samples. Eleven of these samples had methylmercury concentrations less than the detection limit, and one was just above the detection limit.

The one laboratory and one mine facility that submitted data were both small sources of methylmercury. The three samples collected by the laboratory facility had methylmercury concentrations between 0.038 ng/l and 0.082 ng/l. The four samples collected by the mine ranged from 0.025 ng/l to 0.091 ng/l. Permitted discharges from food processing, mining, publishing, and laboratory facilities comprise about 0.3% of the total NPDES discharge volume to the Delta source region. The two manufacturing plants in the Delta source region have since ceased discharge to surface waters.

4.2 Municipal WWTPs

More information is available for municipal WWTPs than for other types of NPDES facility discharges, so staff was able to conduct a more extensive data analysis for WWTPs. Municipal WWTPs contribute about 44% of the total discharge volume (see Table 14) and about 99% of methylmercury loading contributed to the Delta source region by NPDES facilities (see Chapter 5 and Table 36). While the loads from all WWTPs may be a small fraction of the total and methylmercury loads from tributary and Delta sources (see Chapter 5 and Tables 35, 36 and 37), some municipal WWTPs may contribute substantial methylmercury loads to individual water bodies. For example, a six-year comparison of the SRCSD Sacramento River WWTP effluent methylmercury loads as a percentage of its receiving water loads was as high as 30 to 43% during the warm seasons of 2001 and 2002 and less than 1% during the wet seasons of 2005 and 2006 (Figure 4; Bosworth, 2008), ranging from 4.2% to 17% on an annual basis.

Between October 2002 and October 2006 most of the loading was less than 10% during the winter through summer seasons. For some receiving waters, reducing municipal WWTP methylmercury discharges, along with reductions from other point and nonpoint sources, may be an important component in reducing methylmercury levels in Delta water.

Sixty-one municipal WWTPs submitted effluent methylmercury concentration data representing 63 discharges (two facilities had two discharge locations). Twenty-three treatment plants also submitted influent methylmercury data. In addition, inorganic mercury influent and effluent data are available for 9 and 29 discharges, respectively. Hence, Section 4.2 is divided into subsections describing the different types of concentration data and data comparisons:

1. Effluent methylmercury;
2. Influent methylmercury;
3. Effluent inorganic mercury;
4. Influent inorganic mercury;
5. Ratio between effluent methylmercury and influent methylmercury;
6. Ratio between effluent methylmercury and effluent inorganic mercury;
7. Ratio between effluent methylmercury and influent inorganic mercury; and
8. Ratio between effluent inorganic mercury and influent inorganic mercury.

To begin the process of evaluating methylmercury discharges from municipal WWTPs, Board staff conducted a preliminary evaluation of municipal treatment process information available in NPDES permits and project files. Table 20 provides treatment process information with the WWTPs sorted by average effluent methylmercury concentration. Using this treatment process information, staff grouped the Central Valley WWTPs into mutually exclusive categories based on the maximum level of wastewater treatment that the facilities were using in 2005, including the secondary, tertiary and disinfection treatment types (Table 21). A description of the treatment categories is provided in Table 22 and descriptive statistics for these categories are provided in Table 23. For calculations involving inorganic mercury and methylmercury concentration results that were less than the method detection limit (MDL), one half of the MDL was used for those results.

Staff attempted to identify obvious differences and seasonal trends in influent and effluent data between facilities and evaluated those differences in terms of the treatment categories. Identifying the reasons why some WWTPs discharge effluent with higher methylmercury concentrations than others, and why some facilities have seasonal or other treatment-related variability in their methylmercury discharges, could be critical components to the development of methylmercury controls.

4.2.1 Effluent Methylmercury

Municipal WWTPs had the most variability in effluent methylmercury concentrations of any of the NPDES discharger categories evaluated. Individual effluent methylmercury concentrations ranged from nondetect (<0.02 ng/l at 31 WWTPs) to 4 ng/L at the Colusa WWTP, a 200-fold difference. As illustrated by Figure 5, 20 (33%) of the WWTPs had average effluent methylmercury concentrations less than 0.05 ng/l, and 13 (21%) plants had average concentrations less than 0.03 ng/l. In contrast, 18 (30%) WWTPs had average effluent methylmercury concentrations greater than 0.2 ng/l, and 7 of these averaged between 1 and 2.9 ng/l. The highest average effluent methylmercury concentration (2.86 ng/l) observed at a facility was nearly 150 times that of the lowest average concentrations (e.g., facilities with effluent concentrations approaching or less than the detection limit). As shown in Table 1, the variability in the methylmercury concentrations observed in effluent from different municipal WWTPs in the Central Valley is comparable to WWTP effluent concentrations observed elsewhere.

Municipal WWTPs with higher average effluent methylmercury concentrations generally had higher variability, as indicated by a positive relationship ($R^2 = 0.7167$, $p<0.0001$) between the WWTPs' average methylmercury concentrations and corresponding standard deviations (Figure 6).

Seasonal variability was observed in effluent methylmercury concentrations at several municipal WWTPs. Anderson, Cottonwood, Davis, Grass Valley, Lincoln, Oroville, Placer Co. SMD #1, Redding Clear Creek and SRCSD Sacramento River WWTPs had higher effluent methylmercury concentrations in the warm season (e.g., May through November) than the cool season (see Figures 7 and 8). The exception was the Stockton WWTP, which had higher concentrations in the cool season. No obvious relationship between seasonality and treatment processes exists.

The SRCSD Sacramento River WWTP has a six-year methylmercury monitoring record for both the influent and effluent. Monthly averages of all the effluent methylmercury concentrations collected during the six-year period were higher during the warm season than during cold weather (Figure 8). However, the most recent data collected during WY2005-2007 show much less seasonal variability and lower methylmercury concentrations during warm months (May – November) than in earlier years ($p<0.0001$ for both the non-parametric Mann-Whitney U test and the parametric two sample t-test). Overall, SRCSD effluent methylmercury concentrations showed a marked decrease from WY2001 to 2007 (Figure 9).

Staff used statistical tests to determine if significant differences in effluent methylmercury concentrations exist between the treatment categories. Descriptive statistics and normality tests indicate that the treatment categories do not meet the assumptions of parametric hypothesis tests, including homoscedasticity (constant

variance) among all groups and data normality (Table 23). Differences in effluent methylmercury concentrations between the treatment categories were analyzed with non-parametric statistics as transformations could not be found to produce homoscedasticity and data normality among the all of the categories. The "Statistica" software was employed for all the statistical analyses.[4]

Statistically significant differences in effluent methylmercury concentrations exist among the treatment categories ($p<0.0001$, Kruskal-Wallis test). A pair-wise multiple comparison test was conducted to determine which treatment categories had higher concentrations. The two-sided significance levels (p-values) for each treatment category are presented in Table 24.

Facilities that use treatment pond systems as part of their treatment process had the highest effluent methylmercury concentrations (Figures 10 and 11; Table 23). The "Pond + Chlorination/Dechlorination (C/D)" and "Pond + Filtration + C/D" treatment categories had median effluent methylmercury concentrations of 0.52 ng/l and 0.81 ng/l, respectively. Conversely, facilities that have some combination of nitrification/denitrification (N/D), filtration, and ultraviolet (UV) disinfection generally had lower effluent methylmercury concentrations. The "N/D + Filtration + C/D", "Secondary w/ N/D + UV", "N/D + Filtration + UV", "Filtration + UV", "Secondary w N/D + C/D" and "Filtration + C/D" categories had median effluent methylmercury concentrations of 0.06 ng/l or less (Table 23).

These observed trends are confirmed by the multiple comparison p-values for the treatment categories. The "Pond + C/D" and "Pond + Filtration + C/D" categories had significantly higher effluent methylmercury concentrations than the "N/D + Filtration + C/D", "Secondary w/ N/D + UV", "N/D + Filtration + UV", "Filtration + UV", "Secondary w/ N/D + C/D" and "Filtration + C/D" categories ($p<0.00001$; Table 24). In addition, the "Secondary + C/D" category had significantly higher concentrations than every other category ($p<0.01$), excluding the "Pond + C/D" and "Pond + Filtration + C/D" categories (Table 24). Other statistically significant differences in effluent methylmercury concentrations include: the "Pond + C/D" category had higher values than the "Secondary + C/D" category, and the "N/D + Filtration + C/D" category had lower values than the "Secondary w/ N/D + C/D" and "Filtration + C/D" categories.

As indicated by Figure 10, two WWTPs had different effluent methylmercury concentrations than other WWTPs in the same treatment category:

- The Modesto WWTP had lower effluent methylmercury concentrations than other WWTPs in the "Pond + C/D" category ($p<0.0001$ for both the Mann-Whitney U test and the two sample t-test);

[4] Statistica StatSoft, http:// www.statsoft.com

- The Rio Alto WWTP had higher effluent methylmercury concentrations than other WWTPs in the “Filtration + C/D” category. Since only two effluent samples were collected at this WWTP, more data is needed to determine if these concentrations are representative of this facility’s effluent.

These differences suggest that other unique processes are acting at these two facilities that significantly modify methylmercury production or degradation. Staff’s review of the other treatment processes and data for these facilities (e.g., Tables 20 and 21, Figure 7) gave no straightforward reasons for the differences. The Rio Alto WWTP had more variability (i.e., coefficient of variation) than all but one of the 17 WWTPs in the "Filtration +C/D" category. The Modesto WWTP had the lowest average effluent methylmercury concentration and coefficient of variation of all of the 11 WWTPs in the “Pond + C/D” category. It could be helpful to obtain more information about conditions during each of the sampling events for these WWTPs (e.g., variations in treatment methods and differences in nitrate concentrations and temperature) and, in the future, to sample both influent and effluent to assess whether the variability in effluent is due to influent variability or treatment variability.

Nitrification/denitrification, filtration, ultraviolet disinfection or a combination of these treatments may play a role in decreasing effluent methylmercury concentrations. The “N/D + Filtration + C/D” category had significantly lower effluent methylmercury concentrations than the “Secondary w/ N/D + C/D” and “Filtration + C/D” categories (Table 24). This suggests that both filtration and nitrification/denitrification treatment processes may have been responsible for the lower concentrations discharged by the facilities in the “N/D + Filtration + C/D” category.

During the nitrification process, aerobic bacteria convert ammonia to nitrate with the assistance of oxygen (Metcalf and Eddy, Inc., 1972). The denitrification process involves anoxic bacteria converting nitrate to nitrogen gas with the help of a carbon source such as methanol (Metcalf and Eddy, Inc., 1972). The denitrification bacteria potentially could assist in the demethylation of methylmercury to inorganic mercury, because the methyl group is the best carbon source for the conversion of nitrate to nitrogen gas (Pirondini, 2008a). This potential methylmercury demethylation could occur in a fully-nitrified wastewater (low ammonia), but likely not in a partially-nitrified or non-nitrified wastewater (high ammonia) (Pirondini, 2008a). Additional analysis that directly evaluates effluent ammonia/nitrate/nitrite levels and effluent methylmercury concentrations needs to take place.

The “Filtration + C/D” and “Secondary + C/D” treatment categories both contained numerous WWTPs with a variety of secondary treatment types. Staff assigned the WWTPs in each of these groups into three mutually exclusive subcategories based upon their secondary treatment (Table 25). The three subcategories were “Activated Sludge” (includes conventional, pure oxygen and extended aeration activated sludge,

oxidation ditch and sequencing batch reactor treatments), “Activated Sludge + Trickling Filter” and “Fixed Media” (includes trickling filter and rotating biological contactor treatments). Descriptive statistics and normality tests indicate that the subcategories within each treatment grouping do not meet the assumptions of parametric hypothesis tests (Table 26). Differences in effluent methylmercury concentrations between the treatment subcategories were analyzed with non-parametric statistics as transformations could not be found to produce homoscedasticity and data normality among the all of the categories.

Within the “Secondary + C/D” category, no significant differences in effluent methylmercury concentrations exist between the three subcategories ($p=0.07$, Kruskal-Wallis test). However, within the “Filtration + C/D” category, significant differences exist between the subcategories ($p<0.01$, Kruskal-Wallis test). A pair-wise multiple comparison test indicated that the “Activated Sludge” subcategory had lower effluent methylmercury concentrations than the “Fixed Media” subcategory ($p<0.01$; Table 27). Descriptive statistics for the subcategories within each treatment category are presented in Table 26.

Each subcategory within the “Filtration + C/D” category had lower average and median effluent methylmercury concentrations than the same subcategory within the “Secondary + C/D” category (Table 25). These differences are statistically significant as shown by the two-sided significance levels (p-values) in Table 28. This indicates that the filtration treatment process may have assisted in the reduction of methylmercury in the effluent of these facilities.

4.2.2 Influent Methylmercury

A seasonal pattern was observed in influent methylmercury concentrations at a few municipal WWTPs. Several plants appeared to experience a decrease in influent methylmercury concentrations during cool weather months (Chico, Deer Creek and El Dorado Hills WWTPs); while some showed a sharp increase in the spring (Williams and Woodland WWTPs) or the summer (Rio Vista and UC Davis WWTPs) (see Figure 13). The approximately six-year influent methylmercury monitoring record for the SRCSD Sacramento River facility also showed an increase in average influent concentrations during the summer months (Figure 14). As for effluent methylmercury, there appeared to be a decreasing trend in influent methylmercury concentrations at the SRCSD Sacramento River facility between WY2001 to WY2007 (Figure 9).

Average influent methylmercury concentrations ranged from 0.068 at Mariposa WWTP to 14.6 ng/l at Maxwell WWTP, a 215-fold difference (Figure 12). Of the 23 municipal WWTPs that collected influent methylmercury data, three had average influent methylmercury concentrations less than 1 ng/l, ten had average concentrations between 1 ng/l and 2 ng/l, and two had average concentrations greater than 7 ng/l.

4.2.3 Effluent Inorganic Mercury

Effluent inorganic mercury concentrations ranged from non-detect (less than 0.2 ng/l) at the Modesto WWTP to 53.1 ng/l at the Woodland WWTP, which is about a 260-fold difference (Figure 15). The high value observed at the Woodland WWTP was an anomaly when compared to the remainder of the Woodland WWTP data. Of the 28 WWTPs where effluent inorganic mercury data were collected, 10 had average effluent inorganic mercury concentrations less than 3 ng/l, 11 had average concentrations between 3 ng/l and 7 ng/l, and two had average concentrations greater than 10 ng/l. The highest average effluent inorganic mercury concentration (22 ng/l) observed at a WWTP was about 44 times that of the lowest average concentration (0.5 ng/l; Figure 15).

Several WWTPs had higher effluent inorganic mercury concentrations during the winter (Davis [Discharge 1], Manteca, Placer County SMD #1 and Stockton WWTPs) or spring (Redding Stillwater WWTP) (see Figure 16). No obvious relationship between seasonality and treatment processes seemed to exist. The effluent inorganic mercury monitoring record for the SRCSD Sacramento River facility showed relatively constant monthly averages (between 5 ng/l and 7 ng/l) with no apparent seasonal trend (Figure 17). However, effluent inorganic mercury data collected from December 2000 to March 2007 showed an obvious decreasing trend, particularly after 2004 (Figure 18). Furthermore, the effluent inorganic mercury concentrations from 2005 to 2007 had much less variability than the prior years.

4.2.4 Influent Inorganic Mercury

Of the 61 municipal WWTPs that monitored effluent methylmercury, nine WWTPs monitored influent inorganic mercury. Influent inorganic mercury concentrations ranged from 29.0 ng/l at Roseville Pleasant Grove WWTP to 6,100 ng/l at SRCSD Sacramento River WWTP, which is about a 210-fold difference (Figure 19). Two of the nine facilities that collected data had average influent inorganic mercury concentrations less than 100 ng/l, four facilities were between 100 ng/l and 300 ng/l, and 3 facilities had average influent concentrations greater than 300 ng/l. The highest average influent inorganic mercury (2,100 ng/l) observed at a municipal WWTP was about 60 times that of the lowest average concentration (35.5 ng/l).

Because of the limited data set, there was not enough information to discern any seasonal patterns. The Lodi White Slough WWTP had higher influent inorganic mercury concentrations in the fall and winter, the Roseville Pleasant Grove WWTP had higher concentrations in the summer, and two WWTPs (Roseville Dry Creek and Woodland WWTPs) had no discernable pattern (Figure 20).

Board staff compiled influent inorganic mercury data for the SRCSD Sacramento River WWTP collected from December 2000 – December 2004 that were available in a variety of monitoring reports and special study documents in the permit files (SRCSD, 2004; SRCSD, 2005). The influent inorganic mercury data for this four-year period had no interannual (Figure 21) or seasonal trends (Figure 22). The monthly averages for the SRCSD Sacramento River WWTP varied between 120 ng/l and 300 ng/l, with the exception for two months, January and March (Figure 22). These were observably higher than other months as a result of two anomalously high values. One of these two values was collected on 6 January 2004 (6,100 ng/l) and the other on 11 March 2004 (3,400 ng/l). Three other influent samples collected during the four-year period had inorganic mercury concentrations greater than 1,000 ng/l, one each in 2001, 2002 and 2004.

4.2.5 Ratio between Effluent Methylmercury and Influent Methylmercury

The ratios between paired effluent and influent methylmercury concentrations were calculated to determine the methylmercury removal efficiencies of the municipal WWTPs. A percent value less than 100% for a given municipal WWTP indicates that its treatment processes caused a net reduction in methylmercury; a percent value greater than 100% indicates that the plant was a net methylmercury source. Average ratios ranged from 1.1% at El Dorado Hills WWTP (Discharge 2) to 803% at Mariposa WWTP. Of the 23 WWTPs where both effluent and influent methylmercury data were collected, 14 had average effluent:influent methylmercury ratios less than or equal to 10%, and 11 of those had average ratios less than or equal to 5% (Figure 23). In contrast, five WWTPs had average ratios greater than 30%. Municipal WWTPs in the "Secondary + C/D" and "Pond + C/D" treatment categories had lower methylmercury removal efficiencies indicated by higher effluent:influent ratios than WWTPs in all other treatment categories (Figure 24; Table 29; $p<0.04$, Kruskal-Wallis test).

Three facilities (Colusa, Mariposa and SRCSD Walnut Grove WWTPs) had average ratios greater than 100%, indicating that these facilities were net producers of methylmercury. As seen in Figure 23, two of these average effluent:influent methylmercury ratios (254% for Colusa and 803% for Mariposa) were much higher than the average ratios of the remainder of the facilities. The closest value to these is from the SRCSD Walnut Grove WWTP, which had an average ratio of 101%. The Colusa and SRCSD Walnut Grove WWTPs are both in the "Pond + C/D" treatment category, while the Mariposa WWTP is in the "Secondary + C/D" category. These average ratios are based upon one or two paired influent and effluent samples collected at the WWTP. More data is needed to determine if these removal efficiencies are representative of these facilities.

Several facilities exhibited seasonal variability in methylmercury removal (Figures 25 and 26). Lower removal efficiencies indicated by higher ratios occurred during the

summer or fall for some facilities (Grass Valley, Rio Vista, Roseville Dry Creek, Roseville Pleasant Grove and SRCSD Sacramento River WWTPs), and during winter for others (Chico, Deer Creek and El Dorado Hills [Discharge 1] WWTPs). No relationship was apparent between seasonal variability and the type of treatment process.

The methylmercury removal efficiency for SRCSD Sacramento River WWTP's six-year record showed an increasing trend indicated by a decrease in its ratios (Figure 27). These ratios differed temporally, in that the WY2001-2004 period showed much more seasonal variability with higher ratios in the warm season (May – November) than did the ratios for the WY2005-2007 period (Figure 26; $p<0.001$ for both the Mann-Whitney U test and the two sample t-test). This trend between earlier and later time periods was similarly seen in the effluent methylmercury concentrations for SRCSD Sacramento River WWTP and may be the reason for the observed trend in the ratios (Figure 8).

As mentioned in sections 4.2.1 and 4.2.2, decreasing trends were observed both in influent and effluent methylmercury concentrations for the SRCSD Sacramento River WWTP between WY2001 and WY2007 (Figure 9). The decrease in effluent methylmercury concentrations could be partially due to the concurrent decrease in influent concentrations; however, the regression for effluent methylmercury has a steeper decreasing slope (-0.0001) than does the influent line (-0.00008) indicating an improved methylmercury removal efficiency since WY2001 (Figure 9). Furthermore, Figure 27 shows an increasing trend in methylmercury removal efficiency between WY2001 and WY2007.

Staff reviewed scatter plots of paired influent and effluent methylmercury concentrations to determine whether there was a relationship between the two. The paired samples may not represent the same parcels of water due to in-plant residence time. The scatter plot of all paired data from all WWTPs excluding SRCSD Sacramento River WWTP showed a significant positive relationship ($R^2 = 0.1347$, $p<0.0001$; Figure 28a). The scatter plot including data from SRCSD Sacramento River WWTP also showed a statistically significant positive relationship ($R^2 = 0.0715$, $p<0.0001$; Figure 28b). Staff analyzed scatter plots with and without data from SRCSD Sacramento River WWTP because the number of paired data points from the SRCSD Sacramento River WWTP (n=107) was relatively high compared to other WWTPs (n=1 to 16). These significant relationships indicate that reductions in methylmercury in the effluent were in part due to lower influent concentrations. However, only 7-13% of the variability in effluent methylmercury concentrations was explained by influent concentrations, indicating that effluent concentrations were substantially affected by other factors. Influent methylmercury concentrations alone were not a good predictor of effluent concentrations.

Of the 23 WWTPs that submitted both influent and effluent methylmercury concentration data, 10 WWTPs submitted paired data for five or more sampling events (Figures 29 and 30). When analyzed individually, none of these facilities had significant relationships between influent and effluent methylmercury concentrations except Lodi WWTP ($R^2 = 0.404$, $p<0.03$), UC Davis WWTP ($R^2 = 0.388$, $p<0.04$) and SRCSD Sacramento River WWTP ($R^2 = 0.174$, $p<0.0001$; see Table 30 for R^2 and p-values for each WWTP). All three facilities exhibited positive relationships; however, the significant positive relationship for Lodi WWTP appeared to be driven by one paired data point collected on 13 April 2005 (influent 2.74 ng/l, effluent 1.24 ng/l). When this point was removed, no significant relationship exists ($R^2 = 0.090$, $p>0.05$). Influent versus effluent methylmercury scatter plots for SRCSD Sacramento River WWTP indicated a significant positive relationship for the paired data collected during the cool season (December through April; $R^2 = 0.262$, $p<0.001$), but not during the warm season (May through November; $R^2 = 0.015$, $p>0.05$; Figure 30). Again, only about 26% of the variability in cool season effluent methylmercury concentrations was explained by influent concentrations, which indicates that effluent methylmercury concentrations were affected by other factors as well.

4.2.6 Ratio between Effluent Methylmercury and Effluent Inorganic Mercury

The ratios between paired effluent methylmercury and effluent inorganic mercury concentrations were calculated to estimate the percentage of inorganic mercury as methylmercury in the effluent and to see if differences exist between treatment types. Average ratios ranged from 0.60% at Discovery Bay WWTP to 28% at Nevada County Sanitation District #2 Lake of the Pines WWTP. Of the 28 WWTPs where both methylmercury and inorganic mercury were analyzed in the effluent, 24 had average effluent methylmercury:inorganic mercury ratios less than or equal to 10%, and 19 of those had average ratios less than or equal to 5% (Figure 31). Only four discharges had average ratios greater than 10%. The average effluent methylmercury:inorganic mercury ratio for SRCSD Sacramento River WWTP was 10%; the ratio appeared to increase slightly from WY2001 to WY2007 (Figure 32).

Municipal WWTPs in the "Pond + Filtration + C/D" maximum treatment category had higher effluent methylmercury:inorganic mercury ratios than WWTPs in all other treatment categories except for the "Pond + C/D" category (Figure 33; Table 31; $p<0.03$, Kruskal-Wallis test). In addition, the "Pond + C/D" and "Secondary + C/D" categories had higher ratios than the "Secondary w/ N/D + UV", "N/D + Filtration + C/D" and "Filtration + UV" categories ($p<0.01$, Kruskal-Wallis test).

Five municipal WWTPs appeared to have well-defined seasonal variability in their effluent methylmercury:inorganic mercury ratios (Figures 34 and 35). The following WWTPs appeared to experience an increase in their ratio in the spring and/or summer: Davis (Discharges 1 and 2), Manteca, Placer County SMD #1, SRCSD Sacramento

River, and Stockton. No discernable relationship between the seasonal variability of the ratios and the types of treatment processes were apparent.

Staff reviewed scatter plots to determine whether there was a relationship between effluent methylmercury and inorganic mercury concentrations. The scatter plot of all paired data from all WWTPs excluding SRCSD Sacramento River WWTP showed a significant positive relationship ($R^2 = 0.0431$, $p<0.01$; Figure 36a). The anomalous value collected at Woodland WWTP on 9 December 2004 (THg: 53.1 ng/l, MeHg: below detection limit of 0.025 ng/l) appeared to strongly influence the trend-line. The scatter plot after removing the anomalous paired data-point continued to indicate a statistically significant positive relationship ($R^2 = 0.0779$, $p<0.0001$). The scatter plots including data from SRCSD Sacramento River WWTP also showed significant positive relationships with ($R^2 = 0.0704$, $p<0.0001$) and without the Woodland WWTP outlier ($R^2 = 0.1155$, $p<0.0001$; Figure 36b). Only 4-12% of the variability in effluent methylmercury concentrations was explained by effluent total mercury concentrations for the different WWTPs, indicating that effluent concentrations were substantially affected by other factors.

Of the 28 WWTPs that submitted effluent methylmercury and inorganic mercury concentration data for a total of 29 discharges, 20 WWTPs submitted paired data for five or more sampling events (Figures 37 and 38). Some WWTPs appeared to have positive relationships between effluent methylmercury and inorganic mercury, however only four facilities (Discovery Bay, Stockton, SRCSD Sacramento River and Davis WWTPs) had a statistically significant relationship (Discovery Bay : $R^2 = 0.551$, $p<0.03$; Stockton: $R^2 = 0.67$, $p<0.01$; SRCSD: $R^2 = 0.0775$, $p<0.01$; Davis: $R^2 = 0.4445$, $p<0.02$; Table 32). Seasonal scatter plots for SRCSD Sacramento River WWTP did not indicate significant positive relationships for all of the paired data collected from WY2001 to WY2007 for both the warm (May through November; $R^2 = 0.061$, $p>0.05$) and cool (December through April; $R^2 = 0.071$, $p>0.05$) seasons (Figure 38).

4.2.7 Ratio between Effluent Methylmercury and Influent Inorganic Mercury

The ratios between paired effluent methylmercury and influent inorganic mercury concentrations were calculated to determine if a relationship existed between influent inorganic mercury and effluent methylmercury, and to explore how the ratios may relate to treatment processes. Ultimately, it would be very useful to know whether reducing influent inorganic mercury concentrations (e.g., by implementing mercury source minimization measures[5]) would result in reductions in effluent methylmercury, and if so, by how much.

[5] For example, residential drop-off programs for mercury-containing products and best management practices for hospitals, dentists, other medical facilities, laboratories, and pottery studios.

Average ratios ranged from 0.0005% at the Lincoln WWTP to 1.85% at the Davis WWTP (Discharge 1) (Figure 39). The average effluent methylmercury:influent inorganic mercury ratio for SRCSD Sacramento River WWTP was 0.45%; the ratio did not appear to change from December 2000 to December 2004 (Figure 40). Two of the five facilities with more than six paired samples (Lodi White Slough and SRCSD Sacramento River WWTPs) had an apparent seasonal pattern, with an increase in effluent methylmercury:influent inorganic mercury ratio in the summer (see Figures 41 and 42).

Staff reviewed scatter plots to determine whether there was any relationship between effluent methylmercury and influent inorganic mercury concentrations. The scatter plots of all paired data for all WWTPs with and without the SRCSD Sacramento River WWTP data showed no relationship (with SRCSD: $R^2 = 0.0026$, $p>0.05$, Figure 43a; without SRCSD: $R^2 = 0.0206$, $p>0.05$, Figure 43b). The relationship between effluent methylmercury and influent inorganic mercury loads may present a different conclusion, but was not assessed in this report.

Of the nine municipal WWTPs that submitted effluent methylmercury and influent inorganic mercury concentration data, five facilities submitted paired data for five or more sampling events. No relationships between effluent methylmercury and influent inorganic mercury were observed for any of these five facilities individually (Figures 44 and 45a; Table 33). Scatter plots for SRCSD Sacramento River WWTP showed no relationship for data collected from December 2000 to December 2004 (all data: $R^2 = 0.0017$, $p>0.05$; warm season: $R^2 = 0.0311$, $p>0.05$; cool season: $R^2 = 0.0182$, $p>0.05$; Figure 45a). After removing the paired data that included the anomalously high value collected on 6 January 2004 (6,100 ng/l) at the SRCSD Sacramento River WWTP, the scatter plots still indicated no significant relationships (all data: $R^2 = 0.0045$, $p>0.05$; warm season: $R^2 = 0.0311$, $p>0.05$; cool season: $R^2 = 0.0044$, $p>0.05$; Figure 45b).

The SRCSD District Engineer presented a chart of annual influent inorganic mercury and effluent methylmercury loads for 2001 through 2007 during testimony for the April 2008 hearing for the Delta mercury control program (see Figure 46). The SRCSD District Engineer indicated that the WWTP's effluent inorganic mercury and methylmercury decreased as a result of influent inorganic mercury decreases associated with the initiation of their "Be Mercury Free" source control program. This additional influent inorganic mercury data from 2005 to 2007 was not available at the time this report was written.

4.2.8 Ratio between Effluent Inorganic Mercury and Influent Inorganic Mercury

The ratios between paired effluent and influent inorganic mercury concentrations were calculated to determine by how much the municipal WWTPs reduced inorganic mercury- the lower the ratio, the higher the removal efficiency. Average ratios ranged

from 0.6% at the Woodland WWTP to 27% at the Merced WWTP (Figure 47). Of the eight WWTPs that submitted paired influent and effluent inorganic mercury data, five of the facilities had average effluent:influent inorganic mercury ratios less than or equal to 5%, and two had average ratios greater than 15%. No discernable relationship between removal efficiency and the types of treatment processes were observed.

Two of the five facilities with six or more paired samples had an apparent seasonal pattern (Figures 48 and 49). The Lodi White Slough WWTP appeared to have a lower inorganic mercury removal efficiency during the summer, while the Roseville Dry Creek appeared to have a lower removal efficiency during the winter-spring. The ratios for the SRCSD Sacramento River WWTP showed no seasonal patterns (Figure 49).

Scatter plots of all paired data for all WWTPs with and without the SRCSD Sacramento River WWTP data showed no relationships between effluent and influent inorganic mercury concentrations (with SRCSD: $R^2 = 0.0004$, $p>0.05$; without SRCSD: $R^2 = 0.0029$, $p>0.05$; Figure 50). No relationships were indicated by individual WWTP scatter plots as well, though some facilities were more effective at removing inorganic mercury (Figure 51 and Table 34). Scatter plots for SRCSD Sacramento River WWTP showed no significant relationships for the paired data collected from December 2000 to December 2004 (all data: $R^2 = 0.0004$, $p>0.05$; warm season: $R^2 = 0.0038$, $p>0.05$; cool season: $R^2 = 0.0045$, $p>0.05$; Figure 52); however, the scatter plots indicate that as influent concentrations increased, effluent concentrations did not increase.

The average effluent:influent inorganic mercury ratio for SRCSD Sacramento River WWTP was 5.1%; the ratio did not appear to change from December 2000 to December 2004 (Figure 53). The inorganic mercury removal efficiency during this period was consistently high with an average of about 95%, indicating that the SRCSD Sacramento River WWTP was effective in removing most of the inorganic mercury from the waste stream. As mentioned in Section 4.2.3, there was an observed decreasing trend in effluent inorganic mercury from WY2001-2007, particularly from 2005 to 2007. However, as indicated earlier, Board staff does not have influent inorganic mercury data after 2004 and was unable to compare effluent and influent concentrations during this later period.

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5 ESTIMATION OF METHYLMERCURY LOADS FROM CENTRAL VALLEY DISCHARGERS

In response to comments from the Sacramento Regional County Sanitation District on the May 2009 draft report, an additional chapter was added to this report to assess the relative contribution of methylmercury loading to the Delta from NPDES facilities in and upstream of the Delta. This chapter describes the methods used to calculate methylmercury and total mercury loads discharged by the different types of NPDES facilities and provides a brief review of loads by facility type and watershed.

All of the mass load calculations are based on the following equation:

$M_x = C_x * V$

Where: M_x = Mass of constituent, X

C_x = Concentration of constituent, X, in mass per volume

V = Volume of effluent

For example, the annual methylmercury load discharged for the Stockton WWTP was calculated as follows:

$M_x = (0.935 \text{ ng/l} \div 10^9) * (28 \text{ mgd} * 365 * 10^6 * 3.7854118) =$ **36 g/year**

Where: M_x = Mass of methylmercury (grams per year)

C_x = Concentration of methylmercury (ng/l) converted to grams per liter

V = Volume of effluent (million gallons per day) converted to liters per year

Not all facilities in the Central Valley were required to collect methylmercury and/or total mercury by the 2004 13267 Order or by their existing permit requirements. In addition, some facilities only recently began to discharge to surface water; some of these have collected effluent methylmercury and total mercury data and others have not. Table B.5 in Appendix B includes the effluent concentration and volume values used to estimate the loads discharged by each facility. For facilities that have not yet collected effluent total mercury or methylmercury concentration data, staff used the average of concentration data available for similar facilities to calculate the loads and noted where this was done in Table B.5.

Some facilities have ceased to discharge to surface water since effluent methylmercury and total mercury concentration data were collected. Data for such facilities, as well as data for facilities upstream of major dams, were included in the calculation of average methylmercury and total mercury concentrations by facility type used to estimate effluent loads for facilities with no effluent concentration data. Table B.5 does not

include all facilities located upstream of major dams because few of these were required to collect methylmercury data by the 2004 13267 Order. Also, Table B.5 includes several facilities for which total mercury data were available but methylmercury data were not, especially in the tributary watersheds upstream of major dams.

Tables 35 and 36 provide the sums of the annual total mercury loads and methylmercury loads, respectively, discharged by NPDES facilities within each discharger category in the Delta/Yolo Bypass and its tributary watersheds downstream of major dams. Table 37 compares the sum of annual methylmercury loads discharged by NPDES facilities to the sum of all point and nonpoint source methylmercury loading to each Delta subarea identified in the February 2010 Delta TMDL Staff Report (Wood *et al.*, 2010b, Table 8.4). As noted earlier, power, heating/cooling, and aquaculture facilities that use ambient water for cooling water do not appear to act as a net source of methylmercury to receiving waters and therefore are not included. GWF Power Systems is included because it acquires its intake water from sources other than ambient surface water. Only facilities that were discharging during the TMDL methylmercury load evaluation period (WY2000-2003) and/or the total mercury load evaluation period (WY1984-2003) were included in Tables 35, 36 and 37.

Effluent total mercury concentration data were not available for any of the facilities within the food, laboratories, and port terminal categories, and consequently these categories are not included in the load summaries described in Table 35. Because these facilities account for only about a quarter of a percent of the discharge volume from NPDES facilities in the Delta source region, they likely do not affect our understanding of relative contributions from different point and nonpoint sources.

As shown in Tables 35 and 36, about 96% (3,435 g/yr) of the total mercury loading from all NPDES facilities (3,586 g/yr) and more than 99% (228 g/yr) of the methylmercury loading from all NPDES facilities (229 g/yr) comes from municipal WWTPs. About 67% of the total mercury loading from all NPDES facilities and about 89% of the methylmercury loading from all NPDES facilities comes from facilities within the Delta/Yolo Bypass. A comparison of Table 36 to Table B.5 in Appendix B indicates that nearly 90% of the methylmercury loading from the 61 municipal WWTPs that discharge to the Delta and its tributary watersheds downstream of major dams comes from two WWTPs, the SRCSD Sacramento River WWTP (161 g/yr, 71%) and Stockton WWTP (36 g/yr, 16%). This is not surprising given the most populous urban areas in the Sacramento and San Joaquin Basins (the Delta's primary source region) – Sacramento in Sacramento County and Stockton in San Joaquin County – are adjacent to and within the Delta (CDOF, 2007; Wood *et al*., 2010b, Figure 6.9).

The Delta methylmercury TMDL divides the Delta into eight subareas based on the hydrologic characteristics and mixing of the source waters (Wood *et al.*, 2010b). A separate methylmercury reduction strategy was developed for each subarea because

the levels of impairment and the methylmercury sources in the subareas are substantially different (Wood *et al.*, 2010a and 2010b). Table 37 compares the methylmercury loads discharged by NPDES facilities within the Delta and its tributary watersheds downstream of major dams to the total methylmercury loading to each subarea from point and nonpoint sources within the Delta and its tributary inputs.

Overall, NPDES facilities account for about 4% of the methylmercury load to the Delta; NPDES facilities within the Delta contribute about 205 grams per year (g/year) while facilities in upstream watersheds that are downstream of major dams contribute about 24 g/year. The Delta TMDL divides the Delta into hydrologically-defined subwatershed areas; different sources supply the different areas. For example, NPDES facilities within the San Joaquin River and Sacramento River subareas contribute about 7-9% of all methylmercury loading to those subareas, while NPDES facilities within the Central Delta, West Delta, and Yolo Bypass subareas contribute less than 0.2% of all methylmercury loading to these subareas. For some receiving waters (e.g., in the Sacramento and San Joaquin subareas), reducing municipal WWTP methylmercury discharges, along with reductions from other point and nonpoint sources, may be an important component in reducing methylmercury levels in ambient water. For example, the Sacramento River is the largest river in California and drains a 27,000 square-mile area – almost one fifth of the State of California and about one half of the Central Valley – that contains numerous reservoirs and a myriad of point and nonpoint sources downstream of the reservoirs. As noted as early as 1997 in the Sacramento River Mercury Control Planning Project report prepared for SRCSD by Larry Walker Associates, "… mercury sources in the study area appear to be diffusely distributed without any significant "hotspots" …" (LWA, 1997, page 31). As a result, any individual discharge from a point or nonpoint source that provides a notable percentage (e.g., more than 1%) of methylmercury loading to the Sacramento River warrants evaluation.

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6 DISCUSSION & NEXT STEPS

The non-municipal NPDES facilities in the Delta source region typically had low effluent methylmercury concentrations (Table 17). Aquaculture and power generation facilities appeared to be neither significant sources nor sinks of methylmercury. More data is necessary to determine if the other facilities in these two categories and heating/cooling facilities are net methylmercury sources or sinks. The aggregate, paper/saw mills, groundwater remediation, drinking water treatment, and other non-municipal facilities were sources of methylmercury but typically had very low effluent methylmercury concentrations (average of 0.05 ng/L; see Table 17). Of the 198 effluent methylmercury samples submitted by non-municipal facilities, 134 were less than or equal to 0.05 ng/l, and 80 of those were below the method detection limit (typically less than 0.025 ng/l). The highest effluent methylmercury concentration observed in the non-municipal facilities was 1.91 ng/l from a stormwater detention pond at the SPI Shasta Lake Mill; all other sample results from the mill and other non-municipal facilities were less than 0.2 ng/l.

Municipal WWTPs contribute the most discharge (by volume and methylmercury load) to the Delta source region of any one facility category and had average effluent methylmercury concentrations that ranged from non-detect (<0.02 ng/l) to 2.9 ng/l, about a 150-fold difference. Twenty of the 61 Central Valley municipal WWTPs that submitted effluent data had average effluent concentrations less than 0.05 ng/l, and 13 WWTPs had averages less than 0.03 ng/l. In contrast, 18 WWTPs had average effluent methylmercury concentrations greater than 0.2 ng/l, and seven had averages greater than 1 ng/l.

To begin the process of evaluating whether and how methylmercury discharges from municipal WWTPs may be reduced, Board staff conducted a literature review. In addition, staff evaluated treatment process information for Central Valley municipal WWTPs and available methylmercury and inorganic mercury concentration data for influent and effluent. The reviews indicate several trends that merit additional investigation:

- Central Valley WWTPs that use treatment pond systems (oxidation, facilitative, settling or stabilization ponds) as a significant part of their treatment process had the highest effluent methylmercury concentrations. The “Pond + C/D” and “Pond + Filtration + C/D” treatment categories had significantly higher effluent methylmercury values than all other treatment categories, with one exception. The “Pond + Filtration + C/D” category did not have significantly higher effluent methylmercury concentrations than the “Secondary + C/D” category. Similarly in Canada, the West End WWTP, which was the only facility of the three City of Winnipeg treatment plants that has treatment ponds in its treatment process, also had higher effluent methylmercury concentrations than the other two City of Winnipeg treatment plants.

- Municipal WWTPs in the “Secondary + C/D” and “Pond + C/D” treatment categories had lower methylmercury removal efficiencies indicated by significantly higher effluent:influent ratios than WWTPs in all other treatment categories.
- Mercury-contaminated trickling filters at the Fritz Island WWTP in Pennsylvania acted as a substantial source of both inorganic mercury and methylmercury to the plant’s effluent. The average effluent methylmercury concentration at the Fritz Island WWTP was approximately 4 ng/l. Likewise in Central Valley WWTPs, within the “Secondary + C/D” and “Tertiary + C/D” treatment categories, the “Fixed Media” subcategory, which includes trickling filters, had average effluent methylmercury concentrations of 0.22 ng/l and 0.12 ng/l, respectively. Within the “Filtration + C/D” category, the “Fixed Media” subcategory had significantly higher effluent methylmercury concentrations than the “Activated Sludge” subcategory.
- Central Valley WWTPs that have some combination of nitrification/denitrification (N/D), filtration, and ultraviolet (UV) disinfection generally had lower effluent methylmercury concentrations. The “N/D + Filtration + C/D”, “Secondary w/ N/D + UV”, “N/D + Filtration + UV”, “Filtration + UV”, “Secondary w N/D + C/D” and “Filtration + C/D” treatment categories all had significantly lower effluent methylmercury concentrations than the “Secondary + C/D”, “Pond + C/D” and “Pond + Filtration +C/D” categories. In addition, the “N/D + Filtration + C/D” category had significantly lower effluent methylmercury concentrations than the “Secondary w/ N/D + C/D” and “Filtration + C/D” categories, suggesting that both the filtration and nitrification/denitrification treatment processes may have played a role in the decrease in the methylmercury concentrations of these facilities.
- Each secondary treatment subcategory within the “Filtration + C/D” category had significantly lower average and median effluent methylmercury concentrations than the same subcategory within the “Secondary + C/D” category, which suggests that the filtration treatment process may have assisted in the reduction of methylmercury in the effluent of these facilities.
- Several published studies investigated methylmercury at WWTPs that use conventional activated sludge treatment. The effluent methylmercury concentrations were variable with averages of 0.04 ng/l at the San Jose/Santa Clara WWTP, 0.2 ng/l to greater than 2 ng/l at the West End WWTP in Canada, and 1.53 ng/l at the Onondaga County Metropolitan WWTP in New York. Treatment ponds are used at the West End WWTP in Winnipeg, which could explain the elevated effluent methylmercury. The Onondaga County WWTP had an average influent methylmercury concentration of 5.05 ng/l and a removal efficiency of 70%. The methylmercury removal efficiency of the SJ/SC WWTP was 97%. The higher methylmercury removal efficiency of the SJ/SC WWTP could have been due to differences in other treatment processes. Nitrification and denitrification are incorporated in the activated sludge process of the SJ/SC WWTP and tertiary filtration is used as well, while neither is used in the Onondaga County WWTP.
- The SRCSD Sacramento River WWTP and SJ/SC WWTP had similar average influent methylmercury concentrations (1.55 ng/l and 1.6 ng/l, respectively).

However, the SJ/SC WWTP secondary treatment resulted in a much lower average secondary effluent methylmercury concentration (0.05 ng/l) than the SRCSD WWTP (0.38 ng/l). The secondary treatment process of the SRCSD Sacramento River facility is pure oxygen activated sludge without nitrification and denitrification. The differences in methylmercury removal efficiency between the two WWTPs may be either due to the pure oxygen activated sludge, nitrification/denitrification or both.

- The San Jose/Santa Clara WWTP study observed a methylmercury removal efficiency of 40% between the tertiary filter influent (0.05 ng/l) and final effluent (0.03 ng/l). Given the low concentrations, this is a small reduction when compared to the methylmercury removal efficiency of 96% between the secondary influent (1.3 ng/l) and secondary effluent (0.05 ng/l) (see Table 2). This suggests that most of the methylmercury removal occurred during the secondary treatment process.
- Significant relationships between influent and effluent methylmercury concentrations existed for all the paired data from the Central Valley WWTPs. This indicates that reductions in methylmercury in the effluent were in part due to lower influent concentrations. However, 7-13% of the variability in effluent methylmercury concentrations was explained by influent concentrations, indicating that effluent concentrations were affected by other factors as well.
- Seasonal variability was observed in effluent methylmercury concentrations at several Central Valley WWTPs, as well as WWTPs evaluated elsewhere. The City of Winnipeg's West End Plant, which utilizes conventional activated sludge and treatment ponds, had a seasonal trend in its effluent methylmercury concentrations, while its two other plants, which use pure oxygen activated sludge and no treatment ponds, did not have a seasonal trend. At the West End Plant, methylmercury concentrations increased as ambient temperatures increased, with the highest concentration occurring in August. The Onondaga County Metropolitan WWTP, which uses conventional activated sludge, demonstrated that warm temperatures were a catalyst for the methylation process to occur, apparently in both the environment as well as through the treatment process. For the several Central Valley WWTPs where seasonal variability was observed, the effluent methylmercury concentrations were higher in the warm season (e.g., May through November), and lower in the cool season. No obvious relationship between seasonality and the treatment processes of the Central Valley WWTPs seemed to exist.
- Methylmercury production occurred during the secondary activated sludge treatment process at the Onondaga County WWTP. McAlear (1996) hypothesized that mercury methylation occurred in anoxic micro-zones within the activated sludge flocs. A correlation between high concentrations of biological solids and mercury methylation during the activated sludge process was discovered at the Whitlingham Sewage Treatment Works (Goldstone *et al.*, 1990).
- The SRCSD study demonstrated that the removal of solids may have been a removal mechanism for methylmercury; however, inorganic mercury had a greater particle affinity than methylmercury and was removed more efficiently by solids

removal (Parmer *et al.*, 2005). In the Whitlingham Sewage Treatment Works study, the centrifugation and filtration of return activated sludge samples indicated that methylmercury had a greater affinity for the particulate phase of the return activated sludge than for the soluble phase. From the literature reviewed, it appears that the inorganic mercury and methylmercury removed from wastewater is partially due to the removal of solids, with the mechanism being more efficient for inorganic mercury. Board staff did not evaluate this relationship further for the Central Valley WWTPs because of their limited data set; however, this merits additional investigation.

- SRCSD WWTP's influent methylmercury concentrations and effluent inorganic mercury and methylmercury concentrations and loads decreased between 2001 and 2007. This decrease was attributed to a decrease in influent inorganic mercury associated with the initiation of SRCSD's "Be Mercury Free" source control program. No similar pattern was noted between influent inorganic mercury and effluent methylmercury at any other WWTP in the Central Valley.

Municipal WWTPs have multiple treatment processes and the factors affecting methylmercury production and degradation are complex. As a result, the differences in effluent methylmercury concentrations among the Central Valley WWTPs are most likely due to multiple factors and different combinations of treatment processes. Furthermore, a few of the treatment categories evaluated contained only one or two WWTPs, resulting in a limited data set for those categories. Therefore, the data of some of the treatment categories may not be representative of other WWTPs that utilize the same treatment processes. Also, of the 61 WWTPs that submitted effluent methylmercury data, only 23 submitted influent methylmercury data, and only nine submitted influent inorganic mercury data. Therefore, comparisons among WWTPs and treatment categories were done without correcting for influent inorganic mercury and methylmercury concentrations. In addition, influent inorganic mercury and methylmercury concentrations often had substantial day-to-day variability. As a result, comparisons between influent and effluent samples collected on the same day may not be appropriate, depending on the residence time of the wastewater in a particular plant.

The Central Valley Clean Water Association (CVCWA) has conducted a preliminary evaluation of effluent methylmercury data for a subset of WWTPs evaluated in this report. CVCWA's preliminary evaluation similarly found that WWTPs that incorporate any significant effluent storage (e.g., ponds) have higher methylmercury concentrations, and WWTPs with activated sludge treatment processes that result in a fully-denitrified, low ammonia effluent also have lower effluent methylmercury concentrations (Pirondini, 2008b). After completing the QA/QC review of the available effluent and influent methylmercury concentration data (see Chapter 3), Board staff forwarded the completed database to CVCWA so that they could continue a more detailed evaluation.

Additional analyses are needed to continue the evaluation of potential relationships between WWTP treatment processes, mercury minimization measures for mercury

sources to WWTP influent, and effluent methylmercury levels. Board staff and WWTP staff and consultants have informally discussed several ideas for future analyses and key questions to be addressed by those analyses. Some analyses would not require additional influent and effluent sampling, for example:

- Conduct more detailed, focused analyses of the data presented in this report.
- Gather more information about the influent and effluent samples described in this report, for example (but not limited to): specific sampling locations, depths, and time of day; influent inorganic mercury concentrations; pH, alkalinity, dissolved oxygen, temperature, and nitrate, sulfate and ammonia concentrations; and specific treatment processes in place at the time of sample collection.
- Do other factors impact reported concentrations, such as sampling protocols including location, time of day, holding time and composite vs. grab samples?

In addition, the data set presented in this report needs to be updated, with special attention given to facilities that have recently completed treatment process upgrades. For example, the City of Stockton WWTP was upgraded to meet new ammonia effluent limits and Title 22 (or equivalent) tertiary requirements since the data presented in this report were collected. The average effluent methylmercury and total mercury concentrations for January-July 2009 are about 91% and 83% lower than the annual average methylmercury and total mercury concentrations, respectively, observed in 2004/2005. It is not known if the treatment plant upgrades are responsible for the total mercury and methylmercury reductions, or if the reductions are a result of other operational or physical changes. Additional sampling may be needed to determine the cause of the decrease. In addition, methylmercury results for only seven monthly effluent samples have been submitted since the upgrades were completed. As more data are collected, Board staff will work with City of Stockton staff to evaluate whether the above trends are representative of current conditions.

Also, at the time this report was receiving final review, reports for Phases 1 and 2 of the WERF-funded project, "Estimation of Mercury Bioaccumulation Potential from Wastewater Treatment Plants in Receiving Waters", were released (Dean and Mason, 2009a and 2009b). This project assessed changes in mercury bioavailability in wastewater effluents and receiving waters and developed a guidance document for wastewater treatment professionals who want to assess the bioavailability of mercury in their wastewater, compare it to other point and nonpoint sources, and assess changes in bioavailability in their effluent when it is mixed in a receiving water body. The Phase 1 and 2 reports should be considered by future wastewater analyses and control studies, as well as when the Delta mercury TMDL control program goes through future reviews during its implementation.

After additional analyses of existing data are completed, it may be useful to conduct targeted monitoring and pilot scale studies where actual sewage flow may be used to evaluate specific treatment processes and variations.

Possible questions that could be addressed by future analyses include, but are not limited to, the following:

- Do relationships exist between nitrate, ammonia, sulfate, sulfite and TSS concentrations and methylmercury concentrations throughout the treatment process? If so, could treatment processes designed to reduce effluent ammonia also reduce effluent methylmercury?
- Are tertiary treatment processes effective in significantly reducing methylmercury concentrations within a WWTP? What are the affects of filtration and UV treatment on effluent methylmercury?
- Why do some WWTPs have seasonality in their effluent methylmercury concentrations and others do not? What are the causes behind the seasonality observed in methylmercury concentrations?
- Do influent and effluent methylmercury concentrations have any diurnal variability, and if so, what are the causes?
- Is it feasible to modify the biological secondary processes at some plants to increase methylmercury degradation? If so, can "real-time" indicators (e.g., pH or alkalinity) be developed so that plant operators can make immediate adjustments (versus having to wait several weeks for methylmercury analyses)?
- Do WWTPs that use pond systems or other treatments act as greater sources of inorganic mercury and/or methylmercury than WWTPs that utilize other treatment systems?
- How much are effluent inorganic mercury and methylmercury concentrations reduced by reducing influent inorganic mercury concentrations and/or loads (e.g., by implementing inorganic mercury source minimization measures)?

Several Central Valley WWTP staff and consultants have noted that it would be very helpful to establish a working group that coordinates efforts between CVCWA, San Francisco Bay area facilities, and other regional efforts to develop more detailed analyses of the existing information, further evaluate treatment processes, and design additional monitoring studies and pilot projects. Board staff is supportive of this concept and will work with dischargers and working groups to design and review studies.

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TABLES

Table 1: Summary of Literature Review

Facility	Citation	Secondary Treatment	Tertiary Treatment (if any)	Influent MeHg (ng/l)	Influent MeHg: TotHg Ratio [(a)]	Post-Secondary Treatment MeHg (ng/l)	Post-Secondary Treatment MeHg:TotHg Ratio [(a)]	Final Effluent MeHg (ng/l)	Final Effluent MeHg: TotHg Ratio [(a)]	Comments
San Jose / Santa Clara Water Pollution Control Plant	SJ/SC, 2007	Activated sludge with nitrification/ denitrification	Filtration	1.57	0.94%	0.05	0.87%	0.04	2.0%	
Sacramento Regional Wastewater Treatment Plant	Parmer and others, 2005	Pure oxygen activated sludge		1.55	0.80%	0.38	7.7%	0.55	12%	180 MGD activated sludge plant. Slight rise in final effluent MeHg.
City of Winnipeg: North End, West End & South End Water Pollution Control Centres	Bodaly and others, 1998	North and South End: Pure oxygen activated sludge West End: Conventional diffused air activated sludge	West End only: Treatment lagoons	Average of all three plants: 2.2 (range: 0.5 - >4)		Not reported		North and South End: 0.13 - 0.56 West End: 0.2 - >2		Pure oxygen aeration exhibited greater removal efficiency of MeHg in effluent.
Pilot-scale activated sludge plant	Pavlogeor-gatos and others, 2006	Activated sludge		<70 (MDL: 0.07 µg/l)				<70 (MDL: 0.07 µg/l)		Pilot scale activated sludge study using synthetic wastewater containing glucose and ammonia. Spiked Hg concentrations of 10, 100, and 500 µg/l added directly to aeration tanks. No RAS; secondary sludge returned to aeration tanks.
Onondaga County Metropolitan Wastewater Treatment Plant	McAlear, 1996	Activated sludge	Phosphorous removal (addition of $FeSO_4$)	5.05	1.84%	2.76	21%	1.53	8.3%	
Fritz Island Wastewater Treatment Plant	Gilmore and Bloom, 1995	Trickling filters		3.0	1.92%	9.1	3.2%	4.0	3.7%	

Table 1: Summary of Literature Review

Facility	Citation	Secondary Treatment	Tertiary Treatment (if any)	Influent MeHg (ng/l)	Influent MeHg: TotHg Ratio [(a)]	Post-Secondary Treatment MeHg (ng/l)	Post-Secondary Treatment MeHg:TotHg Ratio [(a)]	Final Effluent MeHg (ng/l)	Final Effluent MeHg: TotHg Ratio [(a)]	Comments
Whitlingham Sewage Treatment Works	Goldstone and others, 1990	Activated sludge		11		120		< 10		

[(a)] Staff calculated the MeHg:TotHg ratios for the SJ/SC WWTP and Fritz Island WWTP studies using the average inorganic mercury and methylmercury data provided in their respective reports. The ratios for the SRCSD WWTP and Onondaga County WWTP studies were obtained from the reports.

Table 2: Total Mercury and Methylmercury Concentrations at the San Jose/Santa Clara WWTP

Sample Location	Average TotHg Conc. (ng/l)	Average Dissolved TotHg Conc. (ng/l)	Average MeHg Conc. (ng/l)	MeHg:TotHg Ratio [c]
Raw Sewage	168	2.9	1.6	0.9%
Primary Effluent	92	4.0	1.5	1.6%
Secondary Influent [a]	79	3.6	1.3	1.6%
Secondary Effluent [b]	5.2	1.1	0.05	0.87%
Filter Influent	5.1	1.2	0.05	0.98%
Tertiary Filter Effluent	1.6	1.2	0.03	1.9%
Filter Backwash	1.9	2.1	0.11	5.8%
Final Effluent	2.0	1.4	0.04	2.0%

[a] The SJ/SC WWTP study refers to the secondary influent as "Settled Sewage Influent to Secondary Units".
[b] The secondary treatment process consists of two pathways that are identical in function (biological nutrient removal) and receive the same influent. These numbers are averages of the effluent concentrations of the two pathways.
[c] Staff calculated the MeHg:TotHg ratio from the inorganic mercury and methylmercury data provided in the report.

Table 3: Phase 1A and 1B Total Mercury Concentrations, Mass Loads and Particulate Concentrations at the SRCSD Sacramento WWTP

Location [a]	Average TotHg Conc. (ng/l)	TotHg Mass Load (g/day)	TotHg Particulate Concentration (ng/g) [b]
Influent	192.33	131	1100
Primary Effluent	50.91	35	490
Mixed Liquor	693.33	660	408
Secondary Effluent	4.92	3.3	300
Dechlorinated Final Effluent	4.64	3	305
Waste Activated Sludge	1800	35.13	
Digested Sludge	12,333	60.36	800
Green SSB	170		350
Black SSB	430		770
Harvest SSB	990		1700
BRF Influent	13,166.67	23.92	800
SSB Return Flow	253.33	4.24	740
BRF Return Flow	150.67	0.47	580

[a] SSB: Solids Storage Basins BRF: Biosolids Recycling Facility
[b] Inorganic mercury particulate concentrations obtained from Table 9 in the SRCSD report.

Table 4: Phase 1A and 1B Methylmercury Concentrations, Mass Loads and Particulate Concentrations at SRCSD

Location [a]	Average MeHg Conc. (ng/l)	MeHg Mass Load (g/day)	MeHg Particulate Conc. (ng/g) [b]	MeHg:TotHg Ratio
Influent	1.55	1.06	4.93	0.80%
Primary Effluent	1.34	0.91	7.3	2.6%
Mixed Liquor	11.77	11.2	6.5	
Secondary Effluent	0.38	0.26	20.4	7.7%
Dechlorinated Final Effluent	0.55	0.36	33	12%
Waste Activated Sludge	30.72	0.5988	6.2	
Digested Sludge	245.88	1.176	13.01	
Green SSB	4.66		9.5	
Black SSB	18.35		32.4	
Harvest SSB	13.05		22	
BRF Influent	208.2	0.3585	13.5	
SSB Return Flow	7.39	0.1207	19	2.9%
BRF Return Flow	7.21	0.0215	24.2	5.5%

[a] SSB: Solids Storage Basins BRF: Biosolids Recycling Facility
[b] Methylmercury particulate concentrations obtained from Table 9 in the SRCSD report.

Table 5: Average Total Mercury, Methylmercury and TSS concentrations at the Onondaga County WWTP for the Entire Sampling Period (October 1995 to September 1996)

Location	Average TotHg Conc. (ng/l)	Average MeHg Conc. (ng/l)	MeHg:TotHg Ratio	Average TSS Conc. (mg/l)
Plant Influent	308	5.05	1.8%	206
Primary Effluent	112	1.92	2.2%	88.5
Secondary Effluent	24.0	2.76	21%	26.2
“Tertiary” Effluent	32.9	2.63	14%	9.48
Final Effluent	36.8	1.53	8.3%	11.7

Table 6: Seasonal Average Methylmercury Concentrations at the Onondaga County WWTP [a]

Location	Average Cold Weather (November to April) MeHg Conc. (ng/l)	Average Warm Weather (May to October) MeHg Conc. (ng/l)
Plant Influent	2.34	7.76
Primary Effluent	2.03	1.77
Secondary Effluent	1.94	3.49
"Tertiary" Effluent	2.40	2.87
Final Effluent	1.43	1.63

[a] Staff calculated the primary, secondary and "tertiary" effluent average concentrations for both the warm and cold weather periods from raw data provided in the Appendix of the report.

Table 7: Total Mercury and Methylmercury Concentrations in the Fritz Island WWTP Inputs and Outputs

Location	Total Mercury			Methylmercury		
	# of Samples [a]	Conc. Range (ng/l)	Average Conc. (ng/l)	# of Samples [a]	Conc. Range (ng/l)	Average Conc. (ng/l)
Plant Influent	3	185 - 556	358	3	1.36 - 2.45	1.91
Plant Effluent	3	108 - 448	228	3	4.03 - 5.69	4.74
Plant Sludge	3	3.96 - 4.09 [b]	4.02 [b]	3	1.6 - 5.2 [b]	3.23 [b]

[a] Each sample was a triplicate sample.
[b] The unit of measure for the wet weight sediment concentrations is μg/g.

Table 8: Total Mercury and Methylmercury Loads in the Inputs and Outputs of the Fritz Island WWTP

Site	TotHg Load (g/day)	Percent of TotHg Output Load from WWTP [a]	MeHg Load (g/day)	Percent of MeHg Output Load from WWTP [a]
Plant Influent	19.3		0.104	
Effluent	12.8	8%	0.269	68%
Sludge	144	92%	0.125	32%
Output Load from WWTP (Effluent + Sludge)	157	100%	0.394	100%
Net Output Load generated inside the WWTP (Output - Influent)	138	88%	0.29	74%

[a] The output load from the WWTP is equal to the sum of the effluent and sludge loads.

Table 9: Total Mercury and Methylmercury Concentrations in the Influent and Effluent of Various Components of the Fritz Island WWTP Treatment Processes

Site	TotHg Conc. (ng/l)	MeHg Conc. (ng/l)	MeHg:TotHg Ratio [(a)]
Plant Influent	**156**	**3**	**1.9%**
1st Stage Trickling Filters			
Input	229	7.8	3.4%
Output TF# 1	5660	31.9	0.56%
Output TF# 3	1540	24	1.6%
Intermediate Settling			
Input	2670	29.4	1.1%
Output	215	13	6.1%
Sludge	114,000 mg/kg	71 mg/kg	0.06%
2nd Stage Trickling Filters			
Input	215	13	6.1%
Output TF# 4	629	33.9	5.4%
Output TF# 5	291	10.8	3.7%
Output TF# 6	394	13.1	3.3%
Post 2nd Stage Settling			
Input	288	9.1	3.2%
Output	167	11.1	6.7%
Sludge	39,600 mg/kg	287 mg/kg	0.72%
Aeration			
Input	167	11.1	6.7%
Output	148	4.7	3.2%
Final Settling			
Input	148	4.7	3.2%
Output	76	6.9	9.1%
Sludge	124,000 mg/kg	205 mg/kg	0.17%
Final Effluent	**108**	**4**	**3.7%**

[(a)] Staff calculated the MeHg:TotHg ratio from the inorganic mercury and methylmercury data provided in the report.

Table 10: Summary of Total and Methylmercury Concentrations in Samples Collected in October 1987 at the Whitlingham Sewage Treatment Works

Location	Average TotHg Conc. (ng/l)	Average MeHg Conc. [(a)] (ng/l)	MeHg Conc. Range (ng/l)	Number of MeHg Samples	Number of MeHg Results below the MDL [(a)]
Raw Sewage	200	11	< MDL - 83	11	9
Settled Sewage	100	<10	all < MDL	11	11
Picket Fence Thickener Overflow	300	23	16 - 36	5	0
Returned Activated Sludge	5900	120	68 - 200	4	0
Final Effluent	100	<10	< MDL - 20	13	7

[(a)] The method detection limit was 10 ng/l. The average concentrations were calculated by the study authors assuming that values below the detection limit were zero.

Table 11: Methylmercury Data Excluded from Calculations in this Report

NPDES #	Facility	Sample Date	Sample Location	MeHg Conc (ng/l)
CA0083861	Aerojet Interim GW WTP	11/18/05	EFF1	ND (<0.025)
CA0083861	Aerojet Interim GW WTP	11/18/05	EFF2	ND (<0.025)
CA0083861	Aerojet Interim GW WTP	11/18/05	EFF3	ND (<0.025)
CA0083861	Aerojet Interim GW WTP	11/18/05	EFF4	ND (<0.025)
CA0004111	Aerojet Sacramento Facility	3/18/05	EFF1	0.057
CA0004995	Corning Industries/ Domestic WWTP	9/22/04	EFF1	0.041
CA0078093	Deuel Vocational Institute WWTP	10/26/04	EFF1	ND (<0.02)
CA0078875	DGS Office of State Publishing	7/8/05	EFF1	ND (<0.02)
CA0078671	El Dorado Hills WWTP	8/9/05	EFF1	0.057
CA0078671	El Dorado Hills WWTP	8/9/05	INF1	1.41
CA0081833	General Electric Co. GWCS	10/8/04	EFF1	0.131
CA0081833	General Electric Co. GWCS	10/8/04	EFF2	0.184
CA0081833	General Electric Co. GWCS	10/8/04	EFF3	0.158
CA0081833	General Electric Co. GWCS	10/8/04	INF1	1.112
CA0081833	General Electric Co. GWCS	10/8/04	INF2	1.112
CA0081833	General Electric Co. GWCS	10/8/04	INF3	1.112
CA0084476	Lincoln WWTP	8/25/05	EFF1	0.034
CA0083801	Modesto ID Regional WTP	10/8/04	EFF1	0.038
CA0083801	Modesto ID Regional WTP	10/8/04	INF1	ND (<0.02)
CA0083143	South Feather Water & Power Agency Miners Ranch WTP	9/9/04	EFF1	ND (<0.025)
CA0078794	SRCSD Walnut Grove WWTP (CSD1)	12/29/04	EFF1	0.759
CA0078794	SRCSD Walnut Grove WWTP (CSD1)	12/29/04	INF1	1.15

Table 12: Relative Percent Differences (RPD) of Field Duplicate Samples Analyzed for Methylmercury

Sample Date	NPDES #	Facility Name	[MeHg] (ng/l)		RPD[(a)]
			Duplicate 1	Duplicate 2	
11/16/04	CA0004791	DFG Mokelumne River Fish Hatchery	< 0.020	< 0.020	---
2/4/04	CA0004863	Mirant Delta CCPP	0.084	0.080	4.9
3/3/04	CA0004863	Mirant Delta CCPP	0.120	0.122	1.7
3/8/05	CA0077691	Vacaville Easterly WWTP	0.057	0.055	3.6
8/18/04	CA0078956	Placerville Hangtown Creek WWTP	0.097	0.067	36.6
9/20/04	CA0078956	Placerville Hangtown Creek WWTP	0.063	0.043	37.7
4/28/05	CA0078956	Placerville Hangtown Creek WWTP	0.040	0.040	0.0
8/18/04	CA0079138	Stockton WWTP	1.290	1.380	6.7
9/8/04	CA0079138	Stockton WWTP	0.904	0.903	0.1
10/13/04	CA0079138	Stockton WWTP	0.392	0.384	2.1
11/10/04	CA0079138	Stockton WWTP	0.518	0.515	0.6
12/15/04	CA0079138	Stockton WWTP	1.640	1.830	11.0
1/19/05	CA0079138	Stockton WWTP	1.860	1.490	22.1
2/8/05	CA0079138	Stockton WWTP	2.090	2.080	0.5
3/9/05	CA0079138	Stockton WWTP	1.470	1.480	0.7
4/6/05	CA0079138	Stockton WWTP	0.627	0.703	11.4
5/10/05	CA0079138	Stockton WWTP	0.281	0.261	7.4
6/8/05	CA0079138	Stockton WWTP	< 0.020	< 0.020	---
7/6/05	CA0079138	Stockton WWTP	0.142	0.070	67.9
8/24/04	CA0079260	Yuba City WWTP	0.036	0.038	5.4
10/12/04	CA0079260	Yuba City WWTP	0.042	0.032	27.0
11/22/04	CA0079260	Yuba City WWTP	0.051	0.043	17.0
12/7/04	CA0079260	Yuba City WWTP	0.038	0.041	7.6
1/25/05	CA0079260	Yuba City WWTP	0.047	0.055	15.7
2/8/05	CA0079260	Yuba City WWTP	0.219	0.225	2.7
3/30/05	CA0079260	Yuba City WWTP	0.053	0.068	24.8
4/25/05	CA0079260	Yuba City WWTP	0.057	0.061	6.8
5/26/05	CA0079260	Yuba City WWTP	0.084	0.099	16.4
6/14/05	CA0079260	Yuba City WWTP	0.050	0.048	4.1
7/5/05	CA0079260	Yuba City WWTP	< 0.025	< 0.025	---
1/24/05	CA0081833	General Electric Co. GWCS	< 0.020	< 0.020	---
4/18/05	CA0081833	General Electric Co. GWCS	< 0.020	< 0.020	---
7/5/05	CA0081833	General Electric Co. GWCS	< 0.020	< 0.020	---
12/8/04	CA0081931	Defense Logistics Agency Sharpe GW Cleanup	0.022	< 0.020	---
6/6/06	CA0083861	Aerojet Interim GW WTP	< 0.025	< 0.025	---

[(a)] RPD = |(Duplicate 1 - Duplicate 2)| / ((Duplicate 1 + Duplicate 2)/2) x 100. The RPD was not calculated if one or both samples were reported as below the method detection limit (MDL). Mean RPD = 12.7.

Table 13: Anomalous Values Observed in the Methylmercury and Total Mercury Data

NPDES No.	Facility	Sample Date(s)	Value(s) (ng/l)	Range of values of all other data (ng/l)
Influent Methylmercury				
CA0079898	Grass Valley WWTP	11/4/2004	5.01	0.588 - 3.00
CA0077895	UC Davis WWTP	9/22/2004	11.1	0.074 - 4.92
CA0077950	Woodland WWTP	6/14/2005	7.07	0.767 - 3.94
Effluent Methylmercury				
CA0079049	Davis WWTP (Discharge 2)	6/7/2005	1.44	0.247 - 0.556
CA0078590	Discovery Bay WWTP	10/27/2004	2.03	ND - 0.059
CA0079243	Lodi White Slough WWTP	4/13/2005	1.24	ND - 0.063
CA0079898	Grass Valley WWTP	7/7/2005, 8/4/2005	0.932, 0.938	ND - 0.128
Influent Total Mercury				
CA0084573	Roseville Pleasant Grove WWTP	6/1/2005, 5/26/2005	590, 770	29.0 - 200
CA0079243	Lodi White Slough WWTP	11/9/2004	590	41.0 - 270
CA0079502	Roseville Dry Creek WWTP	10/25/2004	910	46.0 - 290
CA0077682	SRCSD Sacramento River WWTP	3/11/2004, 1/6/2004	3400, 6100	48.5 - 1280
Effluent Total Mercury				
CA0079103	Modesto WWTP	12/29/2004	19	ND - 6.50
CA0079731	Redding Clear Creek WWTP	10/18/2004	23.3	1.37 - 3.01
CA0077682	SRCSD Sacramento River WWTP	11/3/2004	29.5	2.40 - 20.0
CA0077950	Woodland WWTP	12/9/2004	53.1	0.91 - 2.98
CA0079367	Placer Co. SMD #3 WWTP	6/1/2005	7.97	0.88 - 3.12
CA0082589	Redding Stillwater WWTP	3/17/2005	6.19	0.92 - 3.25
CA0084573	Roseville Pleasant Grove WWTP	8/30/2004	3	0.70 - 1.80

Table 14: Sum of Annual Average Daily Discharges (mgd) for Facilities within Each Discharger Type for NPDES Facilities in the Delta Source Region [a]

Facility Type	Proximity to Delta		TOTAL	% of TOTAL
	Delta / Yolo Bypass	Downstream of Major Dam		
Aggregate & Lake Dewatering	9.2	3.9	**13.1**	**1.8%**
Aquaculture		256.5	**256.5**	**34.6%**
Drinking Water Treatment		1.0	**1.0**	**0.1%**
Food Processing		1.7	**1.7**	**0.2%**
Groundwater Remediation		10.5	**10.5**	**1.4%**
Heating/Cooling	5.3	0.02	**5.3**	**0.7%**
Mines		0.1	**0.1**	**0.01%**
Miscellaneous [b]		0.4	**0.4**	**0.05%**
Municipal WWTP	214.6	112.5	**326**	**44.1%**
Paper & Saw Mills		2.6	**2.6**	**0.4%**
Power Generation	124.0	0.02	**124.0**	**16.7%**
Total	**353.0**	**389.2**	**742.3**	**100%**

[a] The average daily discharges of the facilities in the Delta source region were calculated using information available in NPDES permits and monitoring reports, updated in September 2009 because several manufacturing, drinking water treatment, and municipal WWTP facilities recently ceased to discharge to surface waters.

[b] The "Miscellaneous" category includes publishing and laboratory facilities.

Table 15: Number of NPDES Facilities That Received the 13267 Order Categorized by Facility Type and Geographical Region

Facility Type	Proximity to Delta			TOTAL
	Delta / Yolo Bypass	Downstream of Major Dam	Upstream of Major Dam	
Aggregate & Lake Dewatering	1	4		**5**
Aquaculture		12	2	**14**
Drinking Water Treatment		7		**7**
Food Processing		4		**4**
Groundwater Remediation		7		**7**
Heating/Cooling	3	2	1	**6**
Landfill		1		**1**
Manufacturing		2		**2**
Mines			2	**2**
Miscellaneous [a]		3		**3**
Municipal WWTP	16	41	12	**69**
Paper/Saw Mills		4	1	**5**
Power Generation	2	6		**8**
Power Generation/ Domestic WWTP		1		**1**
Grand Total	**22**	**94**	**18**	**134**

[a] The "Miscellaneous" category includes publishing and laboratory facilities.

Table 16: NPDES Facility Receiving Water Information and Map Labels for Figures 1 through 3

NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0083861	Aerojet Interim Groundwater Treatment Plant	Groundwater Remediation	5.00	Buffalo Ck. / American R.	No	38.616667	-121.242777	60
CA0004111	Aerojet Sacramento Facility	Heating / Cooling	0.02	Buffalo Ck. / American R.	No	38.621	-121.2311	59
CA0077704	Anderson WWTP	Mun WWTP	1.40	Sacramento R.	No	40.468889	-122.279167	14
CA0079197	Atwater WWTP	Mun WWTP	3.40	Atwater Drain / Bear Ck. / San Joaquin R.	No	37.341111	-120.605556	108
CA0077712	Auburn WWTP	Mun WWTP	1.17	Auburn Ravine / East Side Canal / Cross Canal / Sacramento R.	No	38.8895	-121.1007	47
CA0083721	Bell Carter Olive Company Inc.	Food Processing	0.38	Sacramento R.	No	39.913889	-122.091667	23
CA0080799	Bella Vista Water District	Drinking Water Treatment	0.50	Boulder Ck. / Churn Ck. / Sacramento R.	No	40.6001	-122.3466	9
CA0078930	Biggs WWTP	Mun WWTP	0.38	Main Drainage Canal (near Biggs) / Butte Ck. / Sacramento R.	No	39.4072	-121.7241	28
CA0084891	Boeing Company Interim Groundwater Treatment System	Groundwater Remediation	0.56	drainage ditch on Mather Field / Morrison Ck. / Stone Lake / Sacramento R.	No [(c)]	38.56875	-121.302278	64
CA0082660	Brentwood WWTP	Mun WWTP	3.09	Marsh Ck.	Yes	37.960278	-121.69	88
CA0082082	CA Dairies, Inc. Los Banos Foods [(b)]	Food Processing	0.50	municipal storm drain / San Luis Canal / Mud Slough and Salt Slough / San Joaquin R.	No	37.0563	-120.8368	112
CA0078581	CA State of, Central Heating/Cooling Facility [(b)]	Heating / Cooling	5.26	Sacramento R.	Yes	38.573889	-121.51	63
CA0083968	CALAMCO - Stockton Terminal [(b)]	Heating / Cooling	5.06	Wine Slip portion of the Deep Water Channel in the Port of Stockton / San Joaquin R.	Yes	37.941389	-121.325	89
CA0081752	Calaveras Trout Farm (Rearing Facility)	Aquaculture	19.40	Merced R. / San Joaquin R.	Yes	37.5156	-120.3747	105
CA0081566	Calpine Corp. Greenleaf Unit One Cogen Plant [(b)]	Power Generation	0.11	unnamed trib / North Drain / E Sutter Bypass	No	39.043889	-121.674167	40

Table 16: NPDES Facility Receiving Water Information and Map Labels for Figures 1 through 3

NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0082040	Camanche Dam Powerhouse [b]	Power Generation	0.04	Mokelumne R.	No	38.22	-121.025278	80
CA0083682	Canada Cove LP French Camp Golf & RV Park	Mun WWTP	0.04	Lone Tree Ck. / Little Johns Ck. / French Camp Slough / San Joaquin R.	No [c]	37.874167	-121.225	93
CA0079081	Chico Regional WWTP	Mun WWTP	7.20	Sacramento R.	Yes	39.7	-121.95	25
CA0083828	Clear Creek CSD WTP	Drinking Water Treatment	0.16	Clear Ck. / Sacramento R.	No	40.597222	-122.538056	10
CA0079529	Colfax WWTP [a]	Mun WWTP	0.024	Smuthers Ravine / Bunch Canyon / N Fk. American R.	No	39.075	-120.941667	38
CA0078999	Colusa WWTP	Mun WWTP	0.66	Powell Slough / Colusa Basin Drain / Sacramento R.	No	39.180556	-122.03	35
CA0004995	Corning Industries/ Domestic WWTP	Mun WWTP	1.00	Sacramento R.	No	39.913889	-122.091667	22
CA0081507	Cottonwood WWTP	Mun WWTP	0.29	Cottonwood Ck. / Sacramento R.	No	40.377778	-122.270833	18
CA0082767	Crystal Creek Aggregate	Aggregate	0.002	Rock Ck. & Middle Ck. / Sacramento R.	No	40.609	-122.4601	8
CA0079049	Davis WWTP [d]	Mun WWTP	5.26	Willow Slough Bypass / Yolo Bypass	No [c]	38.59	-121.663889	62
CA0081931	Defense Logistics Agency Sharpe Groundwater Cleanup [b]	Groundwater Remediation	1.90	South San Joaquin Irrigation District Canal / French Camp Slough / San Joaquin R.	No [c]	37.8405	-121.2622	95
CA0078093	Deuel Vocational Institute WWTP	Mun WWTP	0.47	Deuel Drain / Paradise Cut / Old R.	Yes	37.750556	-121.326389	101
CA0004561	DFG Darrah Springs Fish Hatchery	Aquaculture	18.70	Baldwin Ck. / Battle Ck. / Sacramento R.	No	40.4329	-121.9967	15
CA0080055	DFG Merced River Fish Hatchery	Aquaculture	4.55	Merced R. / San Joaquin R.	Yes	37.5172	-120.372	104
CA0004804	DFG Moccasin Creek Fish Hatchery [a]	Aquaculture	19.62	Moccasin Ck. / Don Pedro Res.	No	37.8136	-120.3063	96

Table 16: NPDES Facility Receiving Water Information and Map Labels for Figures 1 through 3

NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0004791	DFG Mokelumne River Fish Hatchery	Aquaculture	21.00	Mokelumne R.	No	38.2254	-121.0306	79
CA0004774	DFG Nimbus Fish Hatchery	Aquaculture	40.00	American R.	Yes	38.6341	-121.2286	57
CA0004812	DFG San Joaquin Fish Hatchery	Aquaculture	22.60	San Joaquin R.	No	36.997222	-119.718889	113
CA0078875	DGS Office of State Publishing	Misc	0.30	American R.	Yes	38.602	-121.4941	61
CA0078590	Discovery Bay WWTP	Mun WWTP	1.54	Reclamation District 800 drainage ditch / Old R.	Yes	37.905556	-121.5875	92
CA0078662	El Dorado ID Deer Creek WWTP	Mun WWTP	2.52	Deer Ck. / Cosumnes R.	No	38.628333	-120.986389	58
CA0078671	El Dorado ID El Dorado Hills WWTP	Mun WWTP	1.08	Carson Ck. / Deer Ck. / Cosumnes R.	No	38.638333	-121.060556	56
CA0004057	Formica Corporation Sierra Plant [b]	Manufacturing	0.88	Unnamed trib. / Pleasant Grove Ck. / Cross Canal / Sacramento R.	No	38.8232	-121.3077	49
CA0081434	Galt WWTP	Mun WWTP	1.92	Laguna Ck. / Cosumnes R.	No	38.297222	-121.333333	77
CA0004847	Gaylord Container Corp. Antioch Pulp & Paper Mill [b]	Heating / Cooling	- - -	San Joaquin R.	Yes	38.025833	-121.7675	85
CA0081833	General Electric Co. GWCS	Groundwater Remediation	1.60	Doane Lateral Irrigation Canal (Merced Irrigation District) / Miles Ck. / San Joaquin R.	No	37.2918	-120.4234	109
CA0079898	Grass Valley WWTP [a]	Mun WWTP	2.10	Wolf Ck. / Indian Ck. / Bear R.	No	39.208333	-121.07	34
CA0082309	GWF Power Systems	Power Generation	0.05	Storm Drain / San Joaquin R.	Yes	38.025	-121.758333	86
CA0004146	Hershey Chocolate USA, Oakdale	Food Processing	1.03	Oakdale Irrigation District Riverbank Lateral Canal / Modesto Irrigation District Main Canal / Stanislaus R.	No	37.758333	-120.829722	100
CA0083097	J.F. Shea C Fawndale Rock and Asphalt	Aggregate	3.87	W. Fk. Stillwater Ck. / Stillwater Ck. / Sacramento R.	No	40.735	-122.307222	1

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NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0079391	Jackson WWTP [a]	Mun WWTP	0.71	Jackson Ck. / Dry Ck. / Mokelumne R.	No	38.344722	-120.783611	72
CA0081191	Lehigh Southwest Cement Co.	Aggregate		W Fk. Stillwater Ck. / Stillwater Ck. / Sacramento R.	No	40.733889	-122.320833	2
CA0084476	Lincoln WWTP	Mun WWTP	1.13	Auburn Ravine / East Side Canal / Cross Canal / Sacramento R.	No	38.891111	-121.324722	46
CA0079022	Live Oak WWTP	Mun WWTP	1.65	Reclamation District No. 777 Lateral Drain No. 1 / Main Canal / Sutter Bypass	No	39.258333	-121.677222	32
CA0079243	Lodi White Slough WWTP	Mun WWTP	4.51	Dredger Cut / White Slough	Yes	38.093056	-121.396667	84
CA0082783	Manteca Aggregate Sand Plant (Oakwood Lake Subdivision Mining Reclamation)	Aggregate	9.15	San Joaquin R.	Yes	37.7794	-121.2993	98
CA0081558	Manteca WWTP	Mun WWTP	4.63	San Joaquin R.	Yes	37.7794	-121.2993	99
CA0079430	Mariposa PUD WWTP	Mun WWTP	0.245	Mariposa Ck. several miles u/s of Mariposa Ck. Dam	No	37.480278	-119.960833	106
CA0079987	Maxwell PUD WWTP	Mun WWTP	0.14	unnamed trib / Laurline Ck. / Colusa Basin Drain / Sacramento R.	No	39.266667	-122.183333	29
CA0079219	Merced WWTP	Mun WWTP	8.50	Hartley Slough / Owens Ck. / Bear Ck. / San Joaquin R.	No	37.243889	-120.541667	111
CA0004863	Mirant Delta CCPP	Power Generation	124	San Joaquin R.	Yes	38.019444	-121.7625	87
CA0083801	Modesto ID Regional WTP [b]	Drinking Water Treatment	0.04	Modesto Irrigation Main Canal / Stanislaus R. / Tuolumne R. / San Joaquin R.	No	37.653611	-120.6725	102
CA0079103	Modesto WWTP	Mun WWTP	11.8	San Joaquin R.	Yes	37.521944	-121.099444	103
CA0079901	Nevada City WWTP	Mun WWTP	0.43	Deer Ck. / Yuba R.	No	39.25975	-121.03075	31
CA0083241	Nevada Co SD #1 Cascade Shores WWTP [a]	Mun WWTP	0.026	Gas Canyon Ck. / Greenhorn Ck. / Rollins Res. / Bear R.	No	39.261111	-120.905556	30

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NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0077828	Nevada Co SD #1 Lake Wildwood WWTP [a]	Mun WWTP	0.50	Deer Ck. / Yuba R.	No	39.233333	-121.222778	33
CA0081612	Nevada Co SD #2 Lake of the Pines WWTP [a]	Mun WWTP	0.54	Magnolia Ck. / Bear R.	No	39.033333	-121.083611	41
CA0077836	Olivehurst PUD WWTP	Mun WWTP	1.20	Western Pacific Interceptor Drainage Canal / Bear R. / Feather R.	No	39.065278	-121.552222	39
CA0079235	Oroville WWTP	Mun WWTP	3.00	Feather R.	Yes	39.453056	-121.636944	27
CA0082961	Pacific Coast Sprout Farms, Inc. (Sacramento Facility)	Aquaculture	0.10	Morrison Ck.	No [c]	38.5197	-121.3789	70
CA0004821	Pactiv Molded Pulp Mill	Paper/Saw Mill	1.90	Sacramento R.	No	40.1553	-122.2095	21
CA0083488	Paradise Irrigation District	Drinking Water Treatment	1.5	Magalia Reservoir / Little Butte Ck. / Butte Ck. / Sacramento R.	No	39.816389	-121.580556	24
CA0079341	Placer Co. SA #28 Zone #6 [b]	Mun WWTP	0.01	Drainage Ditch / Yankee Slough / Bear R.	No	38.9754	-121.3709	42
CA0079316	Placer Co. SMD #1 WWTP	Mun WWTP	1.90	Coon Ck. / Main Canal / Cross Canal / Sacramento R.	No	38.958333	-121.116667	43
CA0079367	Placer Co. SMD #3 WWTP	Mun WWTP	0.12	Miners Ravine / Dry Ck. / Natomas East Main Drainage Canal / Bannon Slough / Sacramento R.	No	38.797222	-121.118056	50
CA0078956	Placerville Hangtown Creek WWTP [a]	Mun WWTP	1.30	Hangtown Ck. / Weber Ck. / S. Fk. American R. / Folsom Lake / American R.	No	38.733333	-120.841667	52
CA0078950	Planada Comm. Service Dist. WWTP	Mun WWTP	0.38	Miles Ck. / Owens Ck. / Bear Ck. / San Joaquin R.	No	37.276389	-120.333333	110
CA0004316	Proctor & Gamble Co. WWTP [b]	Manufacturing	5.50	Morrison Ck.	No [c]	38.5315	-121.4088	65
CA0078891	Red Bluff WWRP	Mun WWTP	1.40	Sacramento R.	No	40.1625	-122.216667	20
CA0079731	Redding Clear Creek WWTP	Mun WWTP	7.50	Sacramento R.	No	40.498889	-122.360278	11

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NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0082589	Redding Stillwater WWTP	Mun WWTP	3.46	Sacramento R.	No	40.473611	-122.267222	13
CA0077852	Rio Alto WD- Lake CA WWTP	Mun WWTP	0.15	Sacramento R.	No	40.3319	-122.2101	19
CA0079588	Rio Vista Main WWTP	Mun WWTP	0.47	Sacramento R.	Yes	38.154167	-121.677778	82
CA0079502	Roseville Dry Creek WWTP	Mun WWTP	13.0	Dry Ck. / Natomas East Main Drainage Canal / Bannon Slough / Sacramento R.	No	38.731389	-121.316111	53
CA0084573	Roseville Pleasant Grove WWTP	Mun WWTP	4.82	Pleasant Grove Ck. / Pleasant Grove Ck. Canal / Cross Canal / Sacramento R.	No	38.795556	-121.379444	51
CA0083569	Sacramento Cogen Authority Procter & Gamble Plant [b]	Power Generation	- - -	Morrison Ck.	No [c]	38.530278	-121.4075	66
CA0034841	Sacramento International Airport [b]	Heating / Cooling	1.50	Lindbergh ditch / Meister canal / Reclamation District-1000 pump station / Sacramento R.	Yes	38.665833	-121.612778	55
CA0079464	San Andreas SD WWTP [a]	Mun WWTP	0.30	San Andreas Ck. / Murray Ck. / N Fk. Calaveras R.	No	38.203056	-120.688333	81
CA0082848	San Joaquin Co DPW – Flag City [b]	Mun WWTP	0.06	Highline Canal / White Slough, East of I-5	Yes	38.106944	-121.41	83
CA0004693	Shasta Lake WTP	Drinking Water Treatment	0.05	Churn Ck. / Sacramento R.	No	40.6929	-122.4025	4
CA0079511	Shasta Lake WWTP	Mun WWTP	0.64	Churn Ck. / Sacramento R.	No	40.661111	-122.375	6
CA0004758	SMUD Rancho Seco Nuclear Generating Station [b]	Power / Dom WWTP	0.09	Clay to Hadselville to Laguna Ck. / Cosumnes R.	No	38.343056	-121.126111	76
CA0083143	South Feather Water and Power	Drinking Water Treatment	0.25	Miners Ranch Res. / Feather R.	No	39.504722	-121.456389	26
CA0082066	SPI Anderson Division	Paper/Saw Mill		Sacramento R.	No	40.4787	-122.3231	12
CA0081400	SPI Shasta Lake	Paper/Saw Mill	0.15	unnamed trib / Churn Ck. / Sacramento R.	No	40.675278	-122.384722	5
CA0077682	SRCSD Sacramento River WWTP	Mun WWTP	151	Sacramento R.	Yes	38.4607	-121.5031	73

Table 16: NPDES Facility Receiving Water Information and Map Labels for Figures 1 through 3

NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0078794	SRCSD Walnut Grove WWTP (CSD1) [b]	Mun WWTP	0.08	unnamed agricultural ditch / Snodgrass Slough / Mokelumne R. / San Joaquin R.	Yes	38.2344	-121.4998	78
CA0084140	Stimpel Wiebelhaus Associates SWA at Mountain Gate	Aggregate	0.02	Stillwater Ck. / Sacramento R.	No	40.636944	-122.32	7
CA0081965	Stockton Cogen Co. [b]	Power Generation	1.17	North Little Johns Ck. / French Camp Slough / San Joaquin R.	No [c]	37.853889	-121.259722	94
CA0079138	Stockton WWTP	Mun WWTP	27.78	San Joaquin R.	Yes	37.9375	-121.334722	90
CA0079154	Tracy WWTP	Mun WWTP	9.49	Old R. / Middle R. / San Joaquin R.	Yes	37.801944	-121.400833	97
CA0084727	Tuolumne UD Sonora WWTP / Jamestown WWTP [a]	Mun WWTP	0.16	Woods Ck. / Slate Ck. / Don Pedro Res	No	37.922222	-120.431389	91
CA0078948	Turlock WWTP	Mun WWTP	11.71	Harding Drain / San Joaquin R.	Yes	37.463333	-121.031667	107
CA0083551	UA Local 38 Trust Fund Konocti Harbor Resort and Spa [a]	Heating / Cooling	0.22	Clear Lake	Yes	38.9405	-122.7378	45
CA0083348	UC Davis Center for Aquatic Biology & Aquaculture – Putah Ck Facility	Aquaculture	0.14	South Fk. Putah Ck. / Yolo Bypass	Yes	38.5275	-121.805	67
CA0083348	UC Davis Center for Aquatic Biology & Aquaculture – Aquatic Center	Aquaculture	0.67	South Fk. Putah Ck. / Yolo Bypass	Yes	38.525556	-121.788889	69
CA0084182	UC Davis Hydraulics Laboratory	Misc	0.01	North Fk. Putah Ck. / Putah Ck. / Yolo Bypass	No [c]	38.526389	-121.781944	68
CA0077895	UC Davis WWTP	Mun WWTP	1.92	South Fk. Putah Ck. / Yolo Bypass	Yes	38.517778	-121.756944	71
CA0084697	United Auburn Indian Community Casino WWTP	Mun WWTP	0.15	Unnamed trib. / Orchard Ck. / Auburn Ravine / East Side Canal / Cross Canal / Sacramento R.	No	38.841667	-121.316667	48
CA0084905	USDI BR Sliger Mine [a]	Mines	0.06	Middle Fk. American R.	No	38.940994	-120.932769	44

Table 16: NPDES Facility Receiving Water Information and Map Labels for Figures 1 through 3

NPDES No.	Facility	Facility Type	Annual Discharge (mgd)	Receiving Water	Discharges to 303(d) Hg Listed Waterway	LATITUDE (North)	LONGITUDE (West)	Map Code
CA0084298	USDI BR Winter Run Rearing Facility (Livingston Stone) [a]	Aquaculture	1.00	Sacramento R.	No	40.716667	-122.423889	3
CA0004201	USDI FWS Coleman Fish Hatchery	Aquaculture	40.08	Battle Ck. / Sacramento R.	No	40.3981	-122.1438	17
CA0077691	Vacaville Easterly WWTP	Mun WWTP	9.26	Old Alamo Ck. / Ulatis Ck.	No [c]	38.347222	-121.910278	75
CA0079171	West Sacramento WWTP [b]	Mun WWTP	5.60	Sacramento R.	Yes	38.436111	-121.526111	74
CA0081957	Wheelabrator Shasta Energy Co.	Power Generation	0.02	Anderson Cottonwood Canal / Cottonwood Ck.	No	40.430278	-122.275556	16
CA0077933	Williams WWTP	Mun WWTP	0.44	Salt Ck. / Glenn-Colusa Canal / Colusa Basin Drain / Sacramento R.	No	39.169722	-122.153611	36
CA0077950	Woodland WWTP	Mun WWTP	6.05	Tule Canal / Yolo Bypass	No [c]	38.680833	-121.643889	54
CA0079260	Yuba City WWTP	Mun WWTP	5.22	Feather R.	Yes	39.090556	-121.598056	37

[a] Facilities upstream of a major dam.
[b] Facilities for which NPDES permits were rescinded sometime after the facilities completed 13267 Order monitoring.
[c] Facilities that do not discharge to 303(d) Listed mercury-impaired waterways but do discharge to small tributaries that drain directly to the Delta.
[d] The City of Davis WWTP (CA0079049) has two seasonal discharge locations; wastewater is discharged from Discharge 001 to the Willow Slough Bypass upstream of the Yolo Bypass and from Discharge 002 to the Conaway Ranch Toe Drain in the Yolo Bypass. The latitude and longitude coordinates and other information provided in the table are for Discharge 001. The coordinates for Discharge 002 are 38.575833, -121.633889.

Table 17: Summary of all Effluent Methylmercury Concentration Data for the Non-Municipal Facility Categories [a]

Facility Type	# of Effluent MeHg Samples	Average MeHg Conc (ng/l) [b]	# of Nondetect samples	MeHg Conc. Range (ng/l)
Aggregate	10	0.026	7	ND - 0.081
Aquaculture	38	0.041	12	ND - 0.243
Drinking Water Treatment	10	0.033	3	ND - 0.066
Food Processing	12	0.014	9	ND - 0.027
Groundwater Remediation	20	0.012	19	ND - 0.033
Heating/Cooling	14	0.110	3	ND - 0.919
Manufacturing	5	0.023	3	ND - 0.050
Mines	4	0.064	1	ND - 0.091
Miscellaneous	6	0.034	3	ND - 0.082
Paper/Saw Mills	21	0.117	5	ND - 1.190
Power Generation	46	0.061	11	ND - 0.178
Power Generation/ Domestic WWTP	12	0.040	4	ND – 0.104

[a] This table summarizes all of the effluent methylmercury data submitted by non-municipal facilities including multiple discharge locations (e.g., effluents 1-4).

[b] One-half of the MDL was used in calculations for methylmercury concentration results that were less than the MDL.

Table 18: Available Intake and Outfall Methylmercury Concentration Data for Aquaculture, Power and Heating/Cooling Facilities in the Delta Region

Facility [NPDES #, Type]	Sample Date	Outfall 1 MeHg Conc. [(a)] (ng/l)	Outfall 1 MeHg Qual. [(b)]	Outfall 2 MeHg Conc. (ng/l)	Outfall 2 MeHg Qual. [(b)]	Outfall 2 Field Dup. MeHg Conc. (ng/l)	Outfall 2 Field Dup. MeHg Qual. [(b)]	Intake 1 MeHg Conc. [(a)] (ng/l)	Intake 1 MeHg Qual. [(b)]	Intake 1 Dup. MeHg Conc. (ng/l)	Intake 1 Dup. MeHg Qual. [(b)]	Intake 2 MeHg Conc. (ng/l)	Intake 2 MeHg Qual. [(b)]
CALAMCO - Stockton Terminal [CA0083968, Heating /Cooling]	8/26/2004	0.03	B					0.026	B				
Calaveras Trout Farm (Rearing Facility) [CA0081752, Aquaculture]	9/30/2004	0.027	B					0.067					
Camanche Dam Powerhouse [CA0082040, Power Generation]	1/19/2005	ND	<MDL					0.095	(ba)				
DFG Darrah Springs Fish Hatchery [CA0004561, Aquaculture]	9/15/2004	0.029	B, (nn)	0.043	B, X, (mm)			ND	<MDL, (nn)			ND	<MDL, (nn)
DFG Mokelumne River Fish Hatchery [CA0004791, Aquaculture]	11/16/2004	0.048	A					ND	<MDL, A	ND	<MDL, A		
DFG Nimbus Fish Hatchery [CA0004774, Aquaculture]	11/16/2004			0.129	A			0.051	A				
	2/17/2005	0.053										0.031	
	6/20/2005	0.085	A					0.052					
DFG San Joaquin Fish Hatchery [CA0004812, Aquaculture]	9/28/2004	0.073						0.021	B				
GWF Power Systems [CA0082309, Power Generation]	8/11/2004	ND	<MDL					ND	<MDL				
	11/4/2004	ND	<MDL					ND	<MDL				
	2/3/2005	ND	<MDL					0.263					
	5/5/2005	ND	<MDL					ND	<MDL				
Mirant Delta CCPP [CA0004863, Power Generation]	2/4/2004	0.081		0.0835		0.0799		0.296	(l)				
	3/3/2004	0.116		0.127				0.12	(l)	0.122	(l)		
	8/3/2004	0.020	J	0.07				ND	<MDL, (l)				
	9/1/2004	0.08		0.06				0.08	(l)				
	10/5/2004	0.049	B	0.06				0.038	(l), B				
	11/2/2004	0.047	B	0.042	B			0.04	(l), B				
	12/2/2004	0.03	B	0.063				0.07	(l)				

Table 18: Available Intake and Outfall Methylmercury Concentration Data for Aquaculture, Power and Heating/Cooling Facilities in the Delta Region

Facility [NPDES #, Type]	Sample Date	Outfall 1 MeHg Conc. [(a)] (ng/l)	Outfall 1 MeHg Qual. [(b)]	Outfall 2 MeHg Conc. (ng/l)	Outfall 2 MeHg Qual. [(b)]	Outfall 2 Field Dup. MeHg Conc. (ng/l)	Outfall 2 Field Dup. MeHg Qual. [(b)]	Intake 1 MeHg Conc. [(a)] (ng/l)	Intake 1 MeHg Qual. [(b)]	Intake 1 Dup. MeHg Conc. (ng/l)	Intake 1 Dup. MeHg Qual. [(b)]	Intake 2 MeHg Conc. (ng/l)	Intake 2 MeHg Qual. [(b)]
Mirant Delta CCPP [CA0004863, Power Generation]	1/11/2005	0.083		0.081				0.102	(l)				
	2/8/2005	0.097		0.12				0.098	(l)				
	3/8/2005	0.121		0.15				0.15	(l)				
	4/26/2005	0.083			Y			0.069	(l)				
	5/25/2005	0.091			Y			0.077	(l)				
Sacramento Cogen Authority Procter & Gamble Plant [CA0083569, Power Generation]	8/11/2004	0.056	A					ND	<MDL, A				
	10/6/2004	0.069						ND	<MDL				
	1/5/2005	0.07						0.08					
	5/4/2005	ND	<MDL					ND	<MDL				

[(a)] ND: nondetect (below method detection limit). Analytical method detection limits were 0.025 ng/l or less.
[(b)] < MDL: below method detection limit
A: Samples were received out of optimal temperature range.
B: Sample results above the MDL and below the ML; should be considered an estimate.
J: Detected but below the reporting limit; result is an estimated concentration.
X: Collected 9/14/04.
Y: No discharge.
(l): Mirant Delta CCPP Intake 002.
(mm): Darrah Springs Fish Hatchery - Lower Springs.
(nn): Darrah Springs Fish Hatchery - Upper Springs.
(ba): Camanche Dam Powerhouse receiving water received 200 feet upstream of discharge.

Table 19: Comparison of Delta Municipal WWTP Effluent Methylmercury Concentrations to Methylmercury Concentrations in Drinking Water Supplies for Delta Communities

Municipal Area	Municipal WWTP Average MeHg Conc. in Effluent Discharged to Surface Water (ng/l)	Municipal Water Supply [a]				Local Surface Drinking Water Supply [b]	
		Central Valley Project	State Water Project	Ground-water [m]	Local Streams / Reservoirs	Sampling Location	Average MeHg Conc. (ng/l)
Brentwood	0.01		X	X		SWP	0.054
Deuel Vocational Institute [c]	0.01			X		- - -	- - -
Discovery Bay [d]	0.19			X	X	CVP SWP X2	0.064 0.054 0.083
Lodi White Slough	0.15			X		- - -	- - -
Manteca [e]	0.22			X		- - -	- - -
Modesto [n]							
Rio Vista [f]	0.16			X		- - -	- - -
San Joaquin Co DPW CSA 31 Flag City [g]	0.08			X		- - -	- - -
SRCSD Sacramento River [l]	0.73			X	X	Sacramento R. @ Freeport American River	0.103 0.045
SRCSD Walnut Grove [h]	2.16			X		- - -	---
Stockton [j]	0.94			X	X	*No MeHg data available for New Hogan & New Melones Reservoirs*	
Tracy [e, i]	0.15	X		X	X	CVP Stanislaus River	0.064 0.119
West Sacramento [k]	0.05	X			X	Sacramento R. @ Veterans Bridge CVP	0.109 0.064
Woodland	0.03			X		- - -	---

Table 19 Footnotes:

[a] Except where otherwise noted, all water supply information was obtained from the Water Education Foundation's 2006 website, "Where does my water come from?" [http://www.water-ed.org/watersources/]. This site lists the drinking water sources for incorporated cities with a population of 10,000 or greater, as determined from the 2005 Water Education Foundation survey, water agencies, and annual water quality reports.

[b] If methylmercury data were not available for the local surface water supply, data for nearby waterways were included. Methylmercury data for the Central Valley Project (CVP), State Water Project (SWP) and Delta outflows to San Francisco Bay (X2) were used to represent drinking water intakes in the Central and West Delta, such as the Rock Slough and Old River intakes for the Randall-Bold Water Treatment Plant located in Oakley (see footnote "d"). Average methylmercury values were obtained from the February 2008 Delta TMDL draft staff report (Wood *et al.*, 2008b) for all surface water locations with four exceptions. Central Valley Water Board staff collected methylmercury samples from the American River at Discovery Park and Stanislaus River at Caswell State Park as part of a broader CalFed-funded study (Foe *et al.*, 2007; 2008 draft report in peer review). The Sacramento Coordinated Monitoring Program sampled the Sacramento River at Veteran's Bridge (CMP, 2004).

[c] The Deuel Vocational Institute WWTP services the Deuel Vocational Institute (DVI), which is about two miles south of Mossdale and ten miles south of Stockton. Information about its water supply was obtained from a case study described in: Corrollo Engineers, 2007, Drinking Water with Emphasis on Desalination and Membrane Softening Qualifications, available at: http://www.carollo.com/356/section.aspx/333

[d] Groundwater from eight active wells provides approximately 67% of the Discovery Bay water supply; the remaining water comes from the Randall-Bold Water Treatment Plant located in Oakley, which is jointly owned by Contra Costa Water District (CCWD) and Diablo Water District (DWD) and receives water from Rock Slough, Old River, and Los Vaqueros Reservoir. Information about the Discovery Bay water supply is from: Brown and Caldwell, 2006. City of Brentwood 2005 Urban Water Management Plan - Final. Prepared for the City of Brentwood by Department of Public Works by Brown and Caldwell, Walnut Creek, California. January 2006. Available at: http://www.ci.brentwood.ca.us/pdf/new/publicworks/2005_urban_water_plan.pdf

[e] The Water Education Foundation listed Manteca water sources as both groundwater and local streams/reservoirs. The City of Manteca Water Division website [http://www.ci.manteca.ca.us/eng/water/] stated that as of 2005, 100% of the Manteca drinking water supply came from groundwater sources and that in the near future some of its supply will come from the South County Surface Water Supply Project, which will draw water from Woodward Reservoir. The Woodward Reservoir is supplied by the Stanislaus River. The South County Surface Water Supply Project is a project to supply the cities of Tracy, Lathrop, Manteca and Escalon with water from the South San Joaquin Irrigation District and includes construction of a new water treatment plant at Woodward Reservoir and pipelines to supply water to the cities. Currently no methylmercury data are available for Woodward Reservoir.

[f] The City of Rio Vista relies on groundwater sources and has the right to obtain a specified amount of North Bay Aqueduct (NBA, a component of the State Water Project) water in the future, but as of 2003, had no facility to take NBA water. [Information from: Solano County Water Agency, 2002. SWCA Briefing Book. January 2002. Available at: http://www.scwa2.com/briefing_book.html]

[g] County Service Area 31 is an 80-acre parcel that includes Flag City, a collection of hotels, gas stations and restaurants at Interstate 5 and Highway 12 near Lodi.

[h] Per California American Water's 2005 Annual Water Quality Report for Walnut Grove [PWS ID: 3410047], water in the Walnut Grove system comes from wells that pump groundwater from aquifers in the Walnut Grove area. [Report available at: http://www.illinoisamerican.com/awpr1/caaw/pdf/CA-WalnutGrove-web.pdf]

Table 19 Footnotes, *continued*:

[i] According to the City of Tracy Public Works website, 2005 sources of the City of Tracy's water supply include the Delta-Mendota Canal [a.k.a. Central Valley Project] (50%), the Stanislaus River (17%), and groundwater pumped from wells (33%). [http://www.ci.tracy.ca.us/departments/public_works/water_quality/]

[j] In 2005, the City of Stockton obtained about 58% of their drinking water from surface water supplied by the Stockton East Water District (SEWD) and 42% from groundwater sources [City of Stockton / OMI Thames Water 2005 Annual Drinking Water Quality Report, California Water System No. 3910012.] SEWD obtains water from the New Hogan Reservoir in the Calaveras River watershed, and from the New Melones Reservoir in the Stanislaus River watershed. [Report available at: http://www.stocktongov.com/MUD/General/water/documents/2005CCRWaterQualityReport.pdf] Currently no methylmercury data are available for the reservoirs.

[k] The West Sacramento 2006 Water Quality Consumer Confidence Report states that the City of West Sacramento's main water supply is the Sacramento River, with an intake structure at Bryte Bend, upstream of the confluence of the Sacramento and American rivers. The City maintains water supply contracts with the federal Bureau of Reclamation, the Central Valley Project and the North Delta Water Agency. In addition to surface water, the City has five ground water wells that are available to supply additional water during emergencies. The City did not utilize ground water in 2005.

[l] The 2005 City of Sacramento Water Quality Report states that 85% of its water supply comes from the American and Sacramento Rivers and 15% comes from groundwater. [Report available at: http://www.cityofsacramento.org/utilities/pubs/DOU_CCR_2005.pdf] According to the November 2006 City of Sacramento Urban Water Management Plan prepared by West Yost Associates, the City diverts water from the American River downstream from the Howe Avenue Bridge, and from the Sacramento River downstream of the confluence of the American and Sacramento Rivers. [Report available at: http://www.cityofsacramento.org/utilities/urbanwater/] According to available water quality reports for urban areas outside of the City of Sacramento serviced by other water districts and private corporations, water supply for unincorporated areas is a mixture of surface water (e.g., Sacramento River, American River, and Folsom Lake) and groundwater. The effluent methylmercury data used in this analysis was collected from December 2000 to June 2003, since the surface drinking water supply data was collected during the same time period.

[m] Groundwater treatment plant intake and discharge monitoring (Tables B.1 through B.4) indicate that methylmercury concentrations in groundwater are at or below method detection limits (typically < 0.02 ng/l).

[n] The Modesto Irrigation District (ID) Water Treatment Plant (WTP), which supplements groundwater drinking water supplies for the Modesto community, obtains water from the Tuolumne River at Modesto Reservoir. The Modesto ID collected intake samples and analyzed them for methylmercury as part of their 13267 Order monitoring effort (see Table B.3). Modesto ID WTP water supply information is available at: http://www.mid.org/water/drnkwtr.htm

Table 20: Municipal WWTP Treatment Processes in Place at the Time of Methylmercury Sampling

Agency (NPDES No.)	Ave EFF1 MeHg Conc (ng/l) [a]	Title 22 [b]	1. Primary Clarification	2. Activated Sludge	3. Pure Oxygen Act. Sludge	4. RBC's [c]	5. SBR's [c]	6. Fixed Film Reactors	7. Trickling Filters	8. Extended Aeration	9. Settling Ponds	10. Oxidation Ditch	11. Oxidation Ponds	12. Facultative Ponds	13. Lemna/Overland Flow	14. Nitrify / Denitrify	15. Secondary Clarification	16. Dissolved Air Flotation	17. Coagulation / Polymer	18. Microfiltration	19. Filtration	20. Chlorination	21. Chlorination / Dechlor.	22. Ultraviolet Radiation	23. Ozonation	Average Flow (mgd)	Design Maximum Flow (mgd) [e]	Systems in Place during MeHg 13267 sampling [d]
Brentwood WWTP (CA0082660)	0.010	X	X							X		X				X	X		X		X	X				3.1	4.5	Y
Deuel Vocational Institute WWTP (CA0078093)	0.010											X				X	X				X	X				0.47	0.62	Y
United Auburn Indian Comm. Casino WWTP (CA0084697)	0.010	X		X												X	X			X			X			0.15	0.35	Y
Redding Stillwater WWTP (CA0082589)	0.013			X																	X		X			3.5	4.0	Y
El Dorado ID Deer Creek WWTP (CA0078662)	0.015	X	X	X						X		X				X					X		X			2.5	2.5	Y
Roseville Pleasant Grove WWTP (CA0084573)	0.017	X		X								X				X	X		X		X		X			4.8	12	Y
El Dorado ID El Dorado Hills WWTP (CA0078671)	0.018	X	X	X												X		X			X	X				1.1	3.0	Y
Lincoln WWTP (CA0084476)	0.018	X										X				X		X	X		X			X		1.1	3.3	Y
Shasta Lake WWTP (CA0079511)	0.022											X					X				X		X			0.64	1.3	Y
Roseville Dry Creek WWTP (CA0079502)	0.023	X	X	X												X	X		X		X		X			13	18	Y
Vacaville Easterly WWTP (CA0077691)	0.024		X	X													X						X			9.3	10	Y
Red Bluff WWTP (CA0078891)	0.027		X	X													X				X		X			1.4	2.5	Y
Auburn WWTP (CA0077712)	0.028	X										X				X	X		X		X		X			1.2	1.67	Y
Woodland WWTP (CA0077950)	0.031	X										X					X						X			6.1	7.8	Y
Atwater WWTP (CA0079197)	0.034		X	X													X						X			3.4	6.0	N?
UC Davis WWTP (CA0077895)	0.038	X										X				X	X				X			X		1.9	2.7	Y
Redding Clear Creek WWTP (CA0079731)	0.042		X	X													X				X		X			7.5	8.8	Y
Corning Industries/ Domestic WWTP (CA0004995)	0.044											X					X						X			1.0	1.38	Y
Nevada City WWTP (CA0079901)	0.048	X					X														X		X			0.43	0.69	Y
West Sacramento WWTP (CA0079171)	0.050		X	X												X	X						X			5.6	7.5	Y
Placerville Hangtown Creek WWTP (CA0078956)	0.058	X	X	X					X								X				X		X			1.3	2.3	Y
Turlock WWTP (CA0078948)	0.059			X													X						X			11.71	20	Y
San Joaquin Co DPW - Flag City WWTP (CA0082848)	0.081									X							X				X		X			0.06	0.16	Y

Table 20: Municipal WWTP Treatment Processes in Place at the Time of Methylmercury Sampling

Agency (NPDES No.)	Ave EFF1 MeHg Conc (ng/l) [a]	Title 22 [b]	1. Primary Clarification	2. Activated Sludge	3. Pure Oxygen Act. Sludge	4. RBC's [c]	5. SBR's [c]	6. Fixed Film Reactors	7. Trickling Filters	8. Extended Aeration	9. Settling Ponds	10. Oxidation Ditch	11. Oxidation Ponds	12. Facultative Ponds	13. Lemna/Overland Flow	14. Nitrify / Denitrify	15. Secondary Clarification	16. Dissolved Air Flotation	17. Coagulation / Polymer	18. Microfiltration	19. Filtration	20. Chlorination	21. Chlorination / Dechlor.	22. Ultraviolet Radiation	23. Ozonation	Average Flow (mgd)	Design Maximum Flow (mgd) [e]	Systems in Place during MeHg 13267 sampling [d]
Anderson WWTP (CA0077704)	0.090			X													X				X		X			1.4	2.0	Y
Cottonwood WWTP (CA0081507)	0.096											X					X				X		X			0.29	0.43	Y
Placer Co. SMD #3 WWTP (CA0079367)	0.100		X						X								X		X		X		X			0.12	0.3	Y
Jackson WWTP (CA0079391)	0.108	X										X					X				X		X			0.71	0.71	Y
Nevada Co SD #1 Lake Wildwood WWTP (CA0077828)	0.109											X					X				X		X			0.50	1.1	Y*
Chico Regional WWTP (CA0079081)	0.126		X	X						X							X					X				7.2	9.0	Y
Lodi White Slough WWTP (CA0079243)	0.128		X	X													X				X			X		4.5	7.0	Y
Modesto WWTP (CA0079103)	0.130		X					X						X									X			7.2	70	Y
Galt WWTP (CA0081434)	0.139			X						X							X						X			1.9	3.0	Y**
Placer Co. SMD #1 WWTP (CA0079316)	0.141	X	X			X			X								X				X		X			1.90	2.18	Y
Nevada Co SD #1 Cascade Shores WWTP (CA0083241)	0.142	X		X													X				X		X			0.026	0.03	Y
Olivehurst PUD WWTP (CA0077836)	0.144	X	X	X													X						X			1.2	1.8	Y***
Tracy WWTP (CA0079154)	0.145		X	X					X								X						X			9.5	9 *upgrade to 16*	Y****
Canada Cove LP French Camp WWTP (CA0083682)	0.147						X										X				X				X	0.04	0.04	Y
Oroville WWTP (CA0079235)	0.147		X	X													X				X		X			3.0	6.5	Y
Grass Valley WWTP (CA0079898)	0.160	X	X	X												X	X						X			2.1	2.78	Y
Rio Vista Main WWTP (CA0079588)	0.164		X	X													X						X			0.47	0.65	Y
Tuolumne UD Sonora WWTP/ Jamestown WWTP (CA0084727)	0.182		X						X								X					X				0.16	2.6	Y
Discovery Bay WWTP (CA0078590)	0.191											X				X	X							X		1.5	2.1	Y
Colfax WWTP (CA0079529)	0.197	X												X									X			0.024	0.16	Y
Manteca WWTP (CA0081558)	0.216		X	X													X						X			4.6	8.11	Y***
San Andreas SD WWTP (CA0079464)	0.249		X						X								X						X			0.3	0.4	Y

Table 20: Municipal WWTP Treatment Processes in Place at the Time of Methylmercury Sampling

Agency (NPDES No.)	Ave EFF1 MeHg Conc (ng/l) [a]	Title 22 [b]	1. Primary Clarification	2. Activated Sludge	3. Pure Oxygen Act. Sludge	4. RBC's [c]	5. SBR's [c]	6. Fixed Film Reactors	7. Trickling Filters	8. Extended Aeration	9. Settling Ponds	10. Oxidation Ditch	11. Oxidation Ponds	12. Facultative Ponds	13. Lemna/Overland Flow	14. Nitrify / Denitrify	15. Secondary Clarification	16. Dissolved Air Flotation	17. Coagulation / Polymer	18. Microfiltration	19. Filtration	20. Chlorination	21. Chlorination / Dechlor.	22. Ultraviolet Radiation	23. Ozonation	Average Flow (mgd)	Design Maximum Flow (mgd) [e]	Systems in Place during MeHg 13267 sampling [d]
Yuba City WWTP (CA0079260)	0.295		X		X												X						X			5.22	7.0	Y
Merced WWTP (CA0079219)	0.386		X	X													X						X			8.5	10	Y
Mariposa PUD WWTP (CA0079430)	0.393											X					X						X			0.25	0.61	Y
Davis WWTP (CA0079049)	0.546	X	X										X		X								X			5.3	7.5	Y****
Live Oak WWTP (CA0079022)	0.591	X												X									X			1.65	1.6 / 5.9	Y
SRCSD Sacramento River WWTP (CA0077682)	0.613		X		X												X						X			151	181	Y
Placer Co. SA #28 Zone #6 WWTP (CA0079341)	0.668	X									X			X								X				0.01	0.1	Y
Stockton WWTP (CA0079138)	0.935		X						X				X								X		X			28	55	Y
Maxwell PUD WWTP (CA0079987)	0.993	X											X									X				0.14	0.2	Y****
Planada Comm. Service Dist. WWTP (CA0078950)	1.168										X			X							X	X				0.38	0.38	Y
Nevada Co SD #2 Lake of the Pines WWTP (CA0081612)	1.409	X												X			X		X		X		X			0.54	0.72	Y***
Williams WWTP (CA0077933)	1.553	X												X									X			0.44	0.5	Y****
Biggs WWTP (CA0078930)	1.605								X		X			X									X			0.38	0.53	Y
Rio Alto WD- Lake CA WWTP (CA0077852)	1.746											X					X				X		X			0.15	0.64	Y
SRCSD Walnut Grove WWTP (CSD1) (CA0078794)	2.155										X		X										X			0.08	0.5	Y
Colusa WWTP (CA0078999)	2.863	X									X				X								X			0.66	0.9	Y

[a] One-half of the method detection limit (MDL) was used in calculations for methylmercury concentration results that were less than the MDL.

[b] The California Department of Public Health (DPH) has developed reclamation criteria (CCR, Division 4, Chapter 3 (Title 22)) for the reuse of wastewater. Title 22 requires that for spray irrigation of food crops, parks, playgrounds, schoolyards, and other areas of similar public access, wastewater be adequately disinfected, oxidized, coagulated, clarified, and filtered, and that the effluent total coliform levels not exceed 2.2 MPN/100 mL as a 7-day median. The regulatory criteria include numerical limitations and requirements, treatment method requirements, and provisions and requirements related to sampling and analysis, engineering reports, design, operation, maintenance and reliability of facilities.

[c] RBC's: Rotating Biological Contactors SBR's: Sequencing Batch Reactors

[d] *Tertiary, no Title 22. ** No tertiary. *** No Title 22. **** No tertiary, no Title 22.

[e] If two values are provided, the first is design average dry weather flow and the second is design peak wet weather flow.

Table 21: Treatment Categories and Effluent Methylmercury Descriptive Statistics for the Municipal WWTPs

NPDES No.	WWTP	2005 Treatment Category [(a)]	# of Samples	# of Non-detect Samples	Average MeHg Conc. (ng/l)	Median MeHg Conc. (ng/l)	MeHg Conc. Range (ng/l)	Std. Deviation (ng/l)	Coefficient of Variation (%)
CA0077704	Anderson	Filtration + Chlor./ Dechlor.	12	2	0.090	0.067	ND - 0.271	0.084	93
CA0079197	Atwater	Secondary + Chlor./ Dechlor.	12	3	0.034	0.033	ND - 0.084	0.021	62
CA0077712	Auburn	N/D + Filtration + Chlor./ Dechlor.	12	6	0.028	0.023	ND - 0.072	0.021	75
CA0078930	Biggs	Pond + Chlor./ Dechlor.	2	0	1.605	1.605	0.150 - 3.060	2.058	128
CA0082660	Brentwood	N/D + Filtration + Chlor./ Dechlor.	13	13	*(all sample results < MDL)*				
CA0083682	Canada Cove LP French Camp	Filtration + Ozonation	4	0	0.147	0.134	0.029 - 0.291	0.127	86
CA0079081	Chico Regional	Secondary + Chlor./ Dechlor.	12	0	0.126	0.118	0.057 - 0.178	0.035	28
CA0079529	Colfax	Pond + Chlor./ Dechlor.	3	0	0.197	0.126	0.115 - 0.350	0.133	67
CA0078999	Colusa	Pond + Chlor./ Dechlor.	4	0	2.863	2.730	1.970 - 4.020	0.924	32
CA0004995	Corning Industries/ Domestic	Secondary + Chlor./ Dechlor.	2	0	0.044	0.044	0.034 - 0.053	0.013	31
CA0081507	Cottonwood	Filtration + Chlor./ Dechlor.	5	0	0.096	0.047	0.045 - 0.245	0.086	90
CA0079049	Davis (Discharge 1)	Pond + Chlor./ Dechlor.	7	0	0.546	0.533	0.305 - 1.040	0.252	46
CA0079049	Davis (Discharge 2)	Pond + Chlor./ Dechlor.	5	0	0.613	0.514	0.247 - 1.440	0.481	78
CA0078662	Deer Creek	N/D + Filtration + Chlor./ Dechlor.	13	11	0.015	0.013	ND - 0.032	0.006	41
CA0078093	Deuel Vocational Institute	Filtration + Chlor./ Dechlor.	3	3	*(all sample results < MDL)*				
CA0078590	Discovery Bay	Secondary w/ N/D + UV	12	7	0.191	0.013	ND - 2.030	0.579	303
CA0078671	El Dorado Hills (Discharge 1)	N/D + Filtration + Chlor./ Dechlor.	12	10	0.018	0.013	ND - 0.055	0.014	76
CA0078671	El Dorado Hills (Discharge 2)	N/D + Filtration + Chlor./ Dechlor.	2	2	*(all sample results < MDL)*				
CA0081434	Galt	Secondary + Chlor./ Dechlor.	6	0	0.139	0.142	0.027 - 0.220	0.068	49
CA0079898	Grass Valley	Secondary w/ N/D + Chlor./ Dechlor.	16	2	0.160	0.030	ND - 0.938	0.305	190
CA0079391	Jackson	Filtration + Chlor./ Dechlor.	4	0	0.108	0.104	0.061 - 0.161	0.041	38
CA0084476	Lincoln	N/D + Filtration + UV	7	6	0.018	0.010	ND - 0.068	0.022	120

Table 21: Treatment Categories and Effluent Methylmercury Descriptive Statistics for the Municipal WWTPs

NPDES No.	WWTP	2005 Treatment Category [(a)]	# of Samples	# of Non-detect Samples	Average MeHg Conc. (ng/l)	Median MeHg Conc. (ng/l)	MeHg Conc. Range (ng/l)	Std. Deviation (ng/l)	Coefficient of Variation (%)
CA0079022	Live Oak	Pond + Chlor./ Dechlor.	4	0	0.591	0.575	0.427 - 0.785	0.152	26
CA0079243	Lodi White Slough	Filtration + UV	12	4	0.128	0.025	ND - 1.240	0.351	275
CA0081558	Manteca	Secondary + Chlor./ Dechlor.	11	0	0.216	0.229	0.037 - 0.356	0.082	38
CA0079430	Mariposa PUD	Secondary + Chlor./ Dechlor.	4	0	0.393	0.309	0.040 - 0.912	0.417	106
CA0079987	Maxwell PUD	Pond + Chlor./ Dechlor.	4	0	0.993	1.104	0.044 - 1.720	0.849	86
CA0079219	Merced	Secondary + Chlor./ Dechlor.	12	0	0.386	0.369	0.130 - 0.672	0.156	40
CA0079103	Modesto	Pond + Chlor./ Dechlor.	9	0	0.130	0.118	0.108 - 0.170	0.025	19
CA0079901	Nevada City	Filtration + Chlor./ Dechlor.	4	2	0.048	0.018	ND - 0.146	0.066	137
CA0083241	Nevada Co SD #1 Cascade Shores	Filtration + Chlor./ Dechlor.	3	1	0.142	0.131	ND - 0.286	0.138	97
CA0077828	Nevada Co SD #1 Lake Wildwood	Filtration + Chlor./ Dechlor.	12	1	0.109	0.086	ND - 0.320	0.084	77
CA0081612	Nevada Co SD #2 Lake of the Pines	Pond + Filtration + Chlor./ Dechlor.	2	0	1.409	1.409	0.708 - 2.110	0.991	70
CA0077836	Olivehurst PUD	Secondary + Chlor./ Dechlor.	13	1	0.144	0.121	ND - 0.268	0.094	65
CA0079235	Oroville	Filtration + Chlor./ Dechlor.	12	0	0.147	0.148	0.061 - 0.280	0.072	49
CA0079341	Placer Co. SA #28 Zone #6	Pond + Chlor./ Dechlor.	2	0	0.668	0.668	0.474 - 0.862	0.274	41
CA0079316	Placer Co. SMD #1	Filtration + Chlor./ Dechlor.	12	0	0.141	0.142	0.042 - 0.350	0.092	65
CA0079367	Placer Co. SMD #3	Filtration + Chlor./ Dechlor.	12	0	0.100	0.069	0.037 - 0.381	0.095	95
CA0078956	Placerville Hangtown Creek	Filtration + Chlor./ Dechlor.	12	1	0.058	0.044	ND - 0.170	0.041	69
CA0078950	Planada Comm. Service Dist.	Pond + Filtration + Chlor./ Dechlor.	4	0	1.168	1.128	0.374 - 2.040	0.885	76
CA0078891	Red Bluff	Filtration + Chlor./ Dechlor.	12	6	0.027	0.025	ND - 0.057	0.018	67
CA0079731	Redding Clear Creek	Filtration + Chlor./ Dechlor.	12	3	0.042	0.039	ND - 0.084	0.024	57
CA0082589	Redding Stillwater	Filtration + Chlor./ Dechlor.	12	12	*(all sample results < MDL)*				
CA0077852	Rio Alto WD- Lake CA	Filtration + Chlor./ Dechlor.	2	0	1.746	1.746	0.141 - 3.350	2.269	130
CA0079588	Rio Vista Main	Secondary + Chlor./ Dechlor.	4	0	0.164	0.049	0.035 - 0.522	0.239	146
CA0079502	Roseville Dry Creek	N/D + Filtration + Chlor./ Dechlor.	12	4	0.023	0.021	ND - 0.055	0.014	60

Table 21: Treatment Categories and Effluent Methylmercury Descriptive Statistics for the Municipal WWTPs

NPDES No.	WWTP	2005 Treatment Category [a]	# of Samples	# of Non-detect Samples	Average MeHg Conc. (ng/l)	Median MeHg Conc. (ng/l)	MeHg Conc. Range (ng/l)	Std. Deviation (ng/l)	Coefficient of Variation (%)
CA0084573	Roseville Pleasant Grove	N/D + Filtration + Chlor./ Dechlor.	12	10	0.017	0.010	ND - 0.070	0.018	107
CA0079464	San Andreas SD	Secondary + Chlor./ Dechlor.	4	0	0.249	0.262	0.178 - 0.293	0.053	21
CA0082848	San Joaquin Co DPW - Flag City	Filtration + Chlor./ Dechlor.	3	1	0.081	0.078	ND - 0.152	0.070	86
CA0079511	Shasta Lake	Filtration + Chlor./ Dechlor.	2	1	0.022	0.022	ND - 0.034	0.017	77
CA0077682	SRCSD Sacramento River	Secondary + Chlor./ Dechlor.	108	0	0.613	0.551	0.118 - 1.640	0.336	55
CA0078794	SRCSD Walnut Grove	Pond + Chlor./ Dechlor.	2	0	2.155	2.155	0.949 - 3.36	1.705	79
CA0079138	Stockton	Pond + Filtration + Chlor./ Dechlor.	12	1	0.935	0.766	ND - 2.090	0.712	76
CA0079154	Tracy	Secondary + Chlor./ Dechlor.	13	1	0.145	0.132	ND - 0.422	0.104	72
CA0084727	Tuolumne UD Sonora / Jamestown	Secondary + Chlor./ Dechlor.	3	0	0.182	0.213	0.071 - 0.262	0.099	55
CA0078948	Turlock	Secondary + Chlor./ Dechlor.	12	1	0.059	0.062	ND - 0.079	0.019	32
CA0077895	UC Davis	N/D + Filtration + UV	12	3	0.038	0.030	ND - 0.078	0.025	65
CA0084697	United Auburn Indian Community Casino	N/D + Filtration + UV	2	2	*(all sample results < MDL)*				
CA0077691	Vacaville Easterly	Secondary + Chlor./ Dechlor.	12	4	0.024	0.024	ND - 0.057	0.014	57
CA0079171	West Sacramento	Secondary w/ N/D + Chlor./ Dechlor.	12	1	0.050	0.050	ND - 0.085	0.022	44
CA0077933	Williams	Pond + Chlor./ Dechlor.	4	0	1.553	1.775	0.560 - 2.100	0.691	45
CA0077950	Woodland	Secondary + Chlor./ Dechlor.	12	2	0.031	0.031	ND - 0.059	0.014	43
CA0079260	Yuba City	Secondary + Chlor./ Dechlor.	12	0	0.295	0.237	0.106 - 0.625	0.167	57

[a] Chlor./ Dechlor.: Chlorination and Dechlorination N/D: Nitrification/Denitrification UV: Ultraviolet radiation

Table 22: Description of Treatment Categories

2005 Treatment Category	Secondary Treatment	Nitrification/ Denitrification	Tertiary Treatment	Disinfection
Filtration + Chlor./ Dechlor.	Any	No	Yes	Chlorination/ Dechlorination
Filtration + Ozonation	Any	No	Yes	Ozonation
Filtration + UV	Any	No	Yes	Ultraviolet radiation
N/D + Filtration + Chlor./ Dechlor.	Any	Yes	Yes	Chlorination/ Dechlorination
N/D + Filtration + UV	Any	Yes	Yes	Ultraviolet radiation
Pond + Chlor./ Dechlor.	Treatment Pond (a)	No	No	Chlorination/ Dechlorination
Pond + Filtration + Chlor./ Dechlor.	Treatment Pond (a)	No	Yes	Chlorination/ Dechlorination
Secondary + Chlor./ Dechlor.	Any	No	No	Chlorination/ Dechlorination
Secondary w/ N/D + Chlor./ Dechlor.	Any	Yes	No	Chlorination/ Dechlorination
Secondary w/ N/D + UV	Any	Yes	No	Ultraviolet radiation

(a) The municipal WWTPs placed in the pond treatment categories use treatment pond systems (oxidation, facilitative, settling or stabilization ponds) as a significant part of their treatment process. These facilities may also use other types of secondary treatment in addition to the treatment ponds.

Table 23: Descriptive Statistics for the Effluent Methylmercury Concentrations for the Municipal WWTP Treatment Categories [a]

2005 Treatment Category	# of Facilities	# of samples	# of Non-detect samples	Ave. Effluent MeHg Conc. (ng/l)	Median Effluent MeHg Conc. (ng/l)	MeHg Conc. Range (ng/l)	Standard Error (ng/l) [b]	95% Conf. Interval (ng/l)	P_{25} (ng/l) [c]	P_{75} (ng/l) [d]	IQR (ng/l) [e]	g [f]	Shapiro-Wilk p-value [g]
Filtration + Chlor./ Dechlor.	17	134	33	0.105	0.056	ND - 3.350	0.025	0.050	0.025	0.113	0.088	10.39	<0.0001
Filtration + Ozonation	1	4	0	0.147	0.134	0.029 - 0.291	0.063	0.202	0.035	0.272	0.237	0.27	0.39
Filtration + UV	1	12	4	0.128	0.025	ND - 1.240	0.101	0.223	0.010	0.049	0.039	3.45	<0.00001
N/D + Filtration + Chlor./ Dechlor.	6	76	56	0.018	0.013	ND - 0.072	0.002	0.003	0.010	0.020	0.010	2.14	<0.00001
N/D + Filtration + UV	3	21	11	0.029	0.020	ND - 0.078	0.005	0.011	0.010	0.040	0.030	1.16	<0.001
Pond + Chlor./ Dechlor.	10	46	0	0.902	0.522	0.044 - 4.020	0.147	0.296	0.158	1.485	1.327	1.58	<0.00001
Pond + Filtration + Chlor./ Dechlor.	3	18	1	1.040	0.806	ND - 2.110	0.175	0.369	0.388	1.830	1.442	0.23	<0.05
Secondary + Chlor./ Dechlor.	17	252	12	0.351	0.243	ND - 1.640	0.021	0.042	0.076	0.537	0.461	1.39	<0.00001
Secondary w/ N/D + Chlor./ Dechlor.	2	28	3	0.113	0.045	ND - 0.938	0.044	0.091	0.028	0.085	0.057	3.41	<0.00001
Secondary w/ N/D + UV	1	12	7	0.191	0.013	ND - 2.030	0.167	0.368	0.013	0.050	0.037	3.99	<0.00001

[a] One-half of the MDL was used in calculations for methylmercury concentration results that were less than the MDL.
[b] The standard error is estimated standard deviation of the sample mean. It is calculated by dividing the sample standard deviation by the square root of the sample size.
[c] The 25th percentile (P_{25}) is a value which exceeds no more than 25 percent of the data and is exceeded by no more than 75 percent.
[d] The 75th percentile (P_{75}) is a value which exceeds no more than 75 percent of the data and is exceeded by no more than 25 percent.
[e] The interquartile range (IQR) is the 75th percentile minus the 25th percentile. The IQR is a measure of variability that is more resistant to outliers than the standard deviation.
[f] A positive coefficient of skewness (g) indicates that the distribution is right-skewed (i.e. the distribution is asymmetric with extreme values extending out longer to the right side or larger value side). Conversely, a negative coefficient of skewness indicates that the distribution is left-skewed. As the coefficient of skewness increases from zero in either the negative or positive direction, the more extreme the skewness of the distribution.
[g] If the Shapiro-Wilk W statistic is statistically significant (p-value is less than 0.05), then the hypothesis that the data distribution is normal is rejected. Therefore, a p-value less than 0.05 indicates that the distribution is most likely not normal.

Table 24: Kruskal-Wallis Multiple Comparison Results for Median Effluent Methylmercury Concentrations of the Treatment Categories

2005 Treatment Category [a]	Average Effluent MeHg Conc. (ng/l)	Median Effluent MeHg Conc. (ng/l)	Comparison p-values [b]								
			N/D + Filtration + Chlor./ Dechlor.	Secondary w/ N/D + UV	N/D + Filtration + UV	Filtration + UV	Secondary w/ N/D + Chlor./ Dechlor.	Filtration + Chlor./ Dechlor.	Secondary + Chlor./ Dechlor.	Pond + Chlor./ Dechlor.	Pond + Filtration + Chlor./ Dechlor.
N/D + Filtration + Chlor./ Dechlor.	0.018	0.013	--	1.0000	1.0000	1.0000	***0.0218***	***0.0000***	***0.0000***	***0.0000***	***0.0000***
Secondary w/ N/D + UV	0.191	0.013	1.0000	--	1.0000	1.0000	1.0000	1.0000	***0.0022***	***0.0000***	***0.0000***
N/D + Filtration + UV	0.029	0.020	1.0000	1.0000	--	1.0000	1.0000	0.2168	***0.0000***	***0.0000***	***0.0000***
Filtration + UV	0.128	0.025	1.0000	1.0000	1.0000	--	1.0000	1.0000	***0.0008***	***0.0000***	***0.0000***
Secondary w/ N/D + Chlor./ Dechlor.	0.113	0.045	***0.0218***	1.0000	1.0000	1.0000	--	1.0000	***0.0002***	***0.0000***	***0.0000***
Filtration + Chlor./ Dechlor.	0.105	0.056	***0.0000***	1.0000	0.2168	1.0000	1.0000	--	***0.0000***	***0.0000***	***0.0000***
Secondary + Chlor./ Dechlor.	0.351	0.243	***0.0000***	***0.0022***	***0.0000***	***0.0008***	***0.0002***	***0.0000***	--	***0.0488***	0.2101
Pond + Chlor./ Dechlor.	0.902	0.522	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0488***	--	1.0000
Pond + Filtration + Chlor./ Dechlor.	1.040	0.806	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	0.2101	1.0000	--

[a] Due to the small sample size and unusual treatment type, the "Filtration + Ozonation" treatment category was not included in this analysis.

[b] The comparison p-values between pairs were calculated with Statistica software. The p-values are two-sided significance levels multiplied by the number of possible combination pairs [k*(k-1)/2, where k is the total number of groups in the comparison]. The number of possible combination pairs in this comparison analysis is 36. P-values less than 0.05 are highlighted in ***bold and italics*** to identify statistically significant differences between treatment categories.

Table 25: Subcategories Based upon Secondary Treatment for the Municipal WWTPs

NPDES No.	WWTP	2005 Secondary Treatment Subcategory
Secondary + Chlor./ Dechlor.		
CA0079197	Atwater	Activated Sludge
CA0079081	Chico Regional	Activated Sludge
CA0004995	Corning Industries/ Domestic	Activated Sludge
CA0081434	Galt	Activated Sludge
CA0081558	Manteca	Activated Sludge
CA0079430	Mariposa PUD	Activated Sludge
CA0079219	Merced	Activated Sludge
CA0077836	Olivehurst PUD	Activated Sludge
CA0079588	Rio Vista Main	Activated Sludge
CA0079464	San Andreas SD	Fixed Media
CA0077682	SRCSD Sacramento River	Activated Sludge
CA0079154	Tracy	Activated Sludge + Trickling Filter
CA0084727	Tuolumne UD Sonora / Jamestown	Fixed Media
CA0078948	Turlock	Activated Sludge
CA0077691	Vacaville Easterly	Activated Sludge
CA0077950	Woodland	Activated Sludge
CA0079260	Yuba City	Activated Sludge
Filtration + Chlor./ Dechlor.		
CA0077704	Anderson	Activated Sludge
CA0081507	Cottonwood	Activated Sludge
CA0078093	Deuel Vocational Institute	Activated Sludge
CA0079391	Jackson	Activated Sludge
CA0079901	Nevada City	Activated Sludge
CA0083241	Nevada Co SD #1 Cascade Shores	Activated Sludge
CA0077828	Nevada Co SD #1 Lake Wildwood	Activated Sludge
CA0079235	Oroville	Activated Sludge
CA0079316	Placer Co. SMD #1	Fixed Media
CA0079367	Placer Co. SMD #3	Fixed Media
CA0078956	Placerville Hangtown Creek	Activated Sludge + Trickling Filter
CA0078891	Red Bluff	Activated Sludge
CA0079731	Redding Clear Creek	Activated Sludge
CA0082589	Redding Stillwater	Activated Sludge
CA0077852	Rio Alto WD- Lake CA	Activated Sludge
CA0082848	San Joaquin Co DPW - Flag City	Activated Sludge
CA0079511	Shasta Lake	Activated Sludge

Table 26: Descriptive Statistics for the Effluent Methylmercury Concentrations for the Municipal WWTP Subcategories [a]

2005 Secondary Treatment Subcategory	# of Facilities	# of samples	# of Non-detect samples	Ave. Effluent MeHg Conc. (ng/l)	Median Effluent MeHg Conc. (ng/l)	MeHg Conc. Range (ng/l)	Standard Error (ng/l) [b]	95% Conf. Interval (ng/l)	P_{25} (ng/l) [c]	P_{75} (ng/l) [d]	IQR (ng/l) [e]	g [f]	Shapiro-Wilk p-value [g]
Secondary + Chlor./ Dechlor.													
Activated Sludge	14	232	11	0.367	0.258	ND - 1.640	0.023	0.045	0.073	0.552	0.479	1.29	<0.00001
Activated Sludge + Trickling Filter	1	13	1	0.145	0.132	ND - 0.422	0.029	0.063	0.080	0.181	0.101	1.55	0.062
Fixed Media	2	7	0	0.220	0.239	0.071 - 0.293	0.029	0.071	0.178	0.285	0.107	-1.35	0.25
Filtration + Chlor./ Dechlor.													
Activated Sludge	14	98	32	0.107	0.048	ND - 3.350	0.034	0.068	0.013	0.100	0.087	9.20	<0.0001
Activated Sludge + Trickling Filter	1	12	1	0.058	0.044	ND - 0.170	0.012	0.026	0.039	0.062	0.023	2.14	<0.01
Fixed Media	2	24	0	0.121	0.078	0.037 - 0.381	0.019	0.040	0.050	0.151	0.101	1.64	<0.001

[a] One-half of the MDL was used in calculations for methylmercury concentration results that were less than the MDL.

[b] The standard error is estimated standard deviation of the sample mean. It is calculated by dividing the sample standard deviation by the square root of the sample size.

[c] The 25th percentile (P_{25}) is a value which exceeds no more than 25 percent of the data and is exceeded by no more than 75 percent.

[d] The 75th percentile (P_{75}) is a value which exceeds no more than 75 percent of the data and is exceeded by no more than 25 percent.

[e] The interquartile range (IQR) is the 75th percentile minus the 25th percentile. The IQR is a measure of variability that is more resistant to outliers than the standard deviation.

[f] A positive coefficient of skewness (g) indicates that the distribution is right-skewed (i.e. the distribution is asymmetric with extreme values extending out longer to the right side or larger value side). Conversely, a negative coefficient of skewness indicates that the distribution is left-skewed. As the coefficient of skewness increases from zero in either the negative or positive direction, the more extreme the skewness of the distribution.

[g] If the Shapiro-Wilk W statistic is statistically significant (p-value is less than 0.05), then the hypothesis that the data distribution is normal is rejected. Therefore, a p-value less than 0.05 indicates that the distribution is most likely not normal.

Table 27: Kruskal-Wallis Multiple Comparison Results for Median Effluent Methylmercury Concentrations of the Subcategories within the "Filtration + C/D" category

2005 Secondary Treatment Subcategory	Average (ng/l)	Median (ng/l)	Comparison p-values [(a)]		
			Activated Sludge + Trickling Filter	Activated Sludge	Fixed Media
Activated Sludge + Trickling Filter	0.058	0.044	--	1.0000	0.1556
Activated Sludge	0.107	0.048	1.0000	--	***0.0078***
Fixed Media	0.121	0.078	0.1556	***0.0078***	--

[(a)] The comparison p-values between pairs were calculated with Statistica software. The p-values are two-sided significance levels multiplied by the number of possible combination pairs [k*(k-1)/2, where k is the total number of groups in the comparison]. The number of possible combination pairs in this comparison analysis is 3. P-values less than 0.05 are highlighted in ***bold and italics*** to identify statistically significant differences between treatment categories.

Table 28: Two-sided Significance Levels (p-values) for WWTP Treatment Subcategories [(a)]

2005 Treatment Subcategory	Two sample t-test	Mann-Whitney U test
Activated Sludge	<0.0001 [(b)]	<0.0001
Activated Sludge + Trickling Filter	0.014 [(c)]	0.011
Fixed Media	0.015 [(c)]	0.009

[(a)] When comparing the same subcategory within the "Filtration + C/D" and "Secondary + C/D" categories.
[(b)] P-value for two sample t-test assuming equal variances.
[(c)] P-value for two sample t-test assuming unequal variances.

Table 29: Kruskal-Wallis Multiple Comparison Results for Median Effluent:Influent Methylmercury Ratios of the Treatment Categories

2005 Treatment Category [a]	Average Effluent:Influent MeHg Ratio	Median Effluent:Influent MeHg Ratio	Comparison p-values [b]						
			N/D + Filtration + Chlor./ Dechlor.	N/D + Filtration + UV	Filtration + Chlor./ Dechlor.	Filtration + UV	Secondary w/ N/D + Chlor./ Dechlor.	Secondary + Chlor./ Dechlor.	Pond + Chlor./ Dechlor.
N/D + Filtration + Chlor./ Dechlor.	2.4%	1.2%	--	1.0000	1.0000	1.0000	1.0000	***0.0000***	***0.0000***
N/D + Filtration + UV	2.7%	1.5%	1.0000	--	1.0000	1.0000	1.0000	***0.0000***	***0.0019***
Filtration + Chlor./ Dechlor.	4.1%	1.6%	1.0000	1.0000	--	1.0000	1.0000	***0.0109***	***0.0365***
Filtration + UV	6.0%	2.0%	1.0000	1.0000	1.0000	--	1.0000	***0.0004***	***0.0153***
Secondary w/ N/D + Chlor./ Dechlor.	10.2%	2.1%	1.0000	1.0000	1.0000	1.0000	--	***0.0006***	***0.0344***
Secondary + Chlor./ Dechlor.	36.8%	28.1%	***0.0000***	***0.0000***	***0.0109***	***0.0004***	***0.0006***	--	1.0000
Pond + Chlor./ Dechlor.	65.5%	36.4%	***0.0000***	***0.0019***	***0.0365***	***0.0153***	***0.0344***	1.0000	--

[a] The "Pond + Filtration + Chlor./ Dechlor." treatment category was not included in this analysis due to it having a sample size of one. Additionally, the "Secondary w/ N/D + UV" and "Filtration + Ozonation" treatment categories were not included since the facilities with these treatment types did not collect influent samples.

[b] The comparison p-values between pairs were calculated with Statistica software. The p-values are two-sided significance levels multiplied by the number of possible combination pairs [k*(k-1)/2, where k is the total number of groups in the comparison]. The number of possible combination pairs in this comparison analysis is 21. P-values less than 0.05 are highlighted in ***bold and italics*** to identify statistically significant differences between treatment categories.

Table 30: Regression Coefficients (R^2) and Two-sided Significance Levels (p-values) for Influent versus Effluent Methylmercury Concentration Scatter Plots for Each WWTP with Five or More Paired Data Points. [Significant relationships are in bold.]

NPDES #	WWTP	# of paired data points	R^2 value for linear regression	p-value for linear regression
CA0079081	Chico	11	0.026	0.636
CA0078662	Deer Creek	13	0.2374	0.091
CA0078671	El Dorado Hills (Discharge 1)	12	0.0832	0.363
CA0079898	Grass Valley	16	0.0092	0.724
CA0079243	**Lodi**	**12**	**0.4037**	**0.026**
CA0079502	Roseville Dry Creek	9	0.086	0.444
CA0084573	Roseville Pleasant Grove	9	0.02	0.717
CA0077682	**SRCSD Sacramento River**	**107**	**0.1739**	**0.000008**
CA0077895	**UC Davis**	**12**	**0.3875**	**0.031**
CA0077950	Woodland	12	0.0643	0.426

Table 31: Kruskal-Wallis Multiple Comparison Results for Median Effluent Methylmercury:Total Mercury Ratios of the Treatment Categories

2005 Treatment Category [a]	Average Effluent MeHg:THg Ratio	Median Effluent MeHg:THg Ratio	Comparison p-values [b]							
			Secondary w/ N/D + UV	N/D + Filtration + Chlor./ Dechlor.	Filtration + UV	Secondary w/ N/D + Chlor./ Dechlor.	Filtration + Chlor./ Dechlor.	Secondary + Chlor./ Dechlor.	Pond + Chlor./ Dechlor.	Pond + Filtration + Chlor./ Dechlor.
Secondary w/ N/D + UV	0.6%	0.5%	--	1.0000	1.0000	1.0000	***0.0415***	***0.0001***	***0.0002***	***0.0000***
N/D + Filtration + Chlor./ Dechlor.	1.2%	0.9%	1.0000	--	1.0000	1.0000	***0.0146***	***0.0000***	***0.0000***	***0.0000***
Filtration + UV	3.6%	1.0%	1.0000	1.0000	--	1.0000	1.0000	***0.0068***	***0.0095***	***0.0000***
Secondary w/ N/D + Chlor./ Dechlor.	1.8%	1.2%	1.0000	1.0000	1.0000	--	1.0000	0.1489	0.1196	***0.0002***
Filtration + Chlor./ Dechlor.	4.0%	2.9%	***0.0415***	***0.0146***	1.0000	1.0000	--	0.1234	0.3376	***0.0001***
Secondary + Chlor./ Dechlor.	6.7%	5.6%	***0.0001***	***0.0000***	***0.0068***	0.1489	0.1234	--	1.0000	***0.0225***
Pond + Chlor./ Dechlor.	11.0%	5.8%	***0.0002***	***0.0000***	***0.0095***	0.1196	0.3376	1.0000	--	0.7644
Pond + Filtration + Chlor./ Dechlor.	18.8%	16.9%	***0.0000***	***0.0000***	***0.0000***	***0.0002***	***0.0001***	***0.0225***	0.7644	--

[a] The "N/D + Filtration + UV" treatment category was not included in this analysis due to it having a sample size of one. Additionally, the "Filtration + Ozonation" treatment category was not included since the one facility with this treatment type did not collect influent samples.

[b] The comparison p-values between pairs were calculated with Statistica software. The p-values are two-sided significance levels multiplied by the number of possible combination pairs [k*(k-1)/2, where k is the total number of groups in the comparison]. The number of possible combination pairs in this comparison analysis is 36. P-values less than 0.05 are highlighted in ***bold and italics*** to identify statistically significant differences between treatment categories.

Table 32: Regression Coefficients (R^2) and Two-sided Significance Levels (p-values) for Inorganic Mercury versus Methylmercury Effluent Concentration Scatter Plots for Each WWTP with Five or More Paired Data Points. [Significant relationships are in bold.]

NPDES #	WWTP	# of paired data points	R^2 value for linear regression	p-value for linear regression
CA0082660	Brentwood	13	*all MeHg values are nondetect*	
CA0079049	**Davis (Discharges 1 & 2)**	**12**	**0.4445**	**0.018**
CA0078590	**Discovery Bay**	**9**	**0.551**	**0.022**
CA0079243	Lodi	12	0.0513	0.479
CA0081558	Manteca	11	0.2412	0.125
CA0079103	Modesto	9	0.0351	0.629
CA0079316	Placer Co. SMD #1	11	0.0383	0.564
CA0079367	Placer Co. SMD #3	12	0.0009	0.926
CA0079731	Redding Clear Creek	12	0.0055	0.819
CA0082589	Redding Stillwater	12	*all MeHg values are nondetect*	
CA0079502	Roseville Dry Creek	10	0.002	0.902
CA0084573	Roseville Pleasant Grove	11	0.0122	0.746
CA0077682	**SRCSD Sacramento River**	**106**	**0.0775**	**0.004**
CA0079138	**Stockton**	**12**	**0.67**	**0.001**
CA0079154	Tracy	13	0.0303	0.570
CA0078948	Turlock	12	0.0342	0.565
CA0077691	Vacaville Easterly	12	0.00009	0.977
CA0079171	West Sacramento	11	0.0161	0.710
CA0077950	Woodland	12	0.1906	0.156
CA0079260	Yuba City	12	0.1172	0.276

Table 33: Regression Coefficients (R^2) and Two-sided Significance Levels (p-values) for Influent Inorganic Mercury versus Effluent Methylmercury Concentration Scatter Plots for Each WWTP with Five or More Paired Data Points.

NPDES #	WWTP	# of paired data points	R^2 value for linear regression	p-value for linear regression
CA0079243	Lodi	12	0.0121	0.734
CA0079502	Roseville Dry Creek	9	0.1328	0.335
CA0084573	Roseville Pleasant Grove	9	0.1079	0.388
CA0077682	SRCSD Sacramento River	73	0.0017	0.729
CA0077950	Woodland	6	0.1403	0.464

Table 34: Regression Coefficients (R^2) and Two-sided Significance Levels (p-values) for Influent versus Effluent Inorganic Mercury Concentration Scatter Plots for Each WWTP with Five or More Paired Data Points

NPDES #	WWTP	# of paired data points	R^2 value for linear regression	p-value for linear regression
CA0079243	Lodi	12	0.1257	0.258
CA0079502	Roseville Dry Creek	9	0.0036	0.878
CA0084573	Roseville Pleasant Grove	9	0.1029	0.400
CA0077682	SRCSD Sacramento River	228	0.0004	0.764
CA0077950	Woodland	6	0.0117	0.838

Table 35: Sum of Annual Total Mercury Loads (g/yr) Discharged by Facilities within Each Discharger Category for NPDES Facilities in the Delta Source Region Downstream of Major Dams

Facility Type	Proximity to Delta/Yolo Bypass		Total
	Delta/ Yolo Bypass	Upstream of Delta/ Yolo Bypass	
Aggregate & Lake Dewatering	37	26	**63**
Drinking Water Treatment		6.4	**6.4**
Groundwater Remediation	0.36	48.3	**49**
Manufacturing		18	**18**
Municipal WWTP	2,348	1,085	**3,435**
Paper Mill / Saw Mills		16	**16**
Power Generation	0.27		**0.27**
Power/Domestic WWTP		0.10	**0.10**
Publishing		0.62	**0.62**
Total	**2,386**	**1,200**	**3,586**
% of Total Loads			
Aggregate & Lake Dewatering	1.0%	0.7%	**1.8%**
Drinking Water Treatment		0.2%	**0.18%**
Groundwater Remediation	0.01%	1.35%	**1.4%**
Manufacturing		0.5%	**0.5%**
Municipal WWTP	65.5%	30.3%	**95.7%**
Paper Mill / Saw Mills		0.45%	**0.45%**
Power Generation	0.008%		**0.008%**
Power/Domestic WWTP		0.003%	**0.003%**
Publishing		0.02%	**0.02%**
Total	**67%**	**33%**	**100%**

Table 36: Sum of Annual Methylmercury Loads (g/yr) Discharged by Facilities within Each Discharger Category for NPDES Facilities in the Delta Source Region Downstream of Major Dams

Facility Type	Proximity to Delta/Yolo Bypass		Total
	Delta/ Yolo Bypass	Upstream of Delta/ Yolo Bypass	
Aggregate & Lake Dewatering	0.38	0.055	**0.44**
Drinking Water Treatment		0.040	**0.040**
Food Processing		0.040	**0.040**
Groundwater Remediation	0.011	0.23	**0.24**
Laboratory		0.0047	**0.0047**
Manufacturing		0.14	**0.14**
Mines		0.0048	**0.0048**
Municipal WWTP	204.3	23.4	**228**
Paper Mill / Saw Mills		0.22	**0.22**
Power Generation	0.0019		**0.0019**
Power/Domestic WWTP		0.0050	**0.0050**
Publishing		0.0041	**0.0041**
Total	**204.7**	**23.7**	**229**
% of Total Loads			
Aggregate & Lake Dewatering	0.2%	0.02%	**0.2%**
Drinking Water Treatment		0.02%	**0.02%**
Food Processing		0.02%	**0.02%**
Groundwater Remediation	0.005%	0.1%	**0.1%**
Laboratory		0.002%	**0.002%**
Manufacturing		0.06%	**0.06%**
Mines		0.002%	**0.002%**
Municipal WWTP	89.3%	10.2%	**99.5%**
Paper Mill / Saw Mills		0.1%	**0.1%**
Power Generation	0.001%		**0.001%**
Power/Domestic WWTP		0.002%	**0.002%**
Publishing		0.002%	**0.002%**
Total	**89%**	**11%**	**100%**

Table 37: Comparison of Annual Methylmercury Loads (g/yr) Discharged by NPDES Facilities to The Sum of All Point and Nonpoint Source Methylmercury Loading to Each Delta Subarea Identified in The February 2010 Delta TMDL Staff Report (Wood *et al*., 2010b, Table 8.4)

Delta Subarea	**Proximity to Delta**		**Total NPDES Facility Load**	**Sum of MeHg Point and Nonpoint Source MeHg Loads to Each Subarea** [Delta TMDL Report Table 8.4]	**Total NPDES Facility Load as % of Sum of All Point and Nonpoint MeHg Loads**
	Delta/ Yolo Bypass	Upstream of Delta/ Yolo Bypass			
Central	1.3	*[none]*	1.3	668	0.2%
Marsh Creek	0.086	*[none]*	0.086	6.14	1.4%
Mokelumne	*[none]*	0.55	0.55	146	0.4%
Sacramento	163	13	176	2,475	7.1%
San Joaquin	39.6	8.6	48	528	9.1%
West	0.0019	none	0.0019	330	0.001%
Yolo Bypass	1.0	1.7	2.7	1,068	0.3%
TOTAL	**205**	**24**	**229**	**5,221**	**4.4%**

[(a)] Because calculations were completed prior to rounding, some columns may not add to totals shown in Table 36 of this report or Table 6.2 in the TMDL Report.

FIGURES

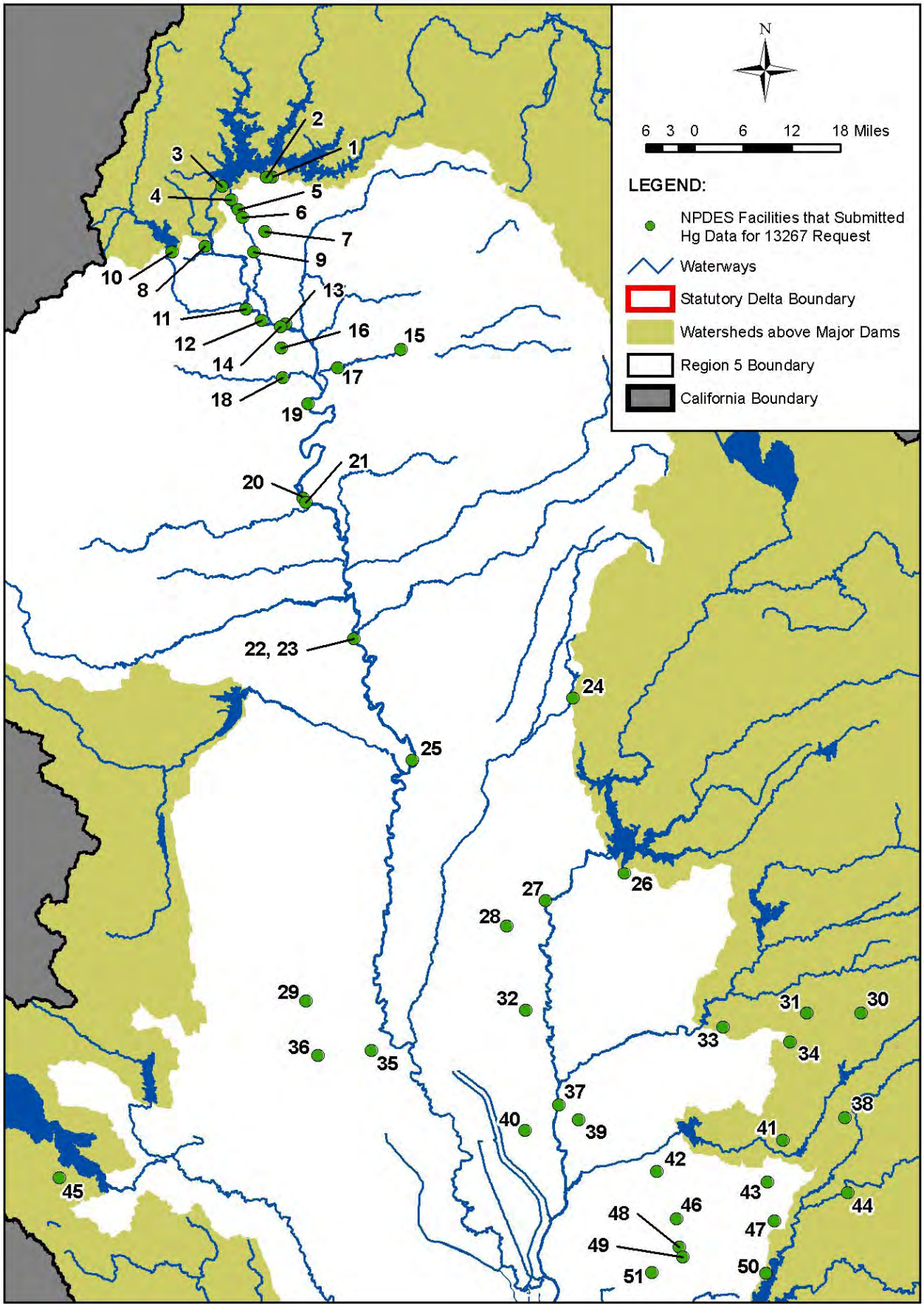

Figure 1: Location of NPDES Facilities (North Panel) [Table 16 defines facility codes]

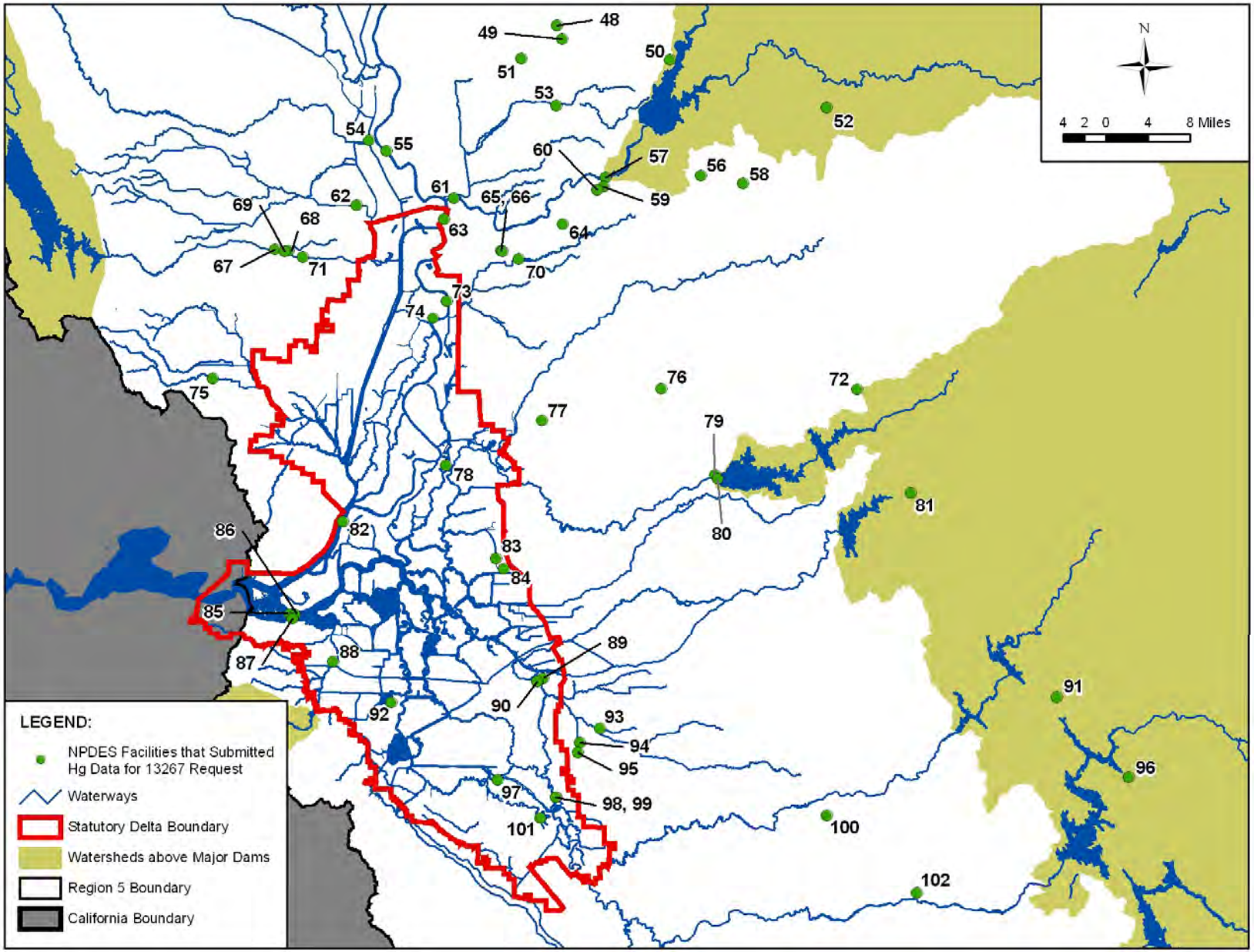

Figure 2: Location of NPDES Facilities (Central Panel) [Table 16 defines facility codes]

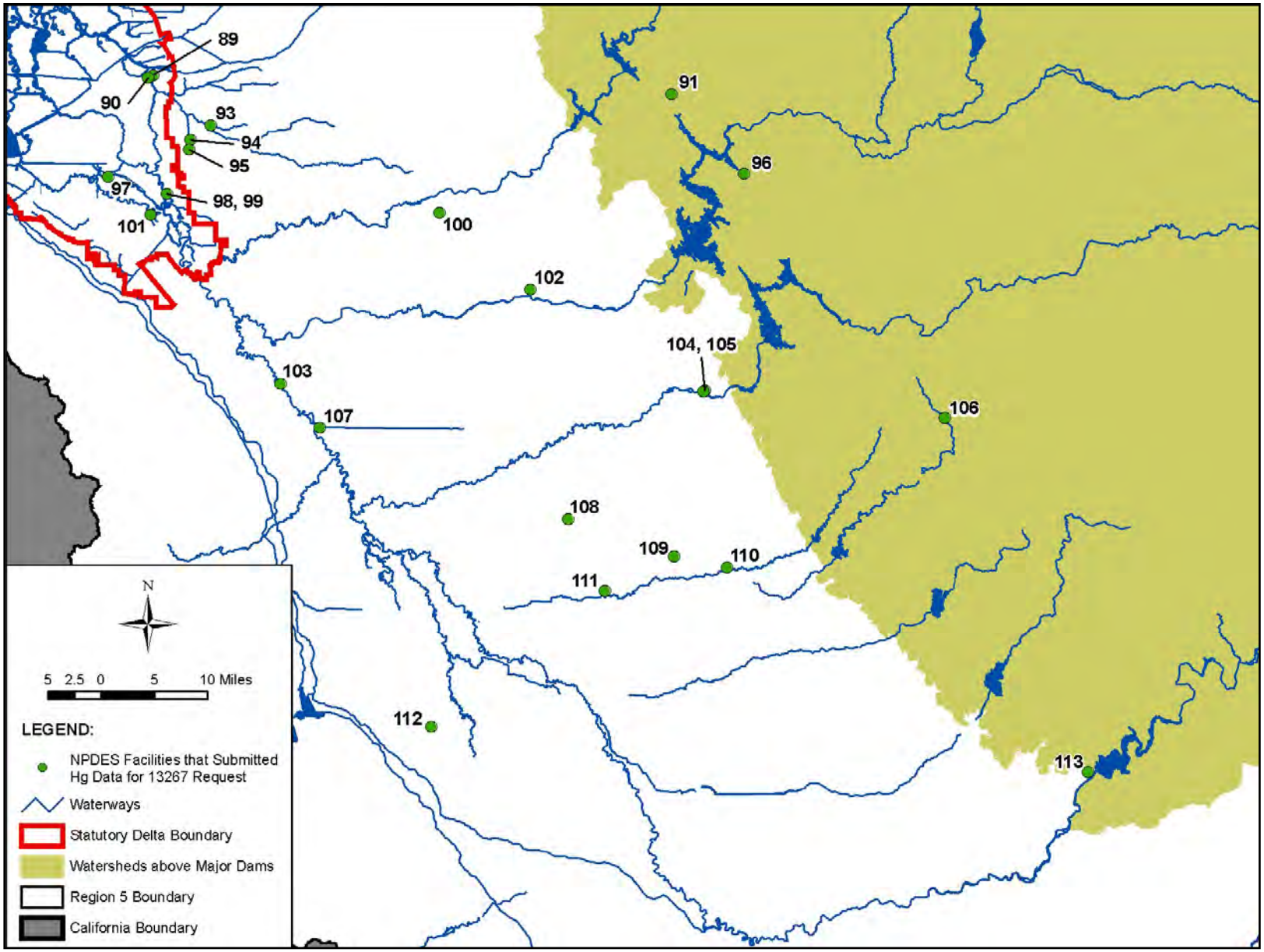

Figure 3: Location of NPDES Facilities (South Panel) [Table 16 defines facility codes]

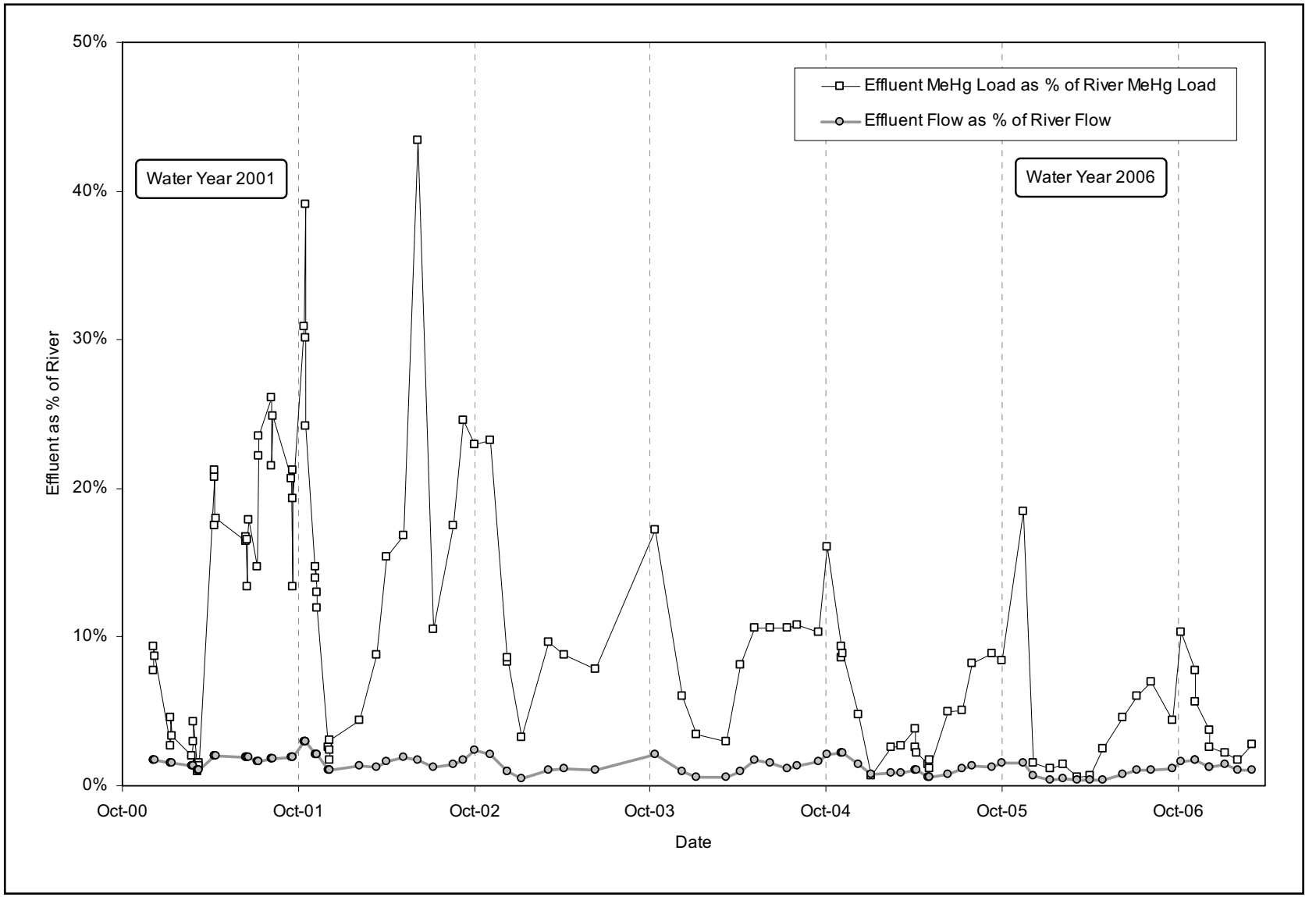

Figure 4: SRCSD Sacramento River WWTP Effluent Methylmercury Load and Flow as a Percent of Sacramento River Methylmercury Load and Flow for Water Years (WY) 2001-2007

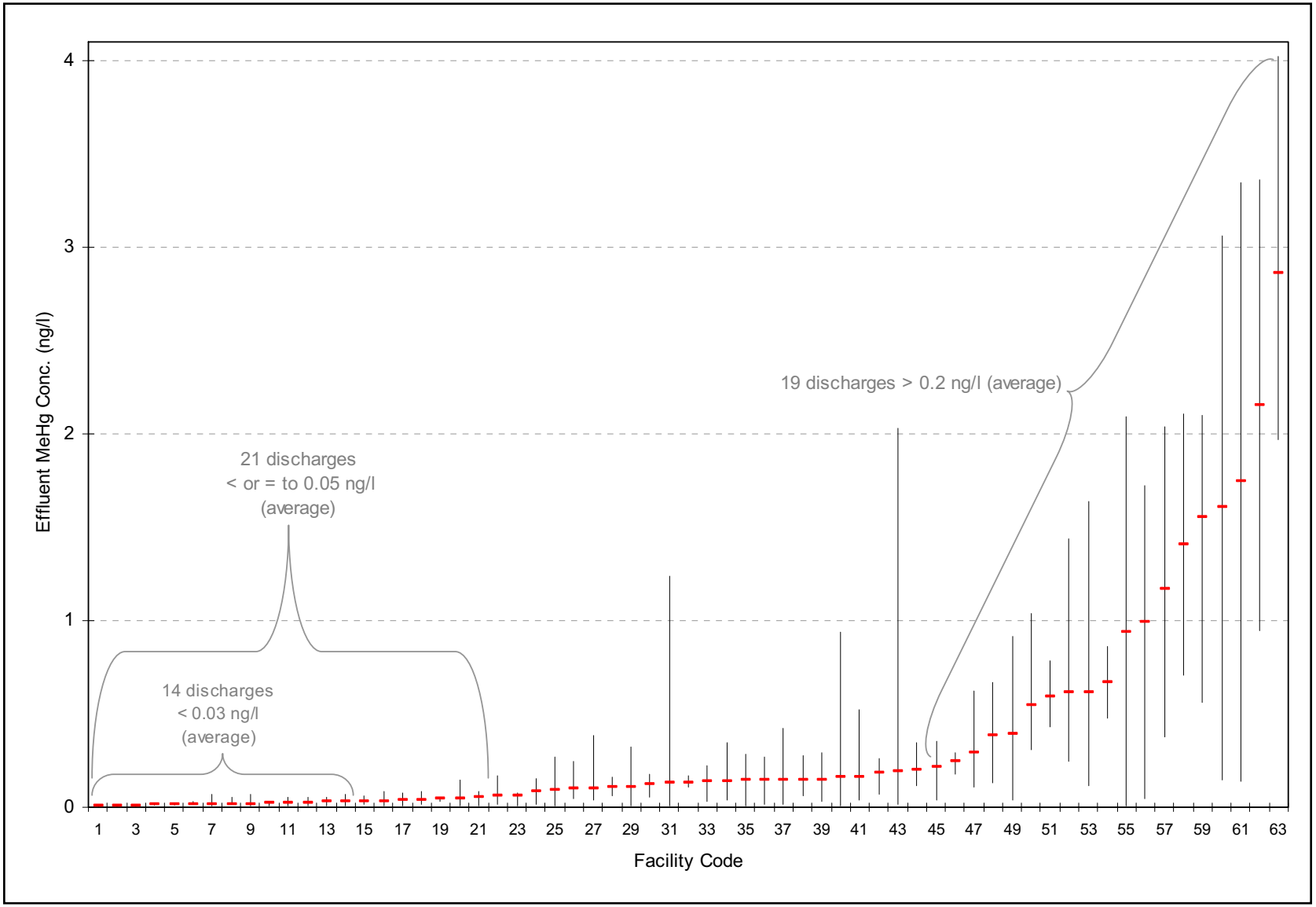

Figure 5: Average and Range of Effluent Methylmercury Concentrations for Each of the Municipal WWTP Discharges

Facility Codes Used in Figures 5 and 10 [(a)]

Facility Code	NPDES No.	Facility
1	CA0082660	Brentwood WWTP
2	CA0078093	Deuel Vocational Institute WWTP
3	CA0084697	United Auburn Indian Community Casino WWTP
4	CA0078671	El Dorado Hills WWTP (Discharge 2)
5	CA0082589	Redding Stillwater WWTP
6	CA0078662	Deer Creek WWTP
7	CA0084573	Roseville Pleasant Grove WWTP
8	CA0078671	El Dorado Hills WWTP (Discharge 1)
9	CA0084476	Lincoln WWTP
10	CA0079511	Shasta Lake WWTP
11	CA0079502	Roseville Dry Creek WWTP
12	CA0077691	Vacaville Easterly WWTP
13	CA0078891	Red Bluff WWTP
14	CA0077712	Auburn WWTP
15	CA0077950	Woodland WWTP
16	CA0079197	Atwater WWTP
17	CA0077895	UC Davis WWTP
18	CA0079731	Redding Clear Creek WWTP
19	CA0004995	Corning Industries/ Domestic WWTP
20	CA0079901	Nevada City WWTP
21	CA0079171	West Sacramento WWTP
22	CA0078956	Placerville Hangtown Creek WWTP
23	CA0078948	Turlock WWTP
24	CA0082848	San Joaquin Co DPW - Flag City WWTP
25	CA0077704	Anderson WWTP
26	CA0081507	Cottonwood WWTP
27	CA0079367	Placer Co. SMD #3 WWTP
28	CA0079391	Jackson WWTP
29	CA0077828	Nevada Co SD #1 Lake Wildwood WWTP
30	CA0079081	Chico Regional WWTP
31	CA0079243	Lodi White Slough WWTP
32	CA0079103	Modesto WWTP
33	CA0081434	Galt WWTP
34	CA0079316	Placer Co. SMD #1 WWTP
35	CA0083241	Nevada Co SD #1 Cascade Shores WWTP
36	CA0077836	Olivehurst PUD WWTP
37	CA0079154	Tracy WWTP
38	CA0079235	Oroville WWTP
39	CA0083682	Canada Cove LP French Camp Golf & RV Park WWTP
40	CA0079898	Grass Valley WWTP

Facility Codes Used in Figures 5 and 10 [(a)]

Facility Code	NPDES No.	Facility
41	CA0079588	Rio Vista Main WWTP
42	CA0084727	Tuolumne UD Sonora RWTP/ Jamestown SDWTP
43	CA0078590	Discovery Bay WWTP
44	CA0079529	Colfax WWTP
45	CA0081558	Manteca WWTP
46	CA0079464	San Andreas SD WWTP
47	CA0079260	Yuba City WWTP
48	CA0079219	Merced WWTP
49	CA0079430	Mariposa PUD WWTP
50	CA0079049	Davis WWTP (Discharge 1)
51	CA0079022	Live Oak WWTP
52	CA0079049	Davis WWTP (Discharge 2)
53	CA0077682	SRCSD Sacramento River WWTP
54	CA0079341	Placer Co. SA #28 Zone #6 WWTP
55	CA0079138	Stockton WWTP
56	CA0079987	Maxwell PUD WWTP
57	CA0078950	Planada Comm. Service Dist. WWTP
58	CA0081612	Nevada Co SD #2 Lake of the Pines WWTP
59	CA0077933	Williams WWTP
60	CA0078930	Biggs WWTP
61	CA0077852	Rio Alto WD- Lake CA WWTP
62	CA0078794	SRCSD Walnut Grove WWTP (CSD1)
63	CA0078999	Colusa WWTP

[(a)] Facilities are sorted by lowest to highest average effluent methylmercury concentration. Some facilities have multiple discharge locations, effluent from which may undergo different treatments.

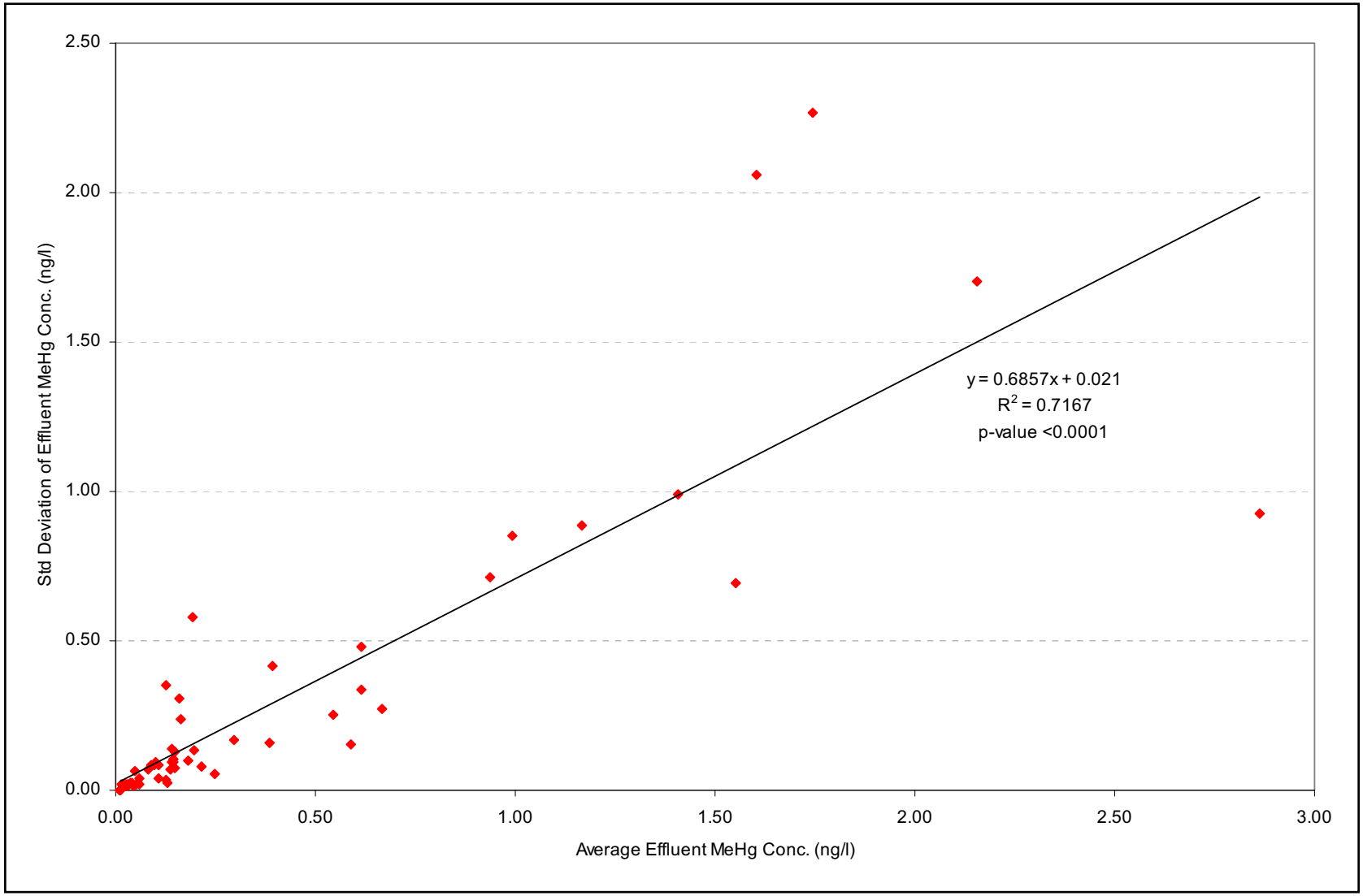

Figure 6: Average Effluent Methylmercury Concentration Versus the Corresponding Standard Deviation of Each Municipal WWTP

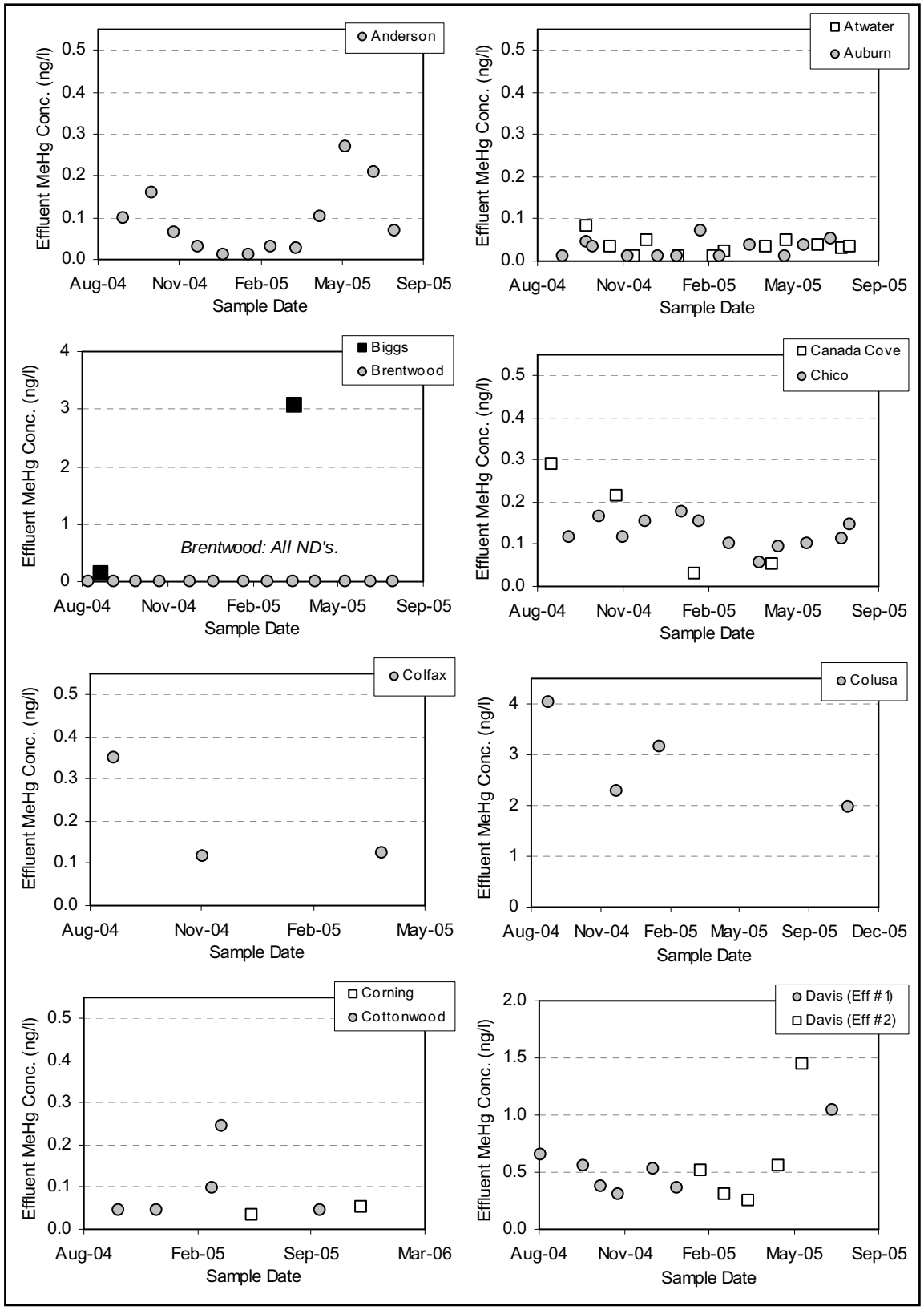

Figure 7a: Time-series Graphs of Municipal WWTP Effluent Methylmercury Concentrations

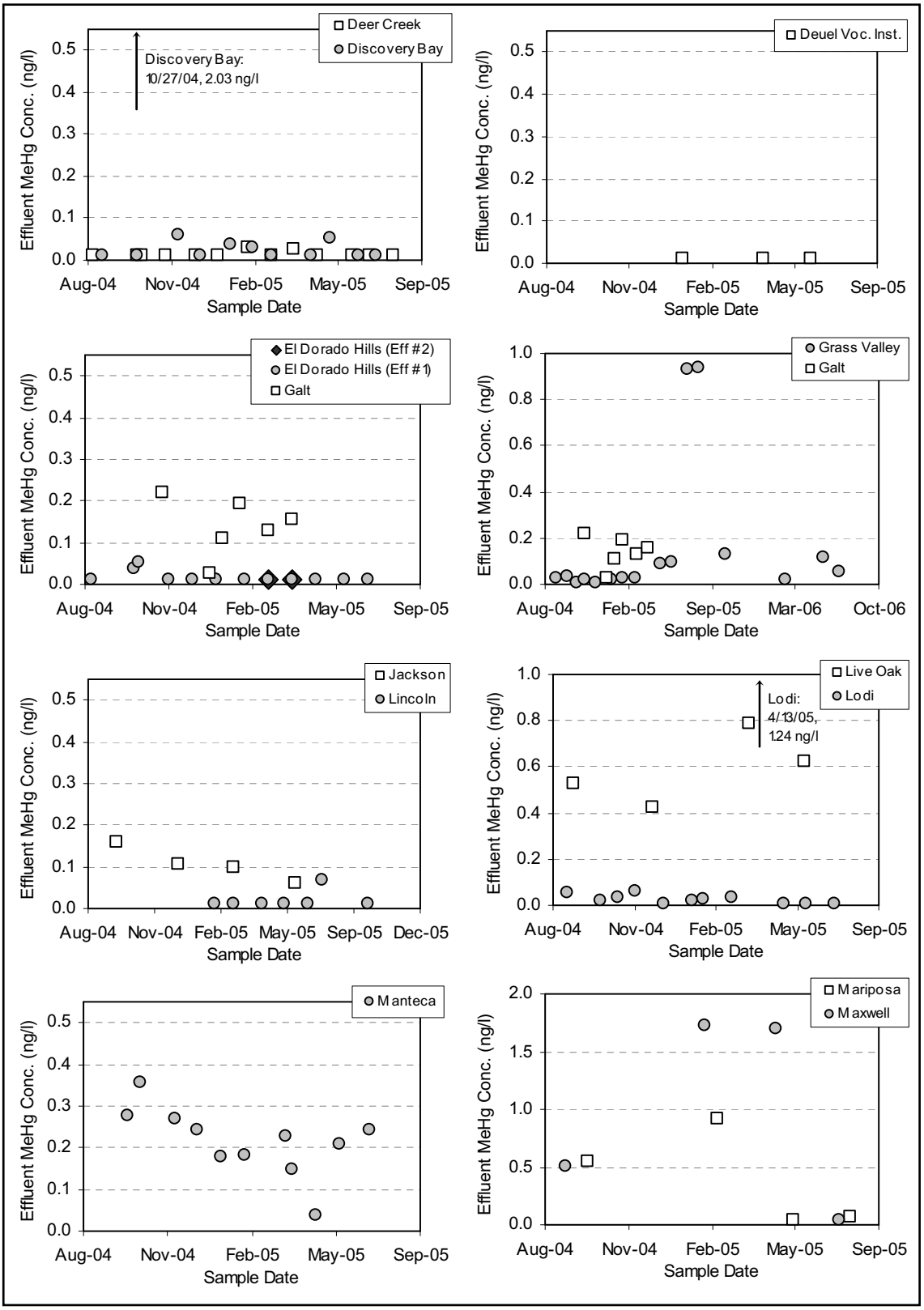

Figure 7b: Time-series Graphs of Municipal WWTP Effluent Methylmercury Concentrations

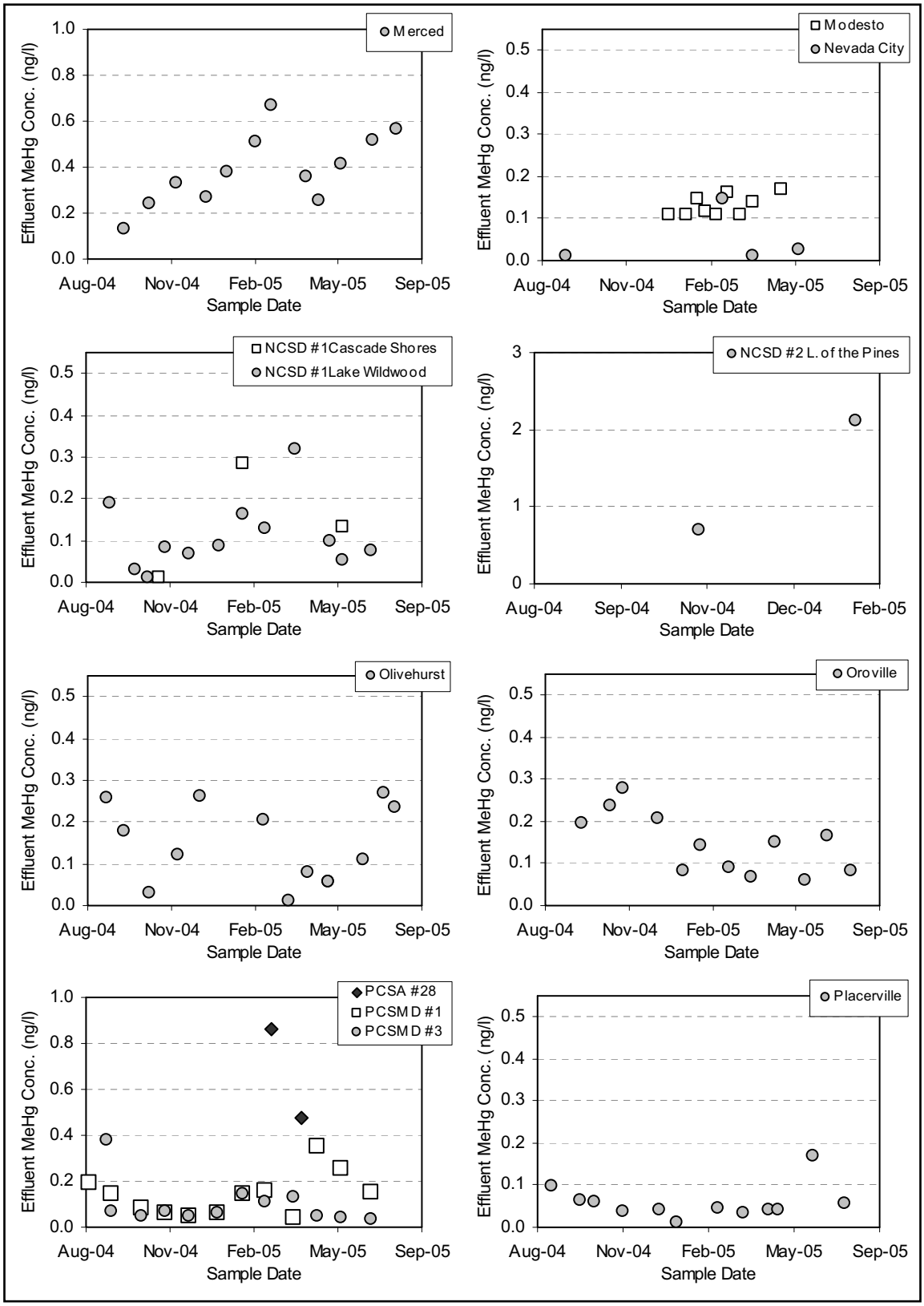

Figure 7c: Time-series Graphs of Municipal WWTP Effluent Methylmercury Concentrations

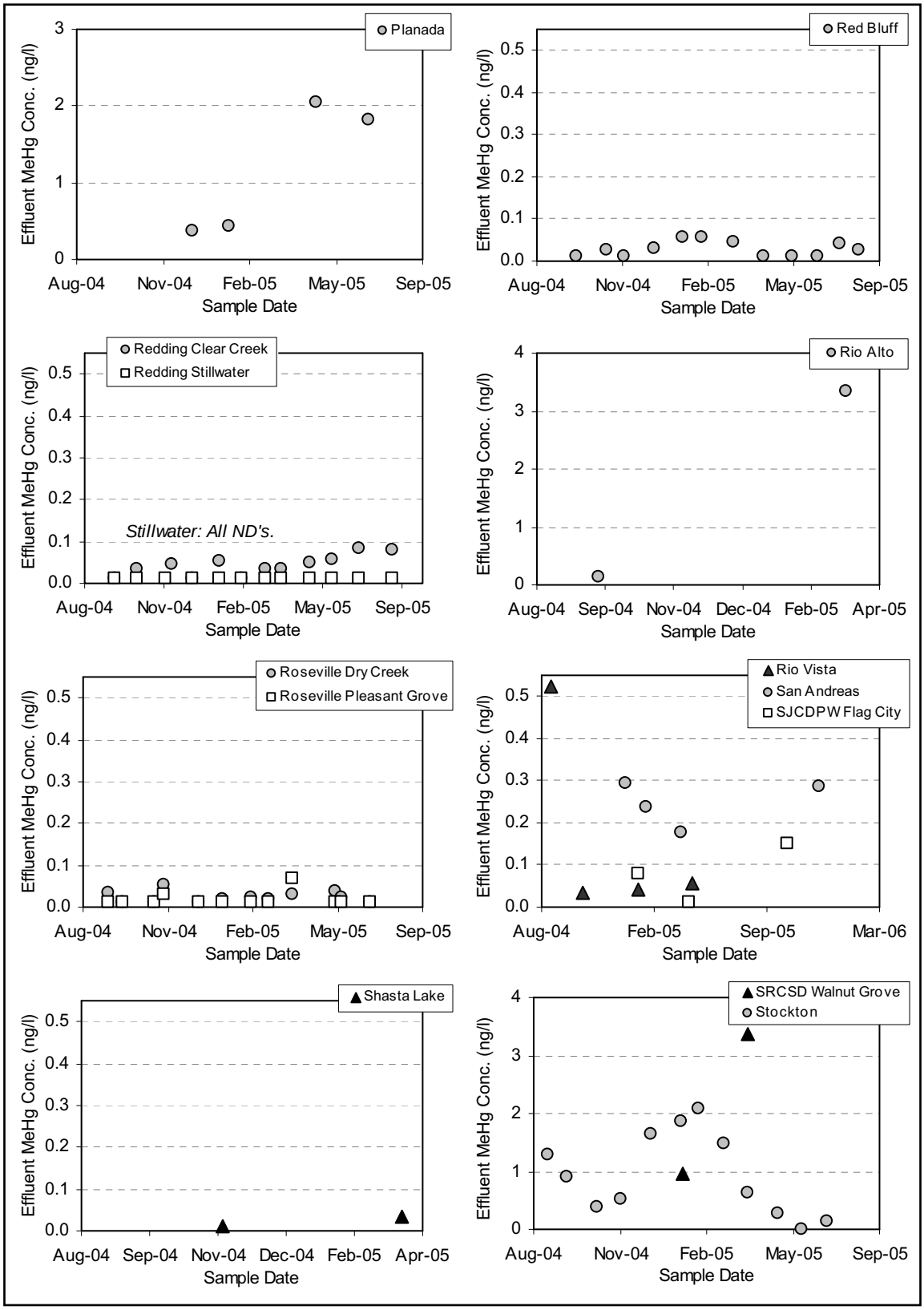

Figure 7d: Time-series Graphs of Municipal WWTP Effluent Methylmercury Concentrations

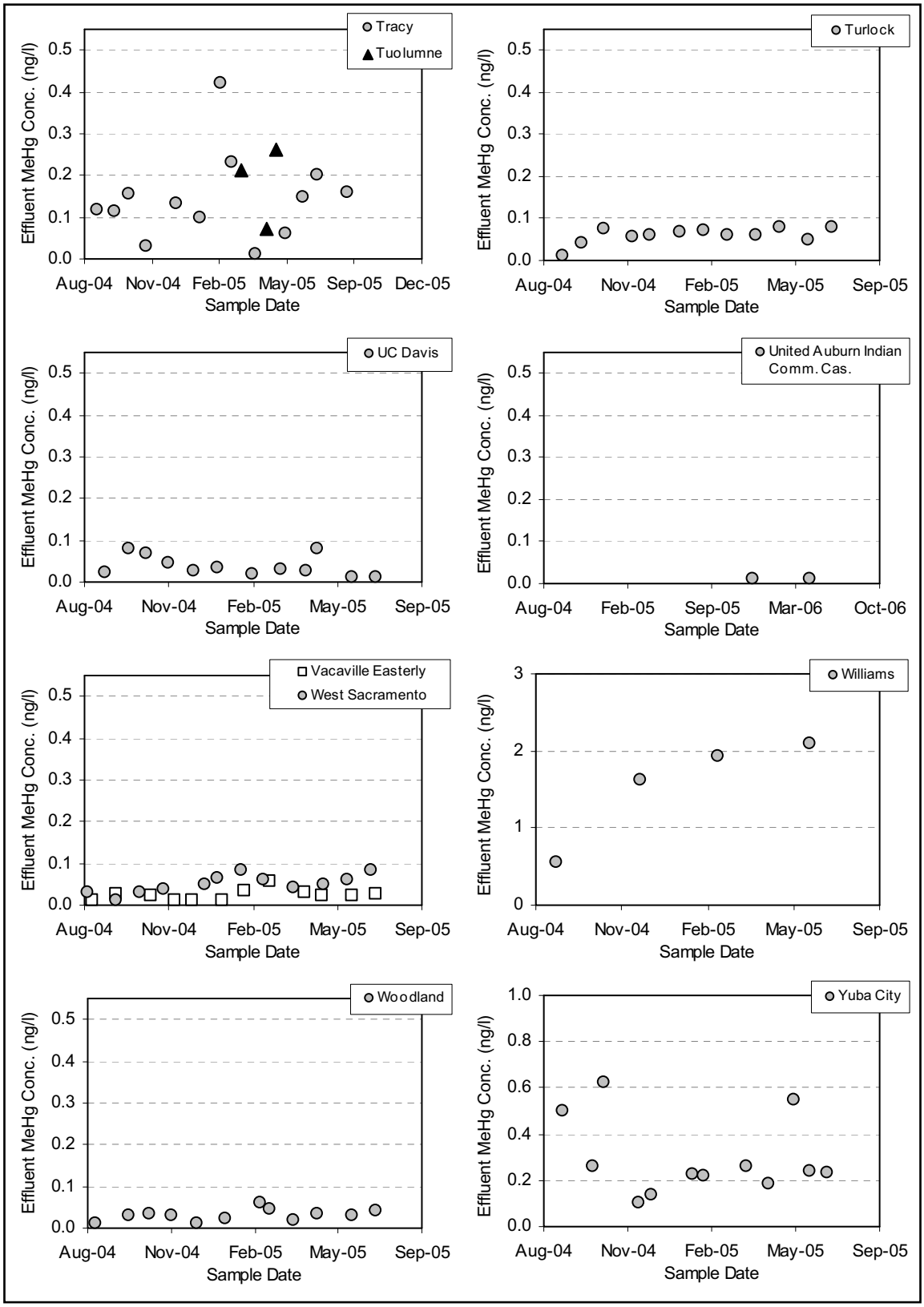

Figure 7e: Time-series Graphs of Municipal WWTP Effluent Methylmercury Concentrations

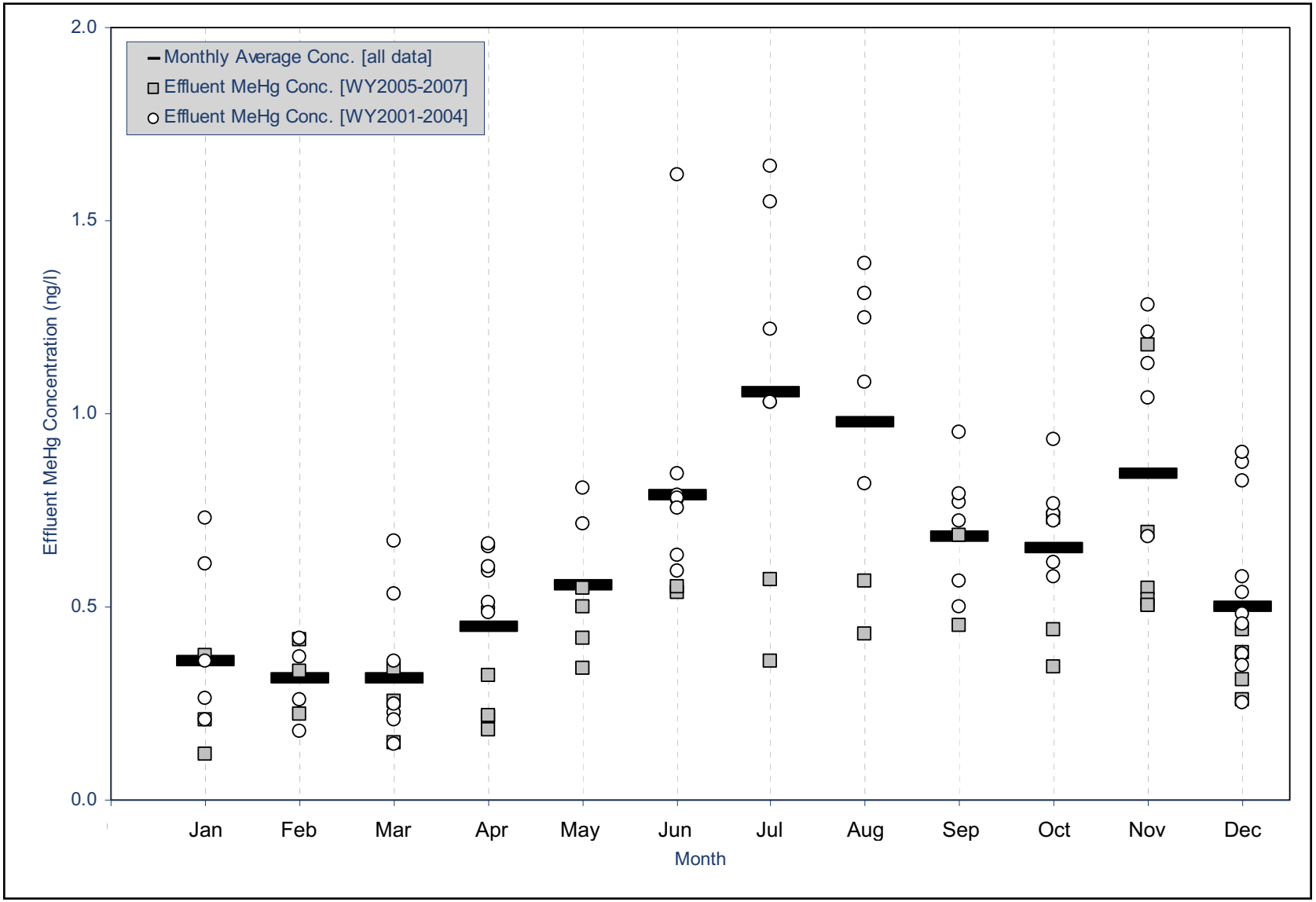

Figure 8: Monthly Effluent Methylmercury Concentrations for the SRCSD Sacramento River WWTP for WY2001-2007

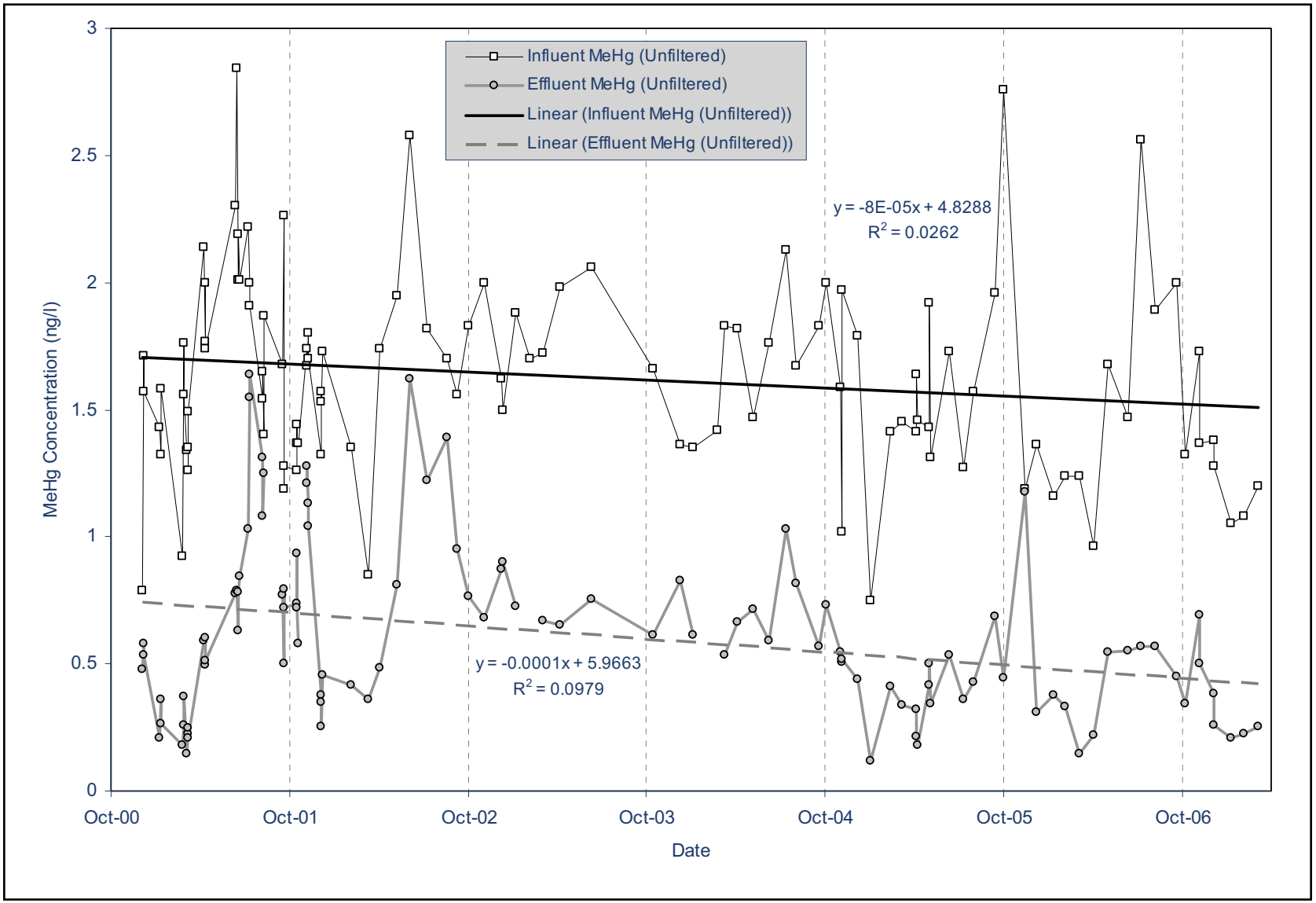

Figure 9: Time-series Graph for SRCSD Sacramento River WWTP Influent and Effluent Methylmercury Concentrations

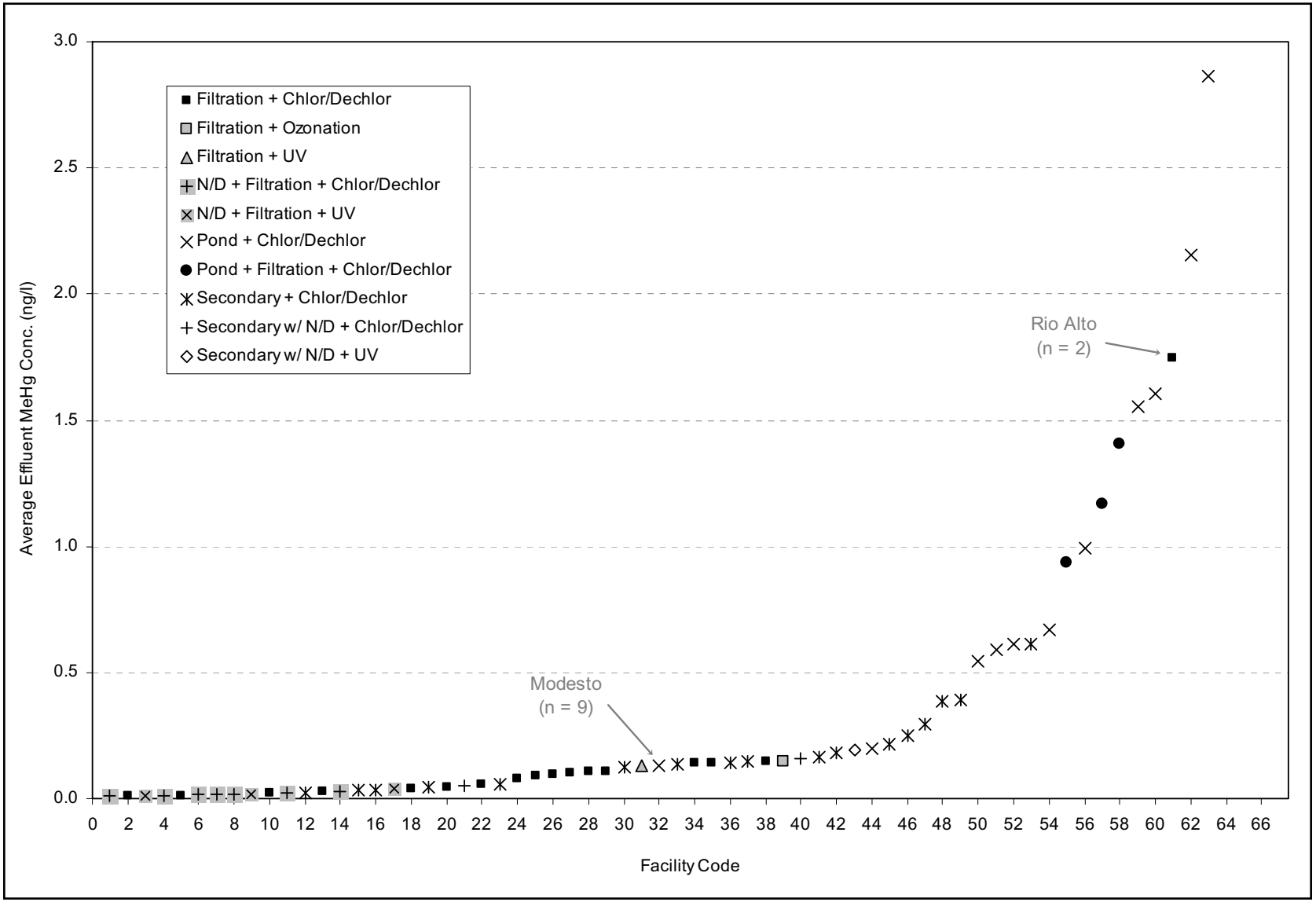

Figure 10: Average Effluent Methylmercury Concentrations for Each Municipal WWTP with the Maximum Treatment Category Defined
[WWTPs with relatively high or low effluent methylmercury concentrations compared to other WWTPs within the same maximum treatment category are labeled.]

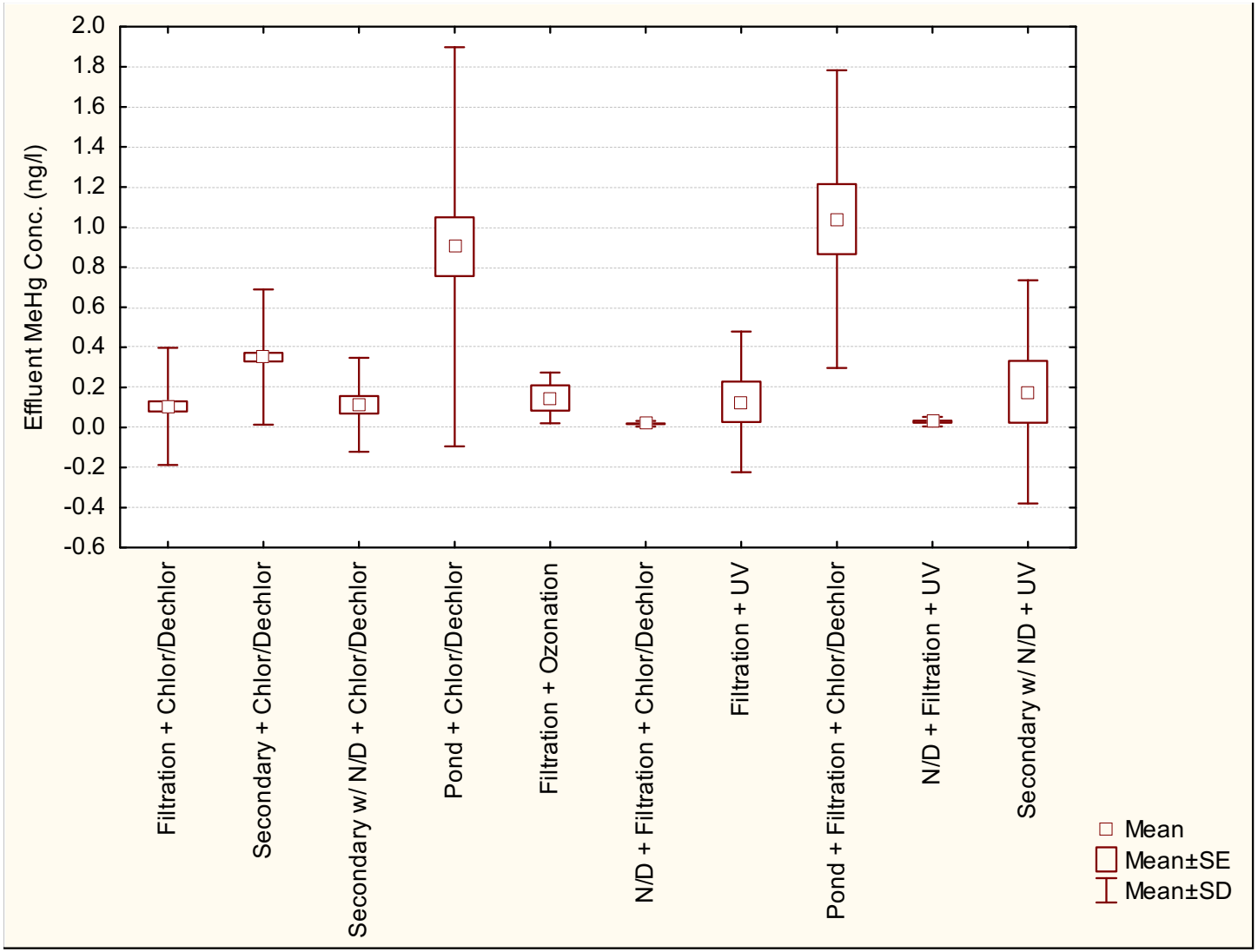

Figure 11: Box and Whisker Plot of Effluent Methylmercury Concentrations for the Municipal WWTP Maximum Treatment Categories

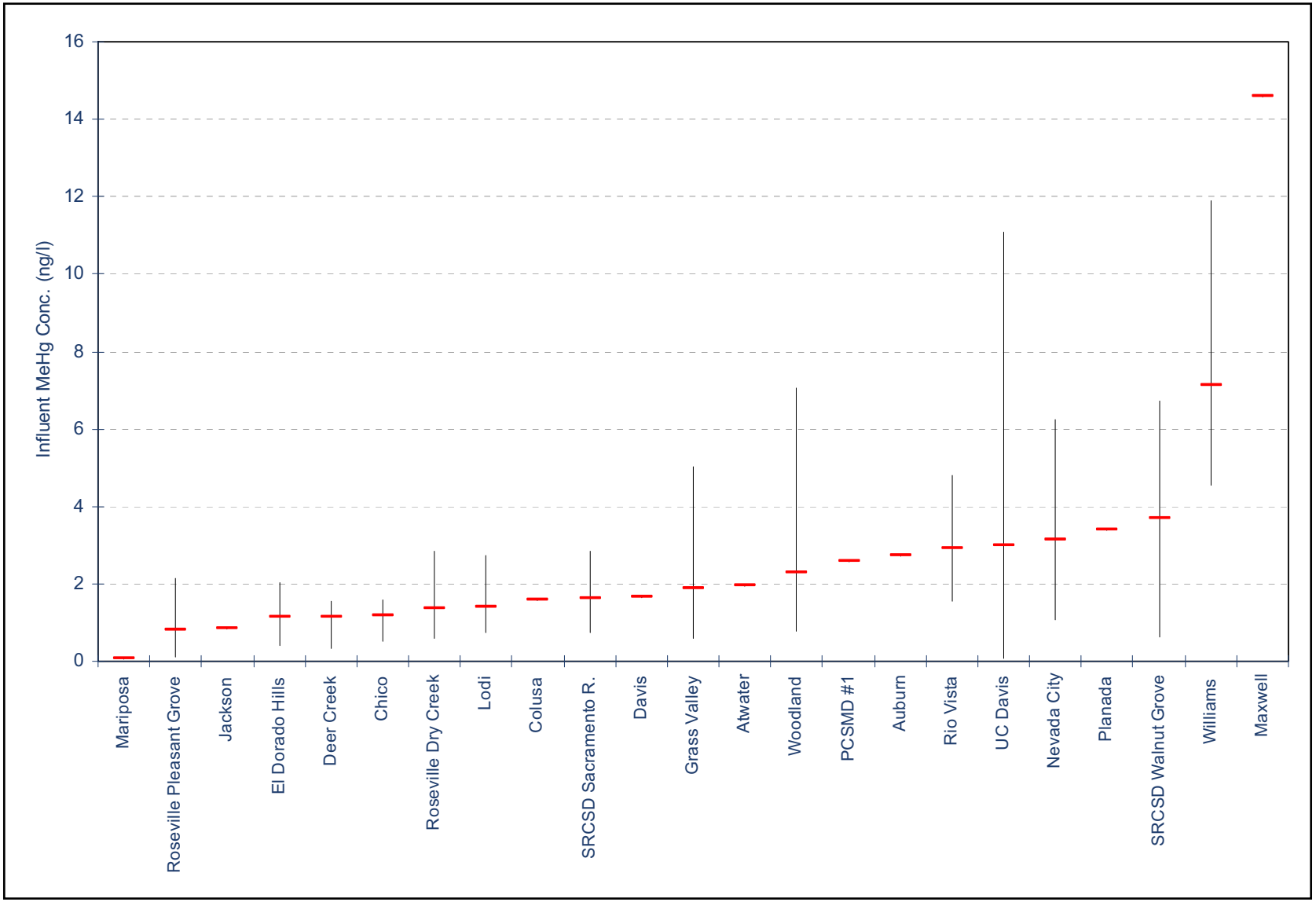

Figure 12: Average and Range of Influent Methylmercury Concentrations for Each Municipal WWTP

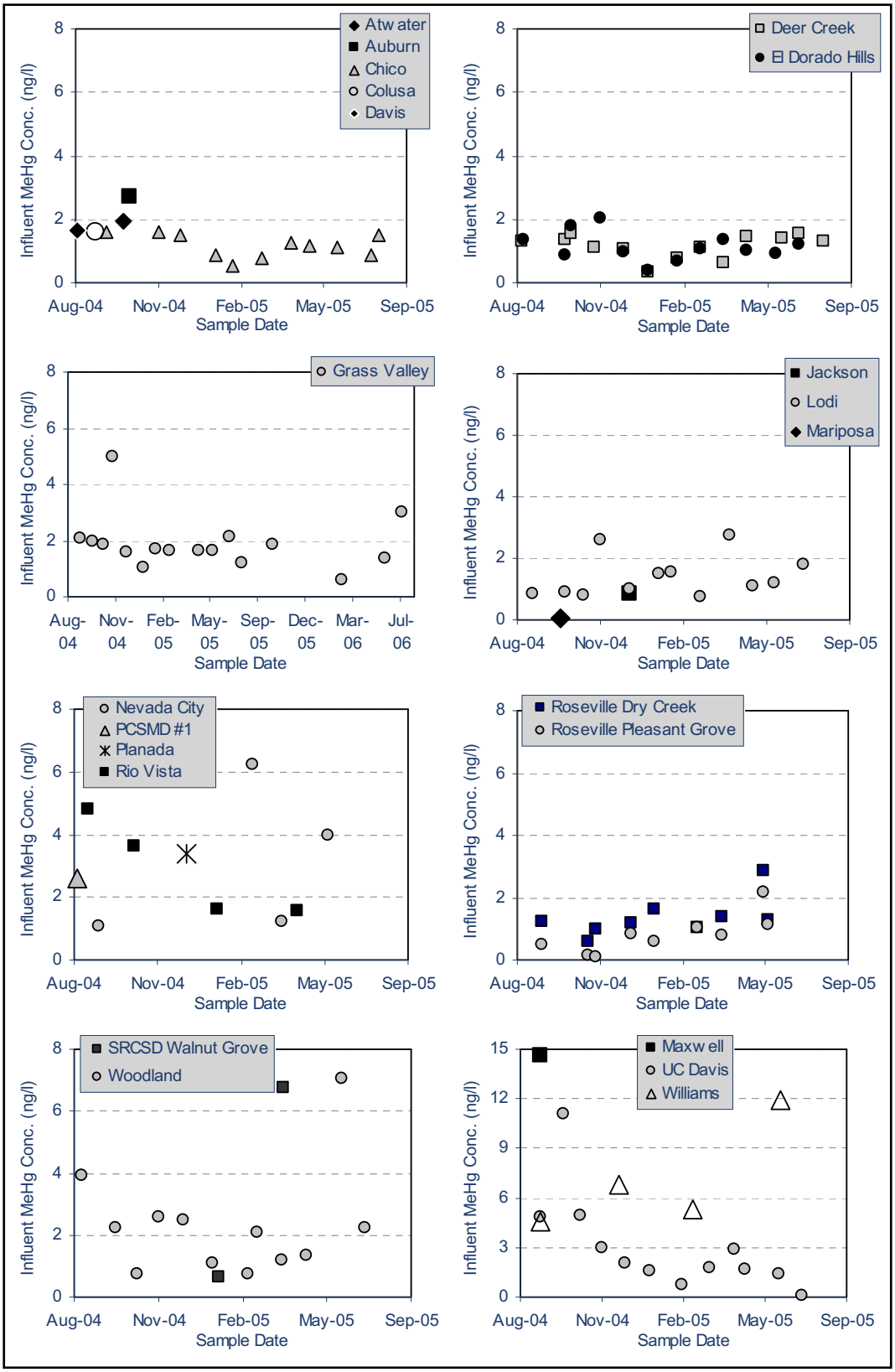

Figure 13: Time-series Graphs of Municipal WWTP Influent Methylmercury Concentrations

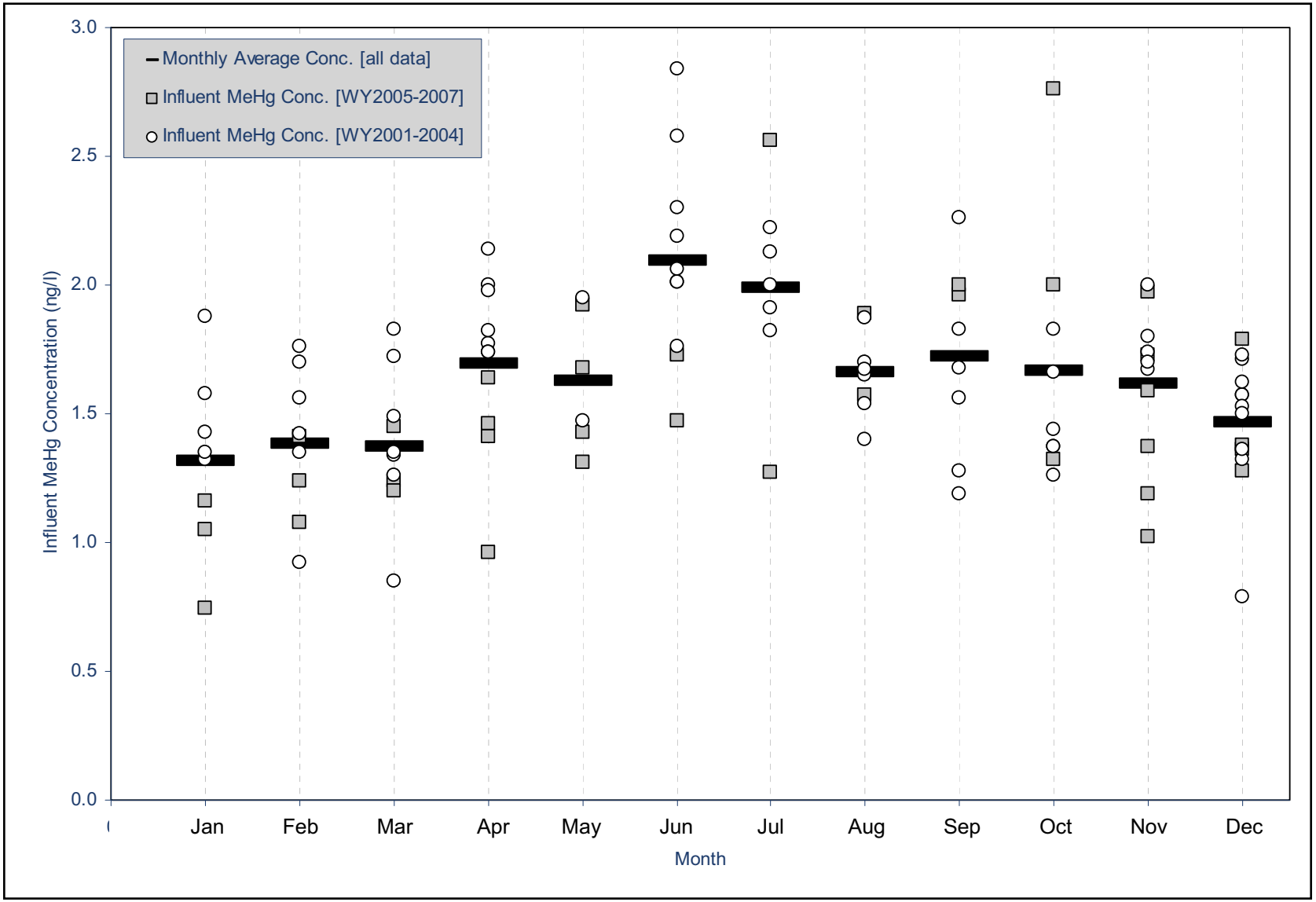

Figure 14: Monthly Influent Methylmercury Concentrations for the SRCSD Sacramento River WWTP from WY2001-2007

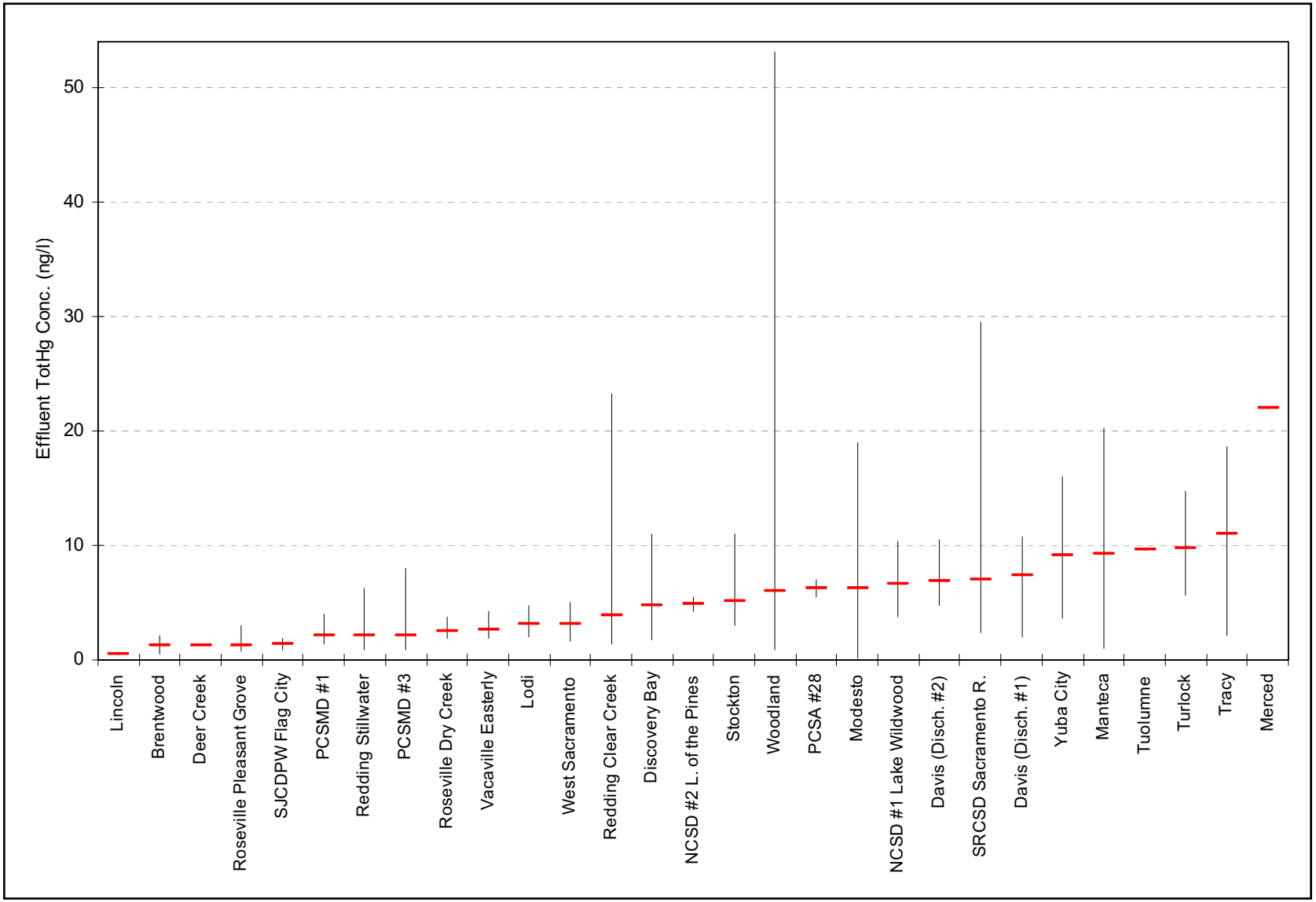

Figure 15: Average and Range of Effluent Inorganic Mercury Concentrations for Each Municipal WWTP

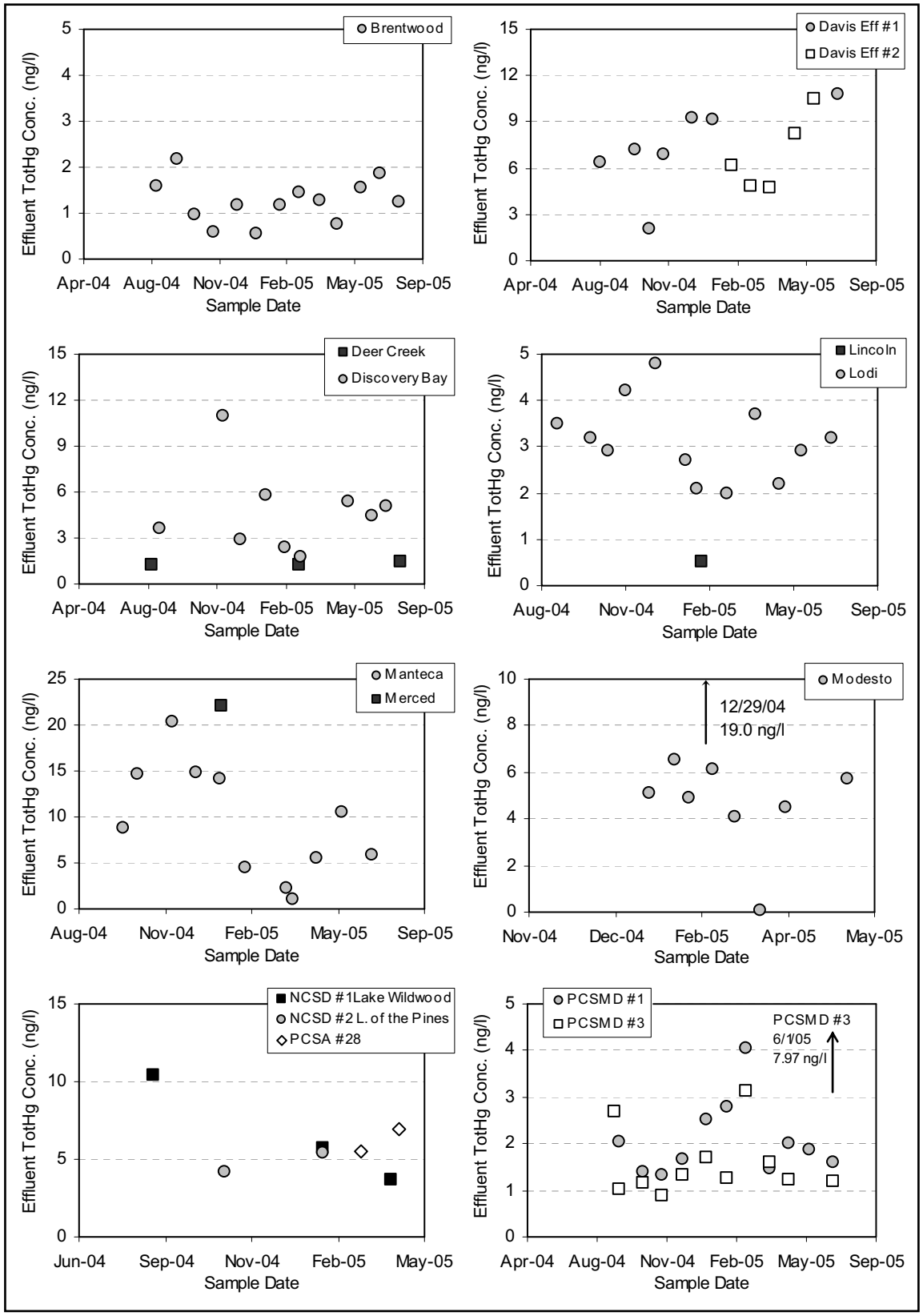

Figure 16a: Time-series Graphs of Municipal WWTP Effluent Inorganic Mercury Concentrations

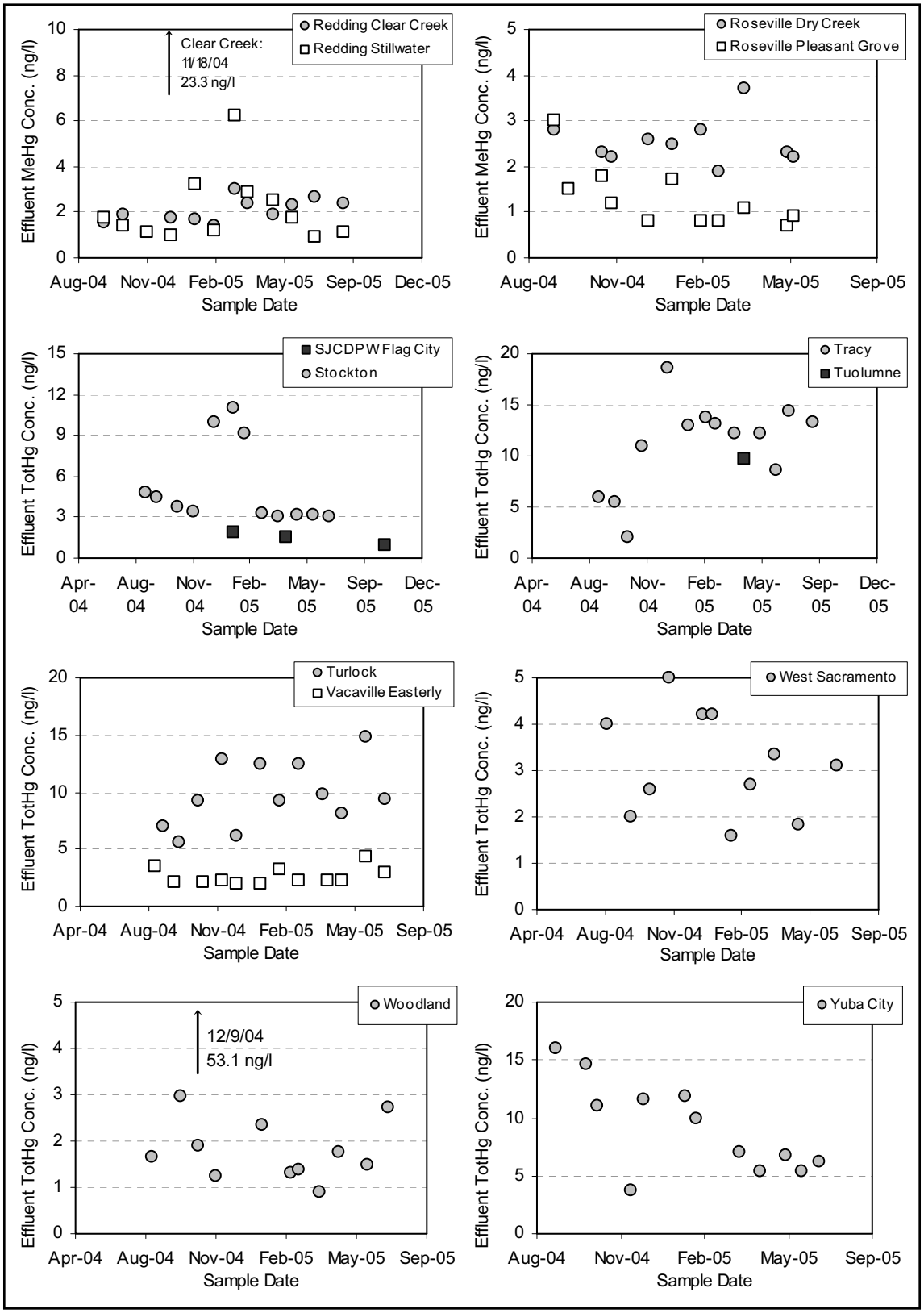

Figure 16b: Time-series Graphs of Municipal WWTP Effluent Inorganic Mercury Concentrations

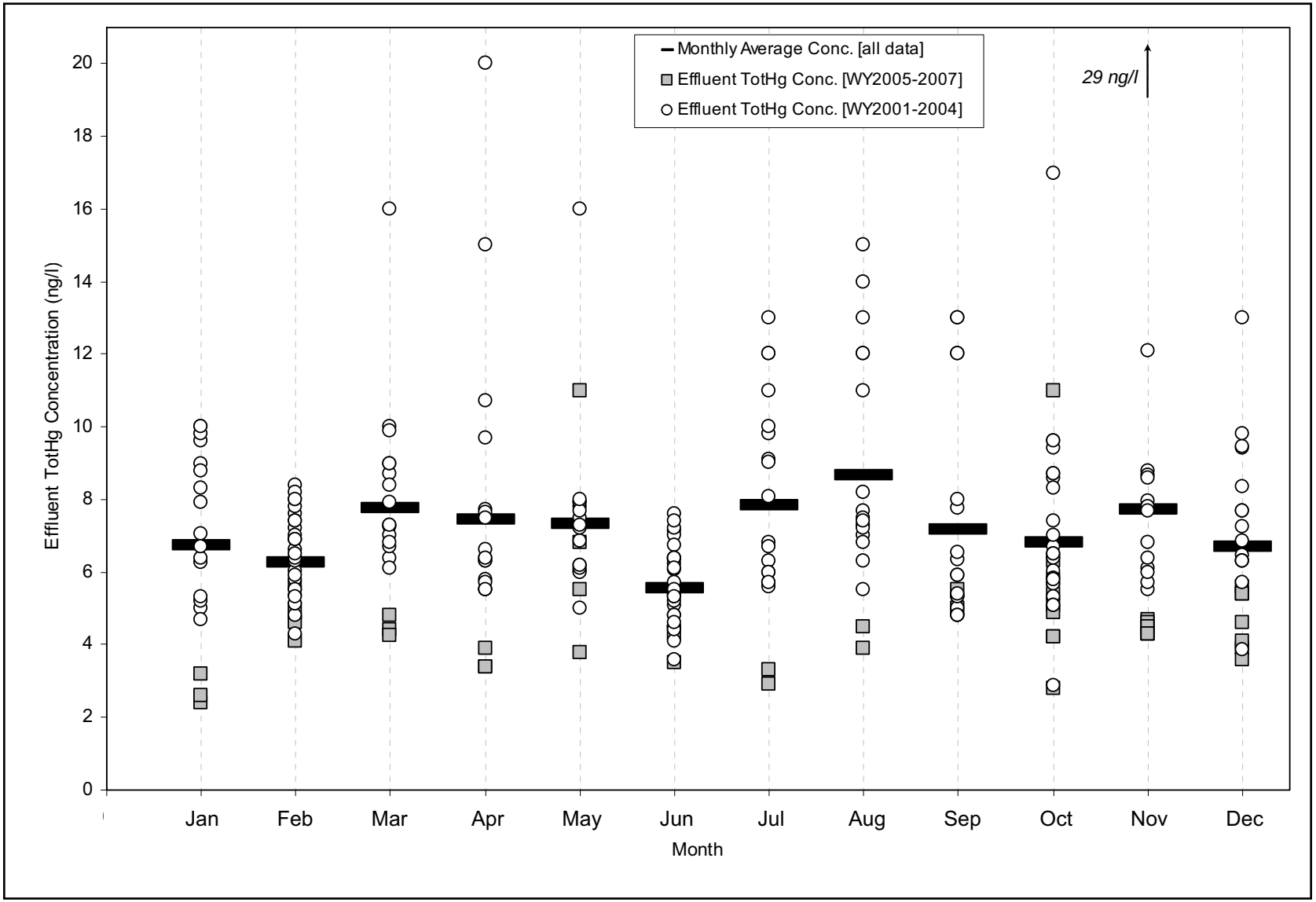

Figure 17: Monthly Effluent Inorganic Mercury Concentrations for the SRCSD Sacramento River WWTP from WY2001-2007

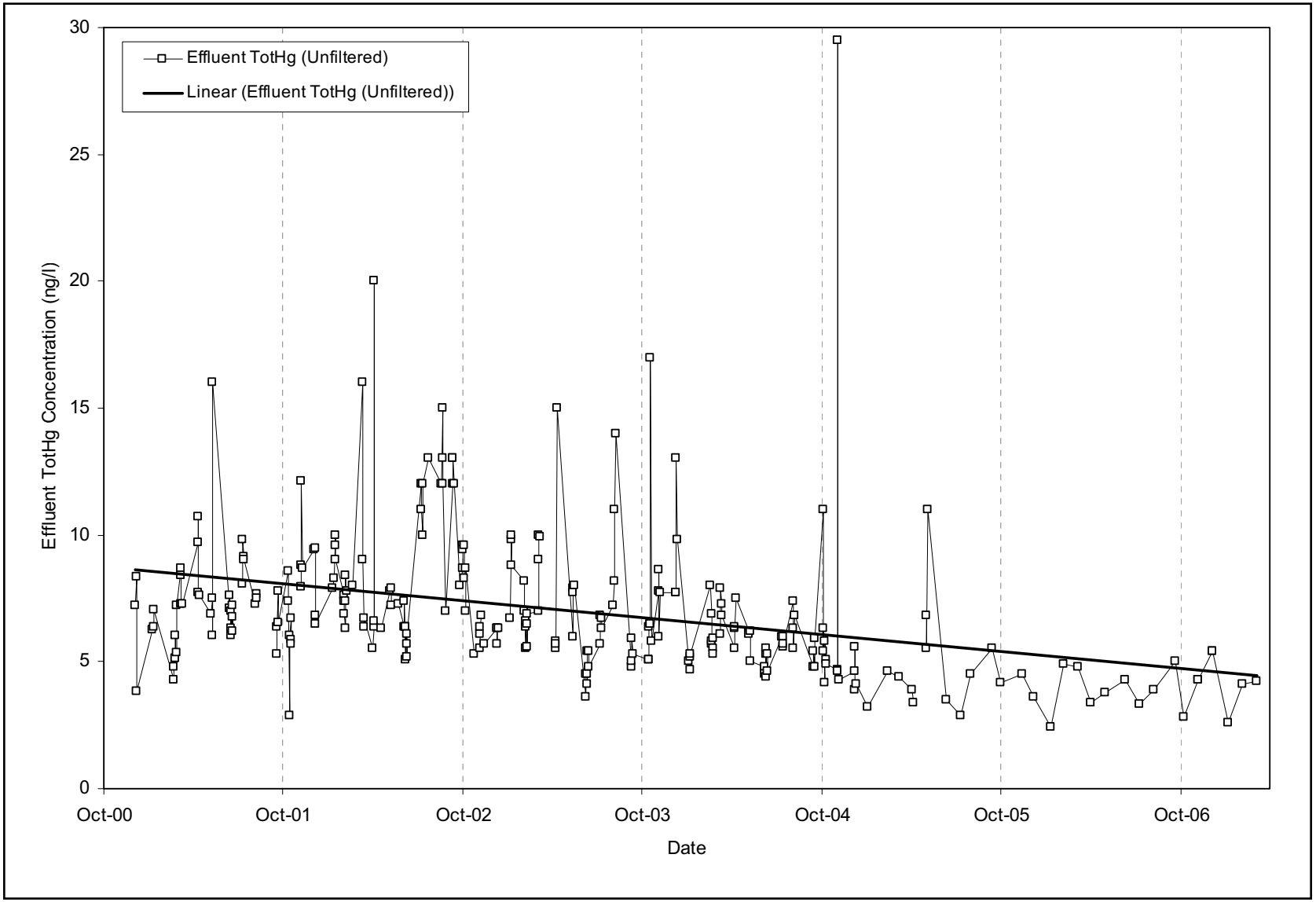

Figure 18: Time-series Graph of SRCSD Sacramento River WWTP Effluent Inorganic Mercury Concentrations

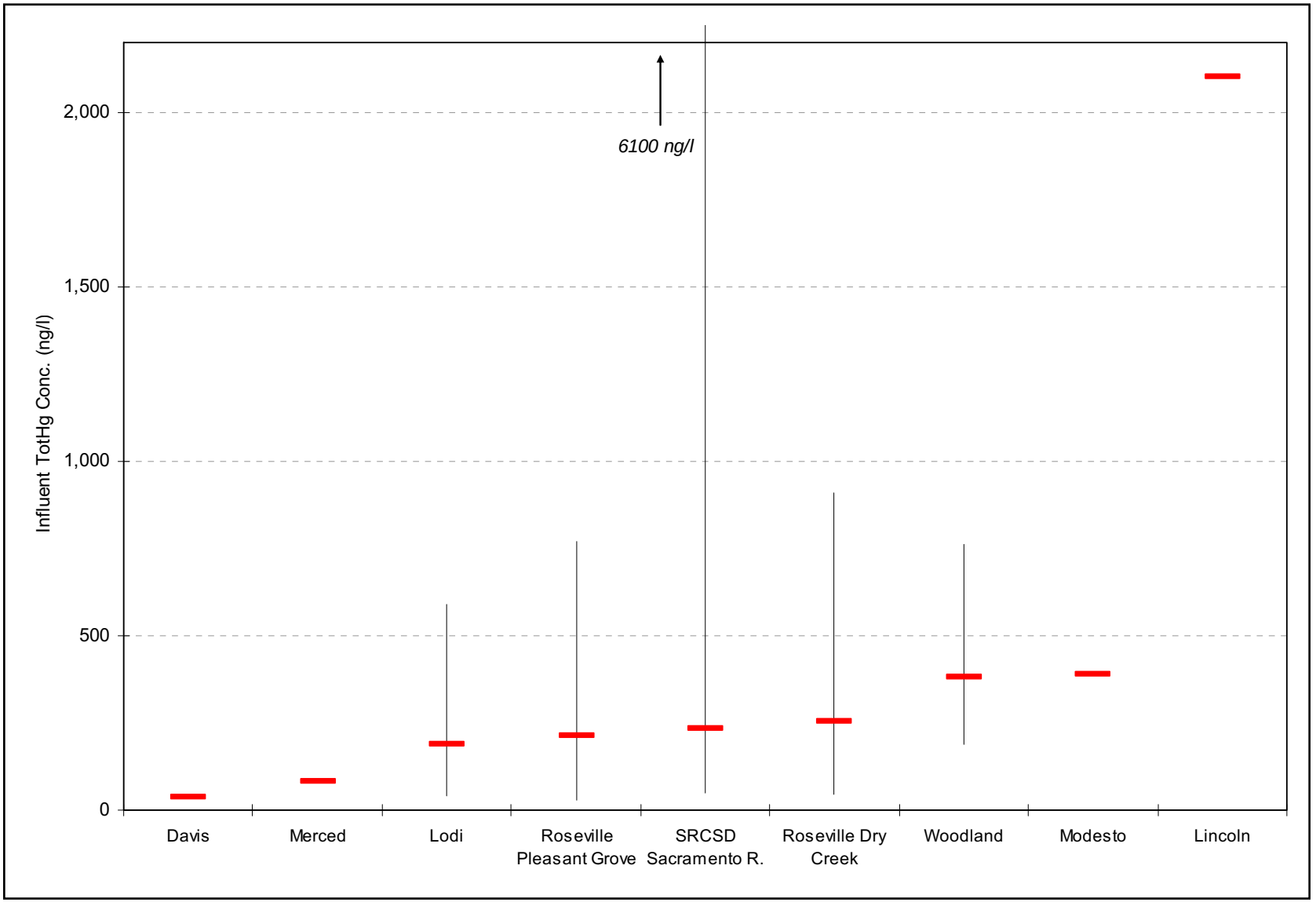

Figure 19: Average and Range of Influent Inorganic Mercury Concentrations for Each Municipal WWTP

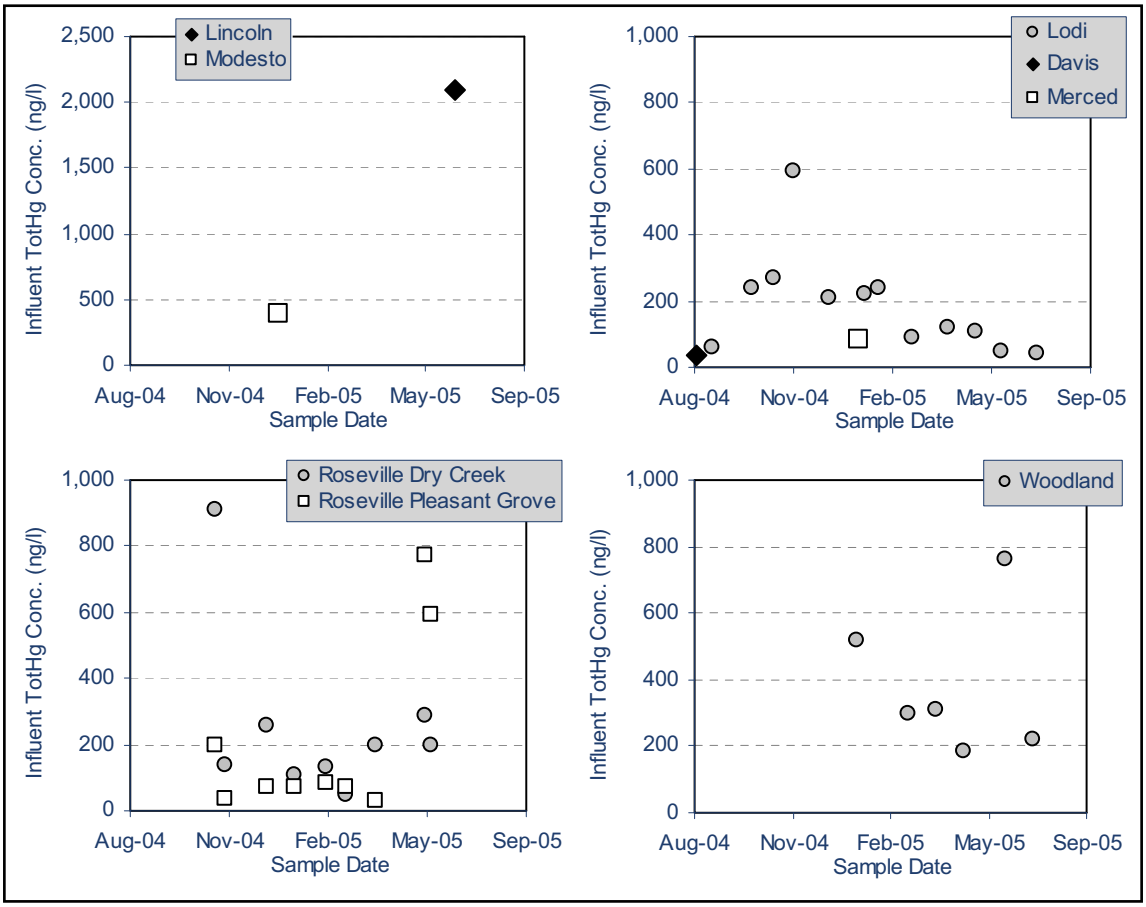

Figure 20: Time-series Graphs of Municipal WWTP Influent Inorganic Mercury Concentrations

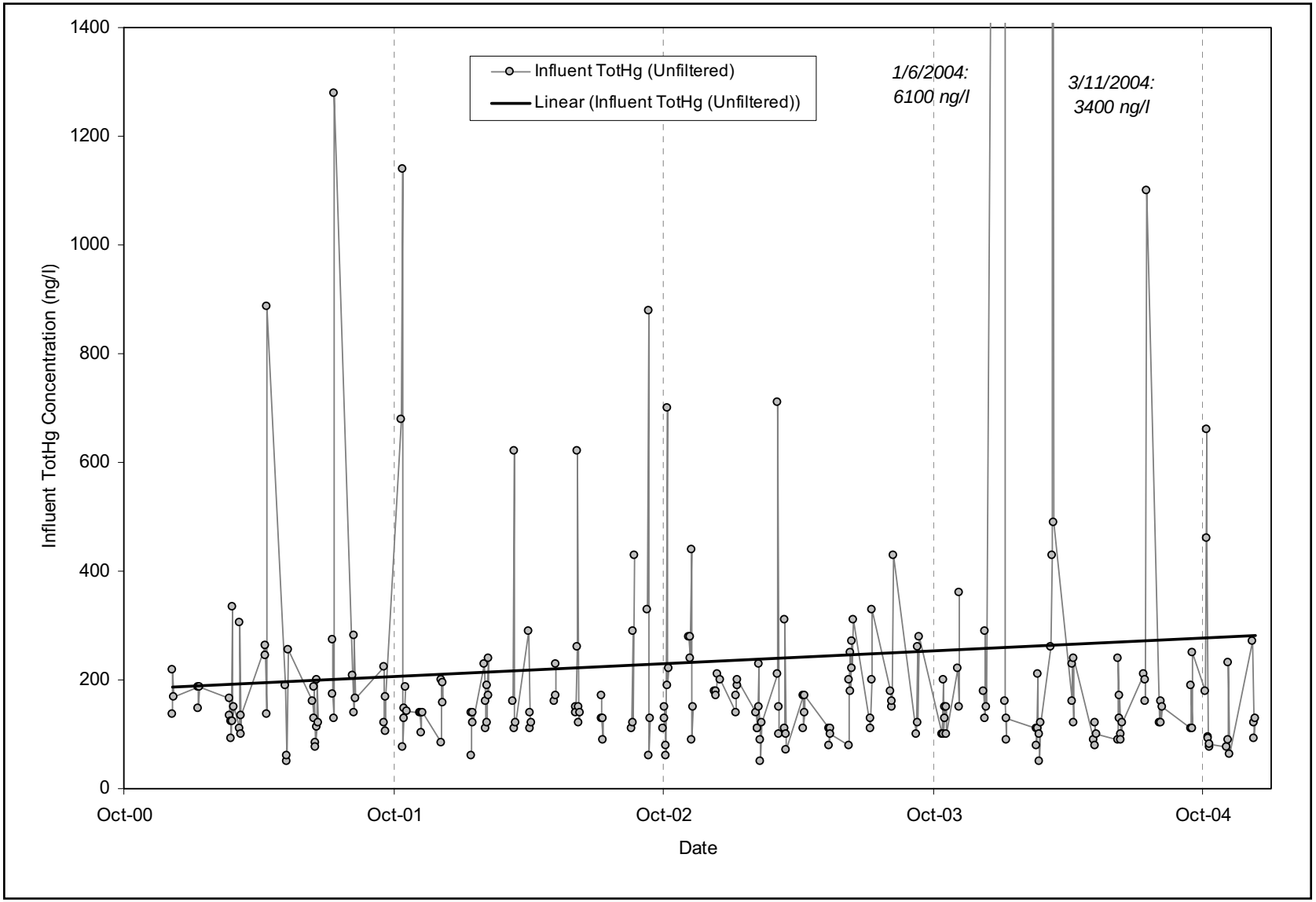

Figure 21: Time-series Graph of SRCSD Sacramento River WWTP Influent Inorganic Mercury Concentrations

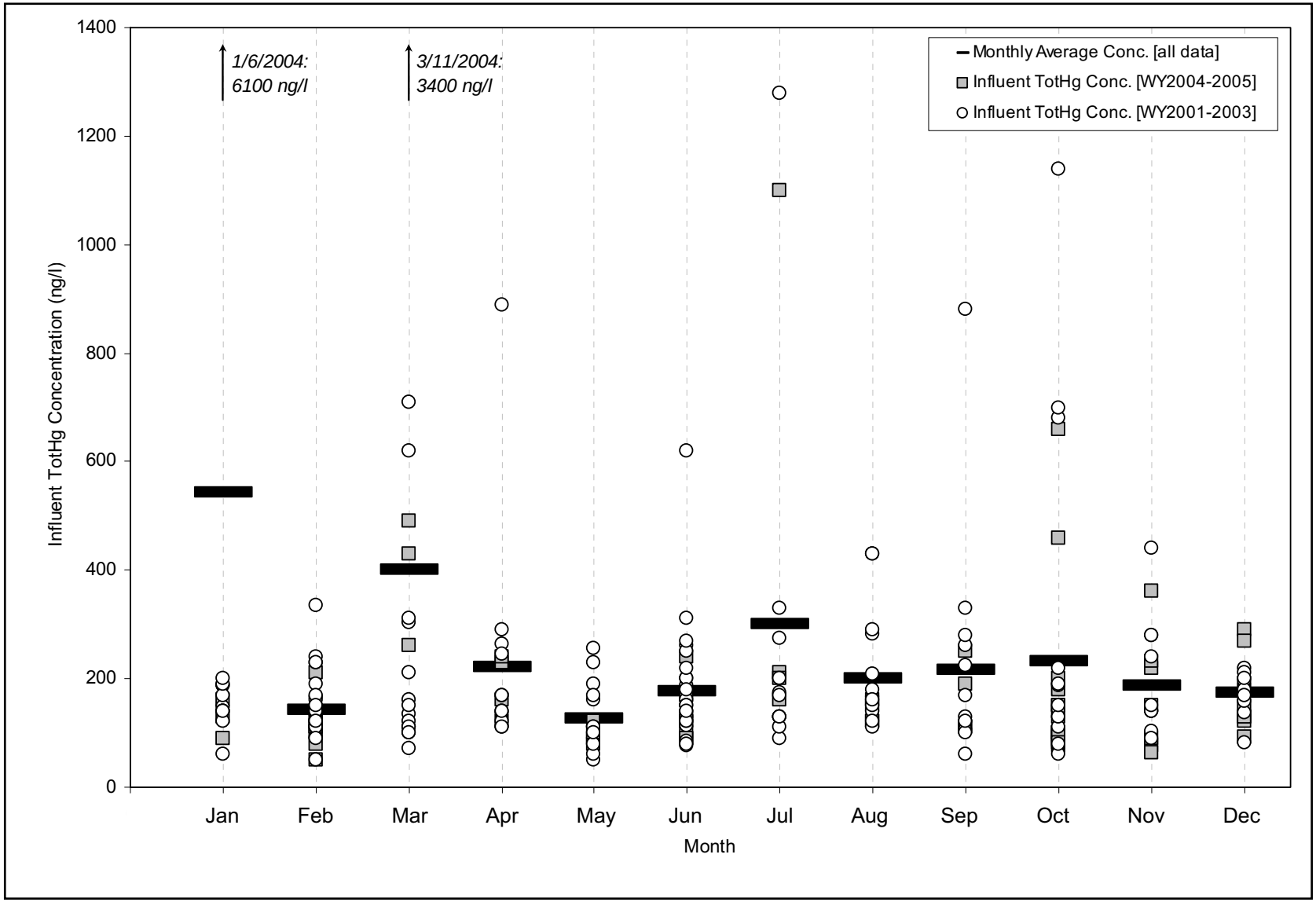

Figure 22: Monthly Influent Inorganic Mercury Concentrations for the SRCSD Sacramento River WWTP from December 2000 – December 2004

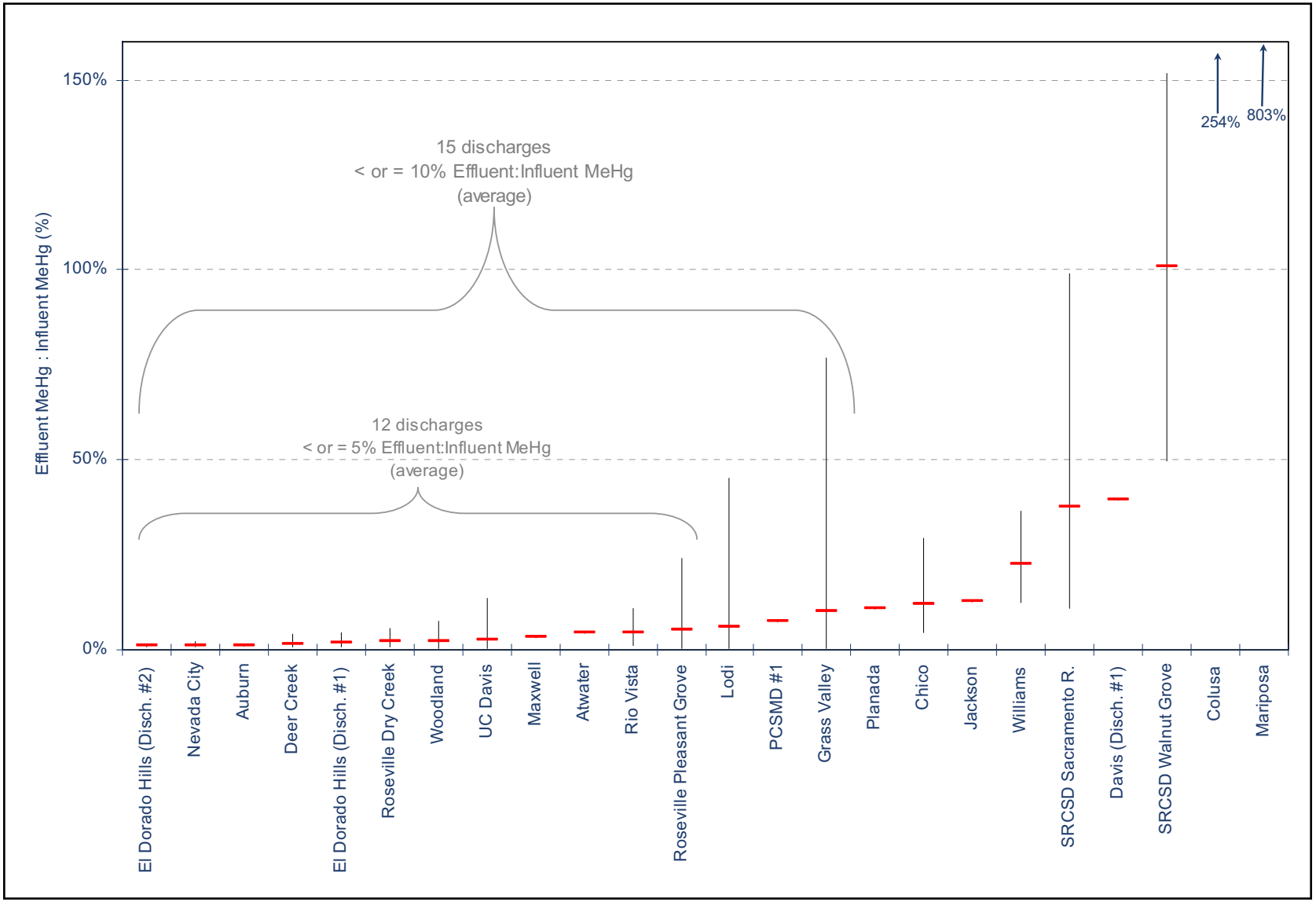

Figure 23: Average and Range of Effluent:Influent Methylmercury Concentration Ratios for Each Municipal WWTP

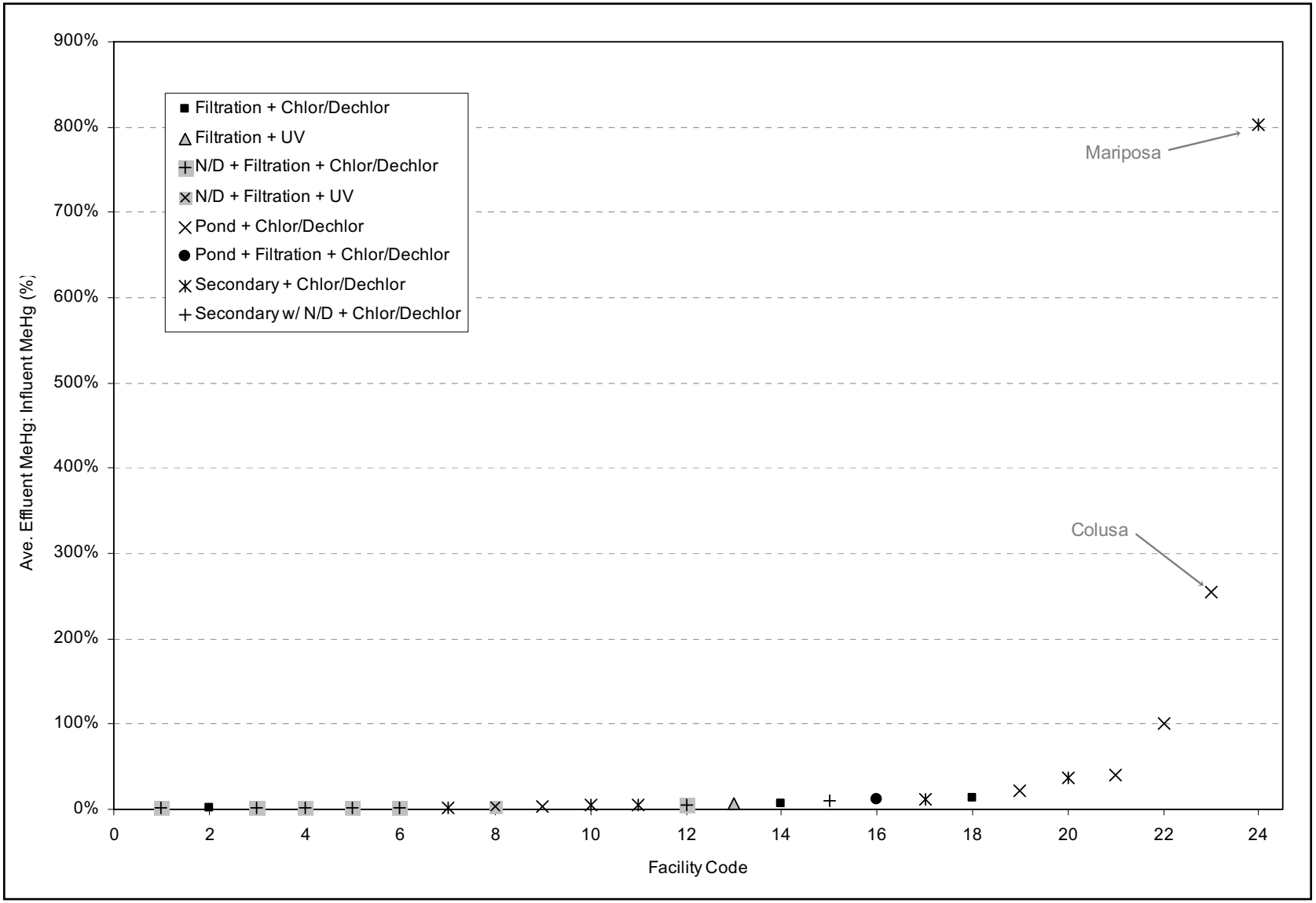

Figure 24: Average of Effluent:Influent Methylmercury Concentration Ratios with the Secondary Treatment Category Defined for Each Municipal WWTP

Facility Codes Used in Figure 24

Facility Code	NPDES No.	Facility
1	CA0078671	El Dorado Hills WWTP (Discharge 2)
2	CA0079901	Nevada City WWTP
3	CA0077712	Auburn WWTP
4	CA0078662	Deer Creek WWTP
5	CA0078671	El Dorado Hills WWTP (Discharge 1)
6	CA0079502	Roseville Dry Creek WWTP
7	CA0077950	Woodland WWTP
8	CA0077895	UC Davis WWTP
9	CA0079987	Maxwell PUD WWTP
10	CA0079197	Atwater WWTP
11	CA0079588	Rio Vista Main WWTP
12	CA0084573	Roseville Pleasant Grove WWTP
13	CA0079243	Lodi White Slough WWTP
14	CA0079316	Placer Co. SMD #1 WWTP
15	CA0079898	Grass Valley WWTP
16	CA0078950	Planada Comm. Service Dist. WWTP
17	CA0079081	Chico Regional WWTP
18	CA0079391	Jackson WWTP
19	CA0077933	Williams WWTP
20	CA0077682	SRCSD Sacramento River WWTP
21	CA0079049	Davis WWTP (Discharge 1)
22	CA0078794	SRCSD Walnut Grove WWTP (CSD1)
23	CA0078999	Colusa WWTP
24	CA0079430	Mariposa PUD WWTP

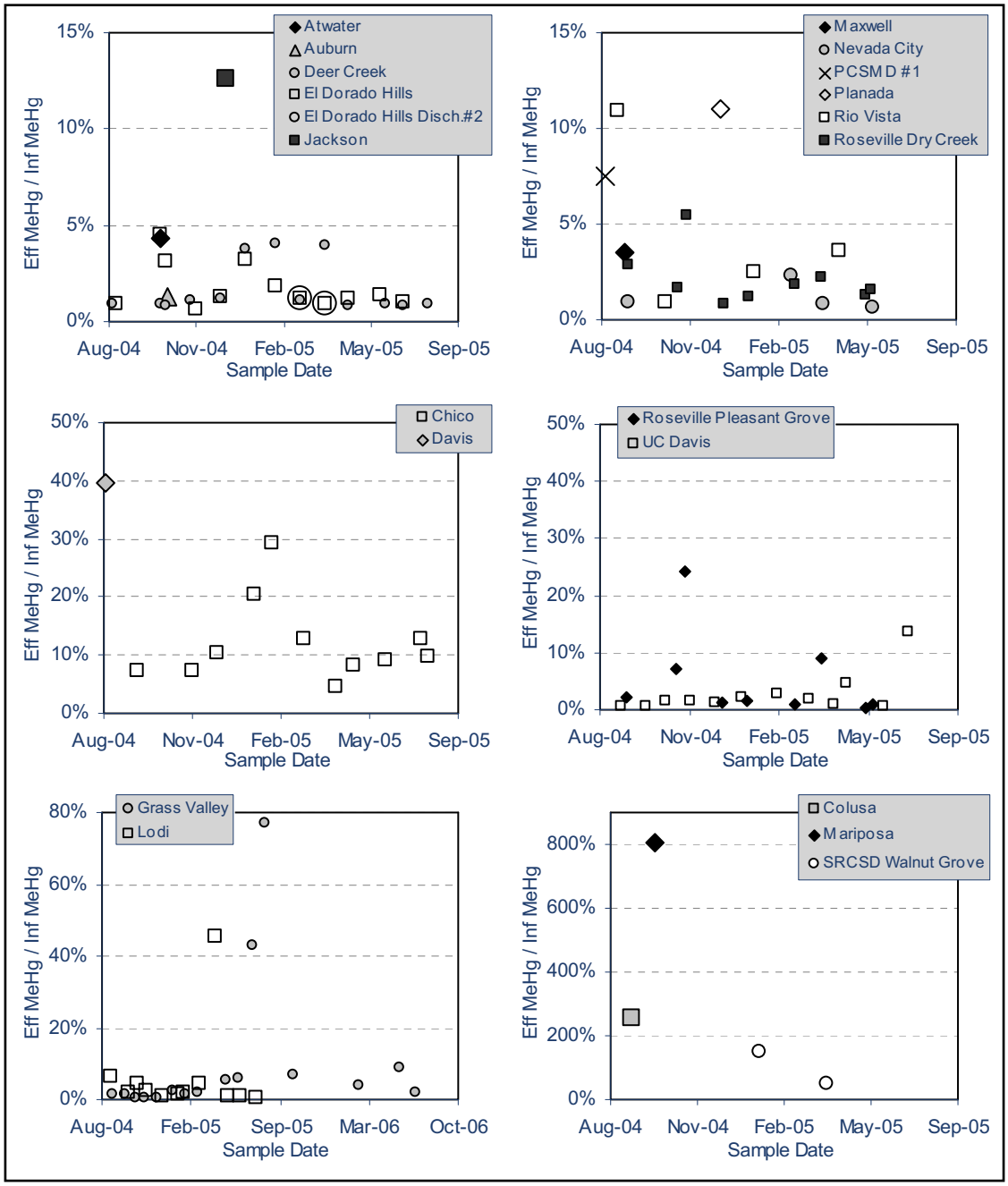

Figure 25: Time-series Graphs of Municipal WWTP Effluent:Influent Methylmercury Concentration Ratios

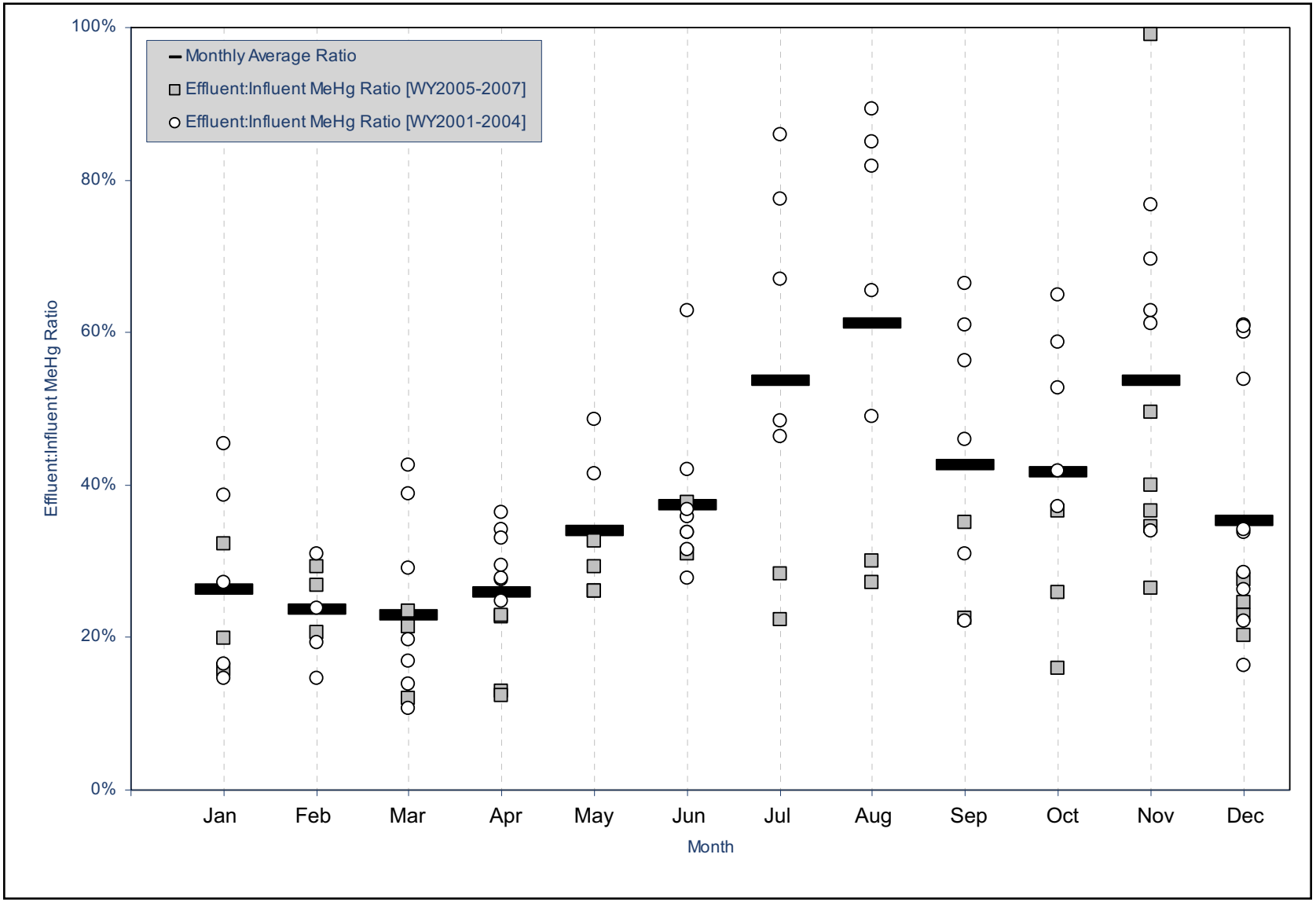

Figure 26: Monthly Effluent:Influent Methylmercury Concentration Ratios for the SRCSD Sacramento River WWTP from WY2001-2007

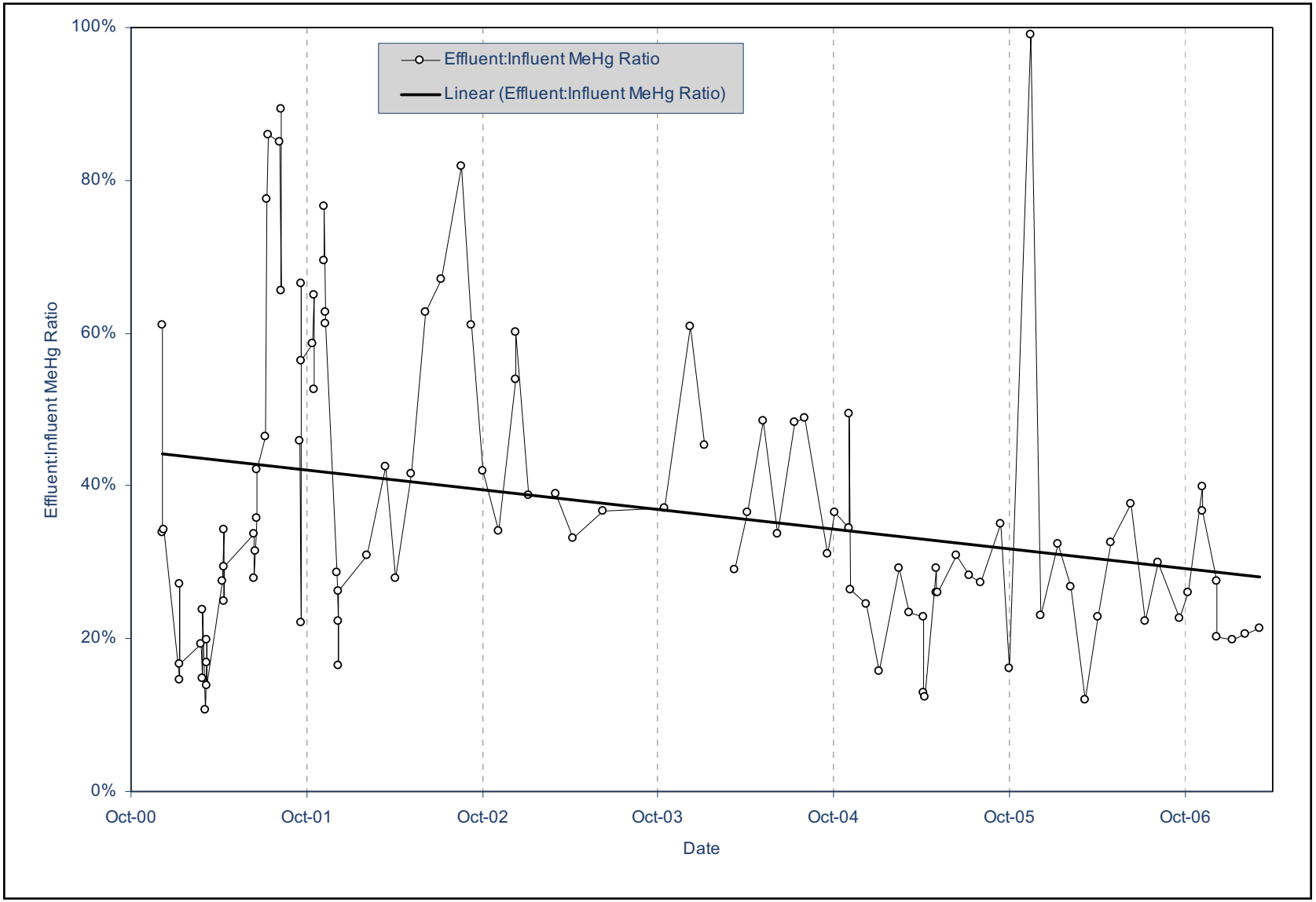

Figure 27: Time-series Graph of SRCSD Sacramento River WWTP Effluent:Influent Methylmercury Concentration Ratios

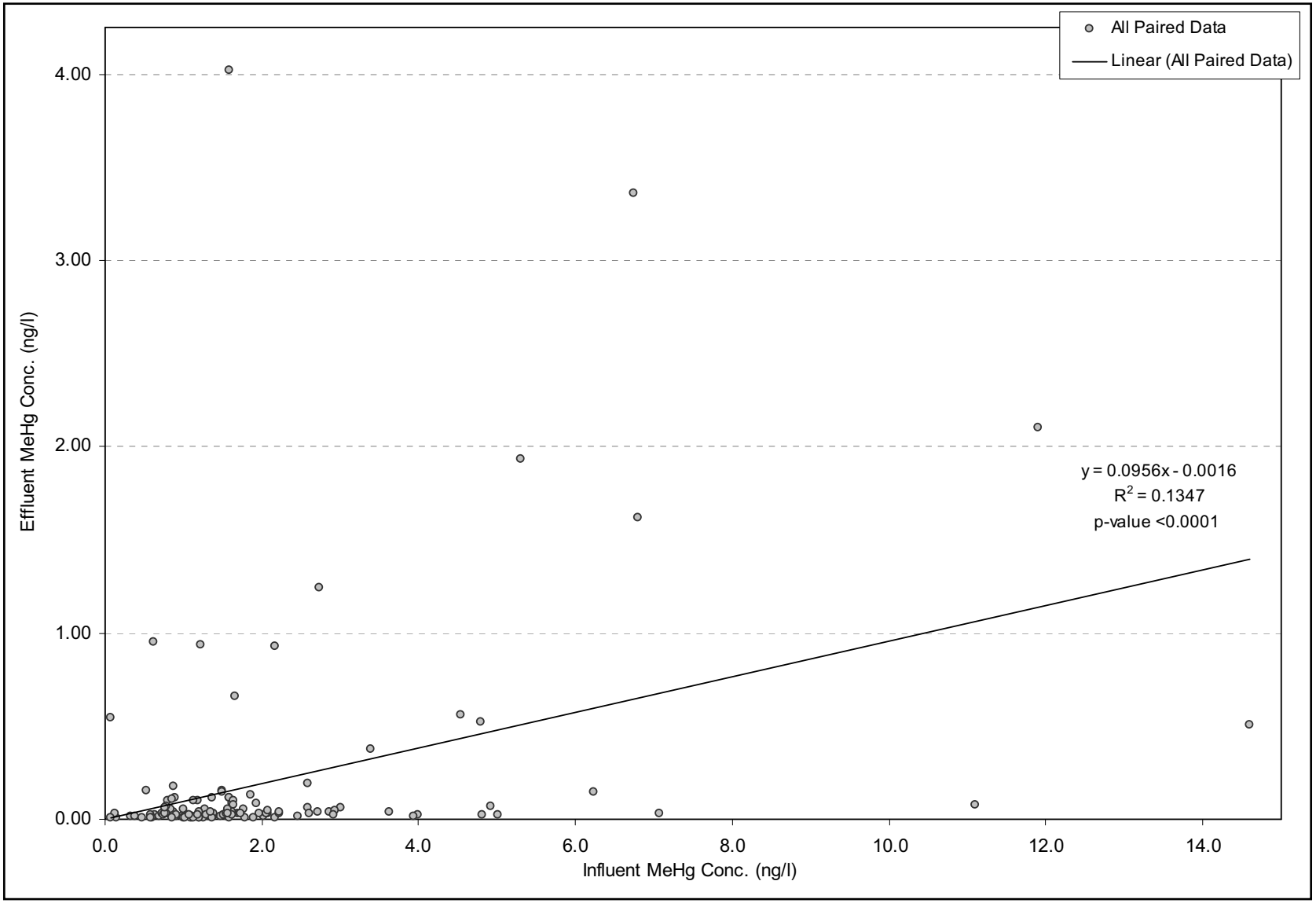

Figure 28a: Scatter-plot of Municipal WWTP Influent versus Effluent Methylmercury Concentrations for All Paired Data [excluding SRCSD Sacramento River WWTP data]

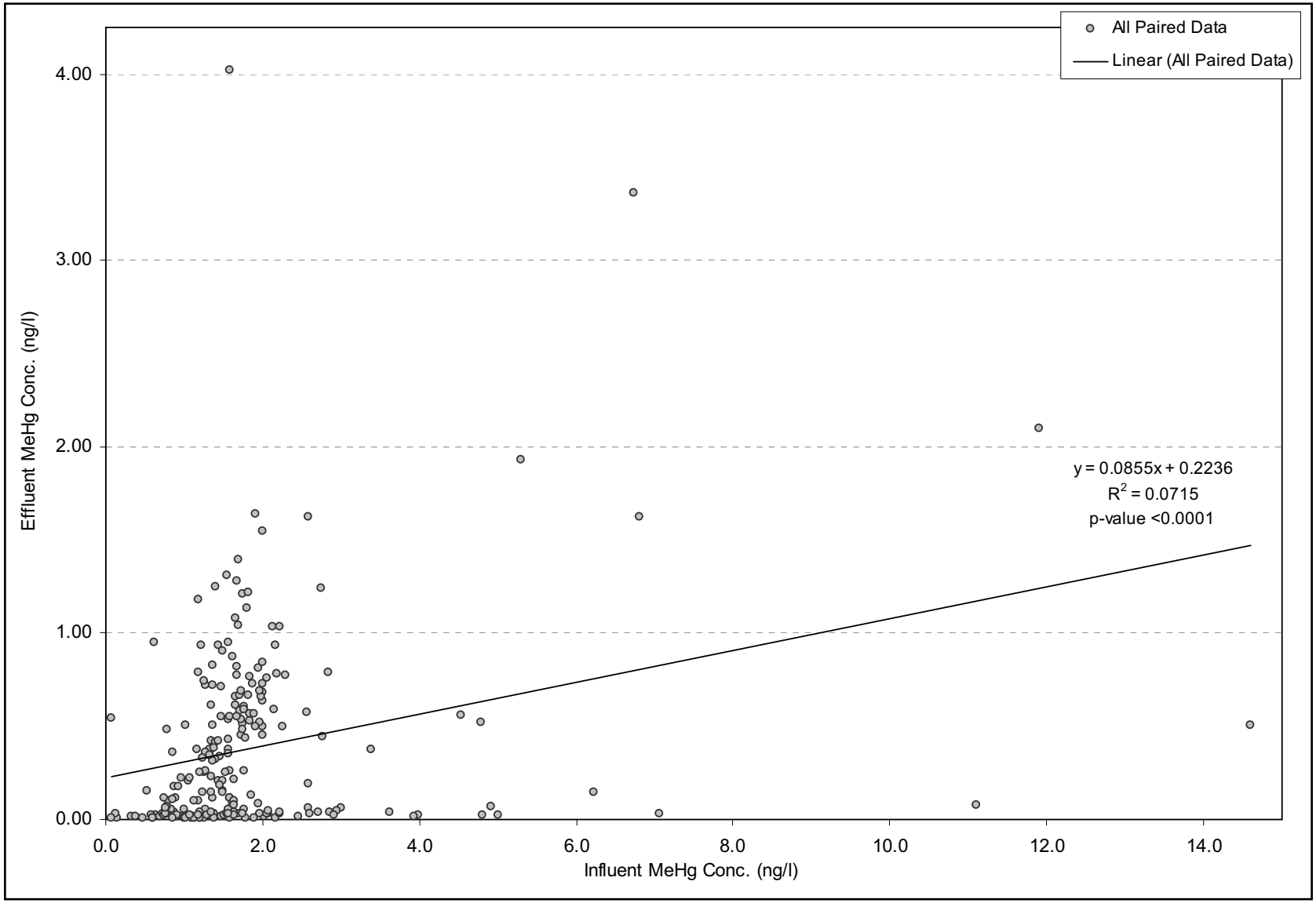

Figure 28b: Scatter-plot of Municipal WWTP Influent versus Effluent Methylmercury Concentrations for All Paired Data [including SRCSD Sacramento River WWTP data]

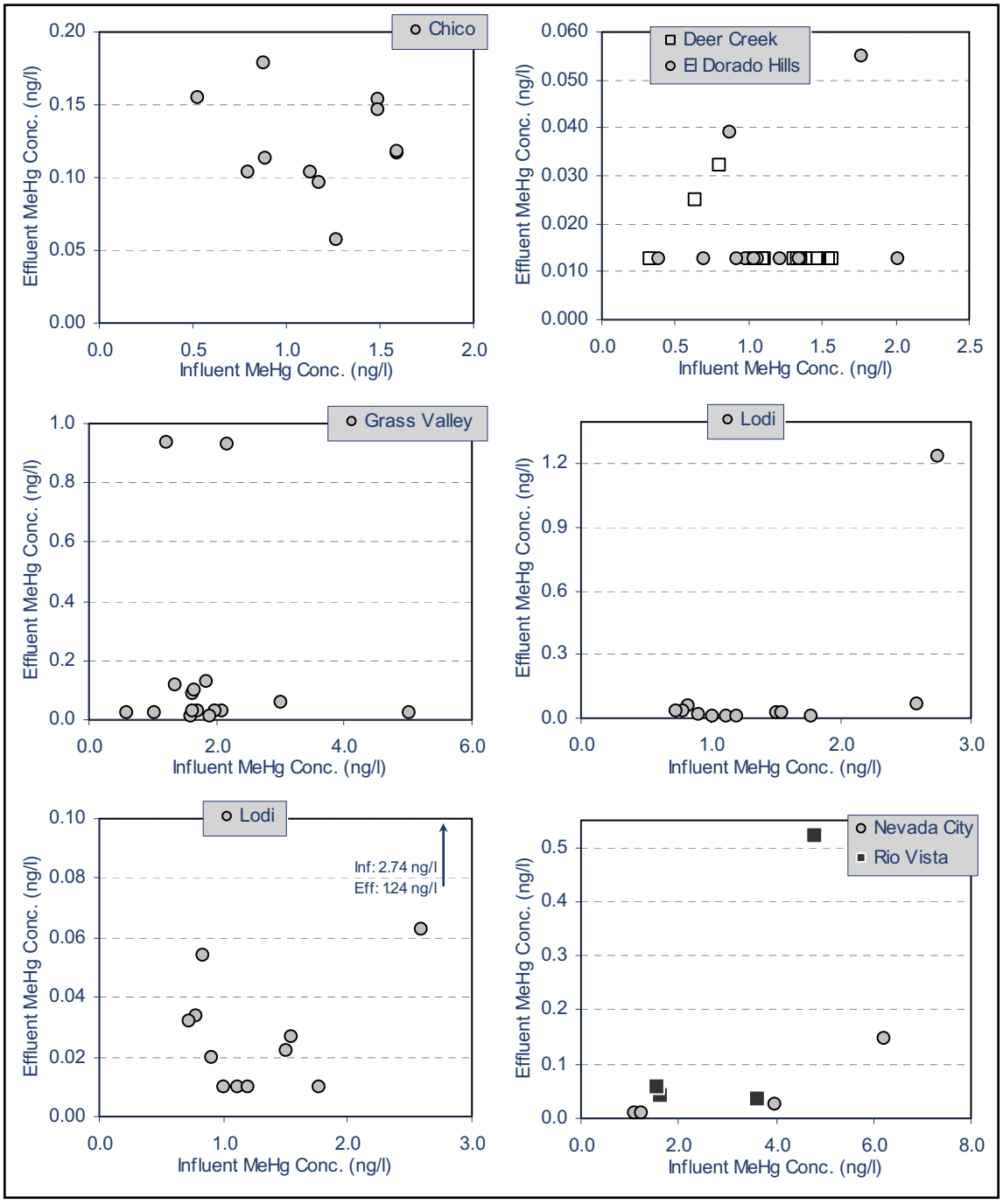

Figure 29a: Scatter-plots of Influent versus Effluent Methylmercury Concentrations for Each Municipal WWTP

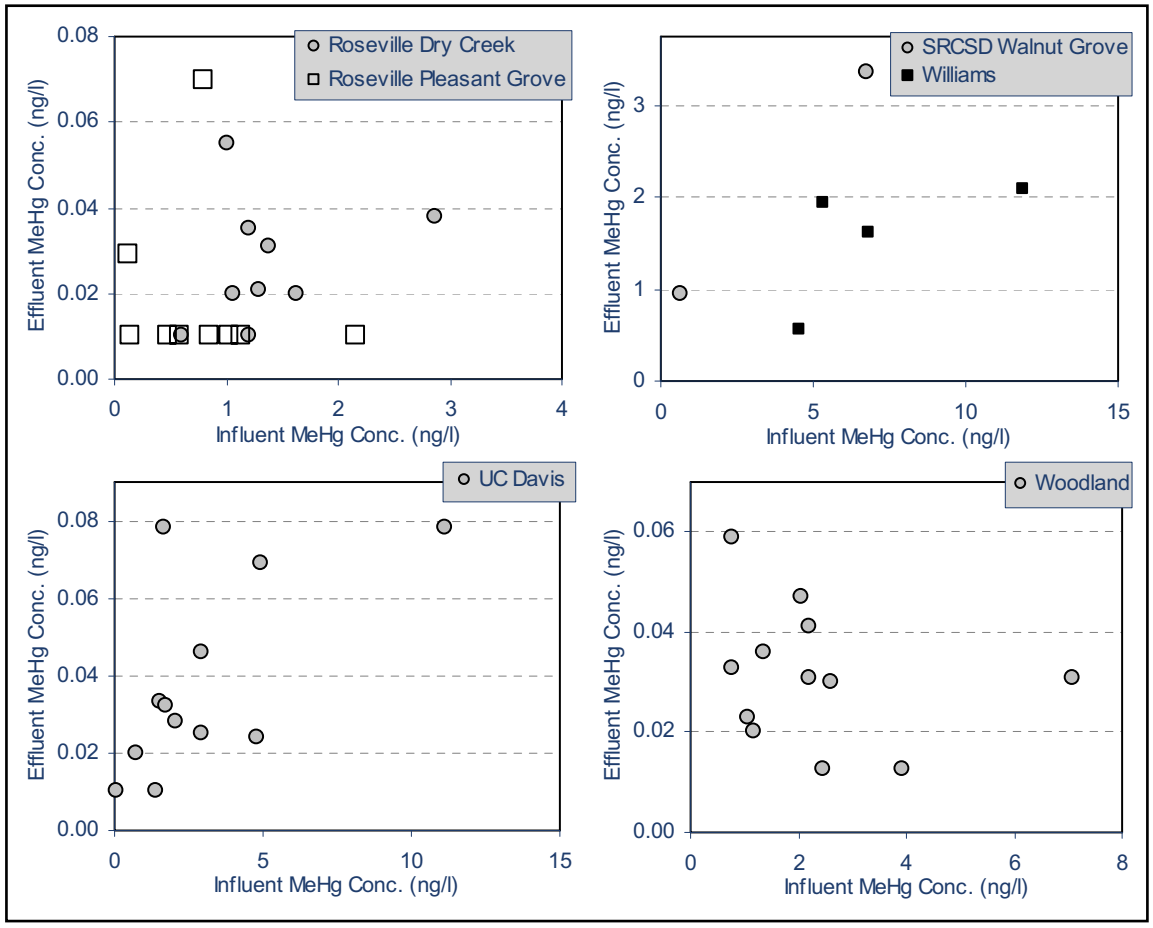

Figure 29b: Scatter-plots of Influent versus Effluent Methylmercury Concentrations for Each Municipal WWTP

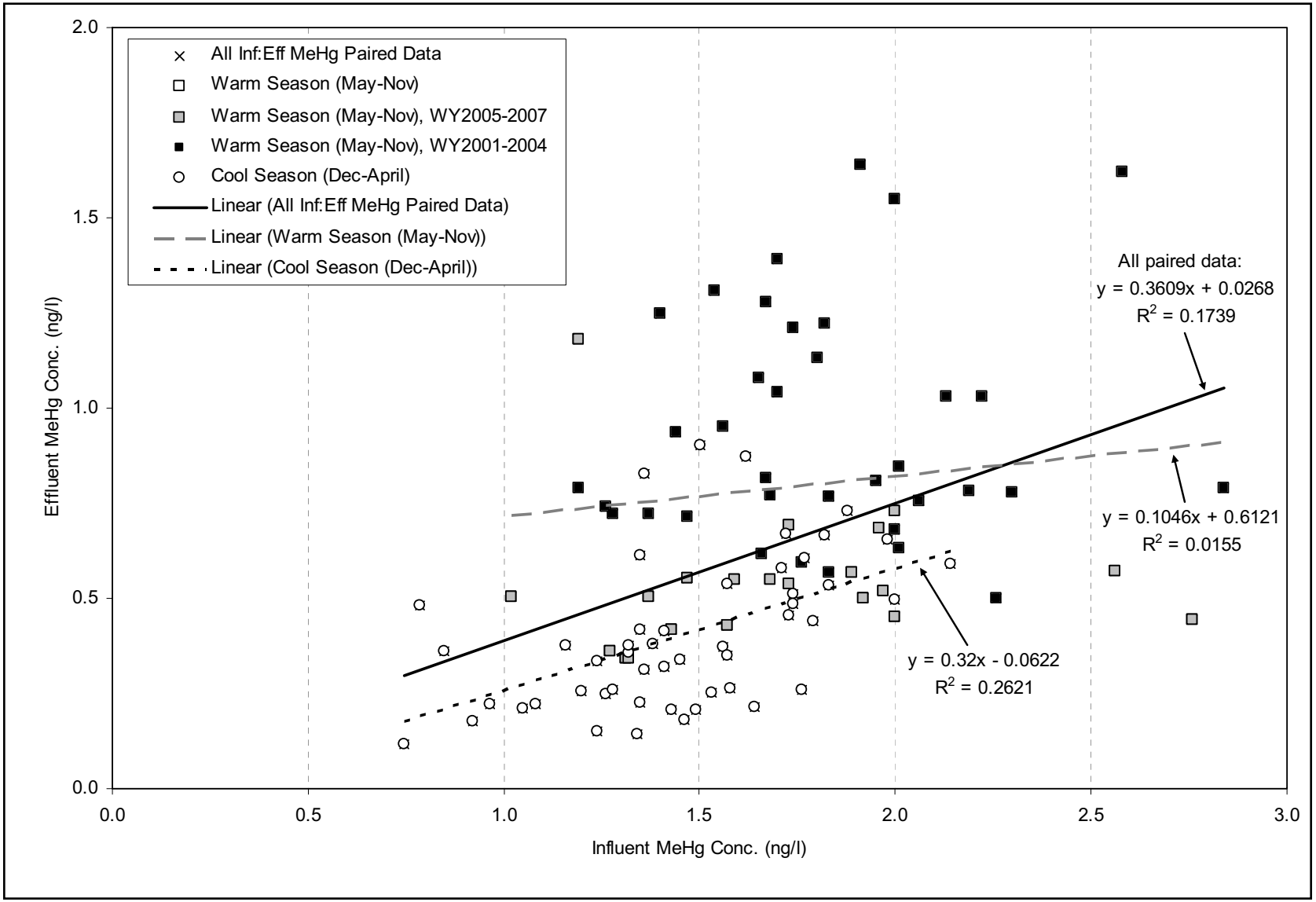

Figure 30: Scatter-plot of Influent versus Effluent Methylmercury Concentrations for the SRCSD Sacramento River WWTP

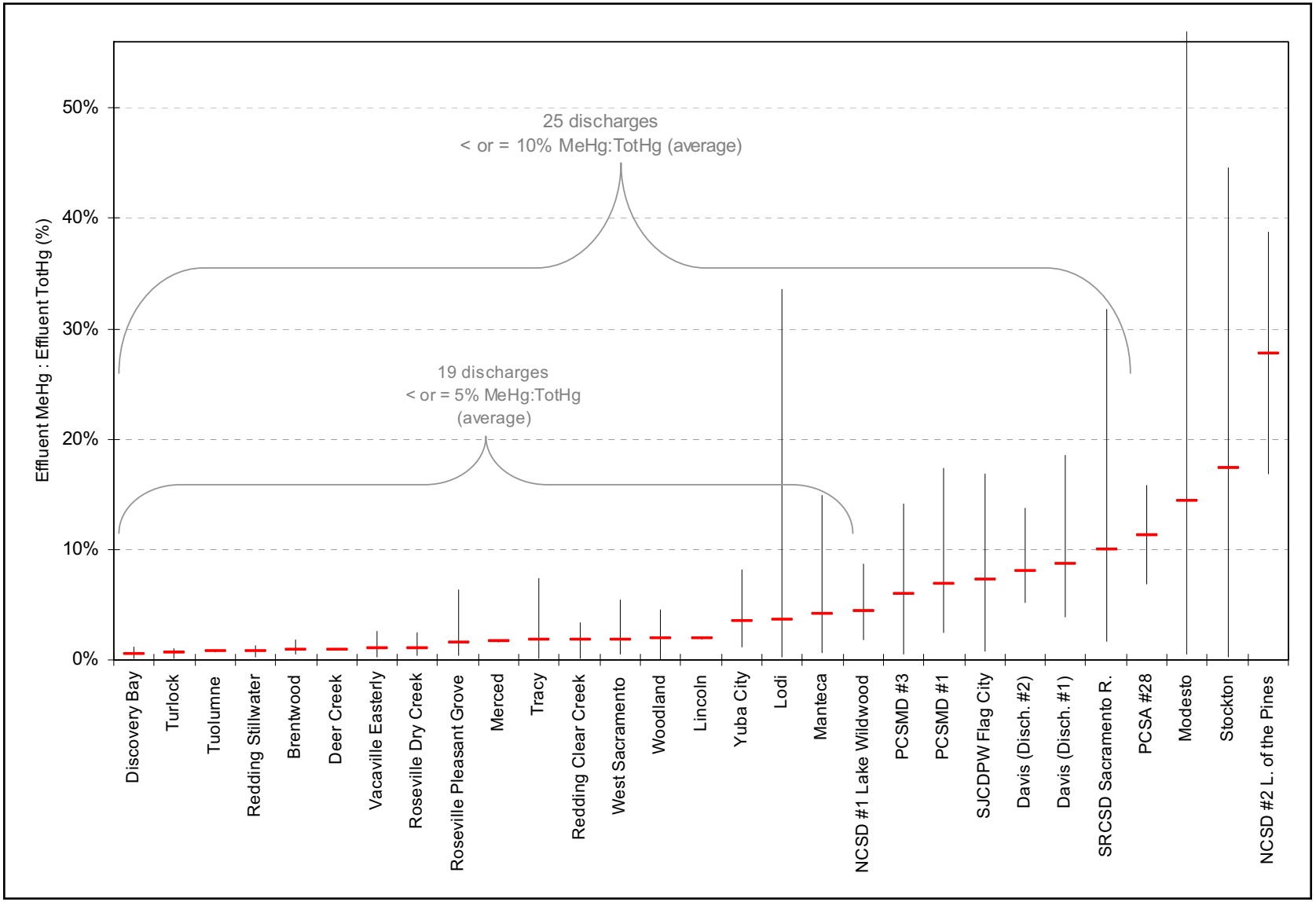

Figure 31: Average and Range of Effluent MeHg:TotHg Concentration Ratios for Each Municipal WWTP

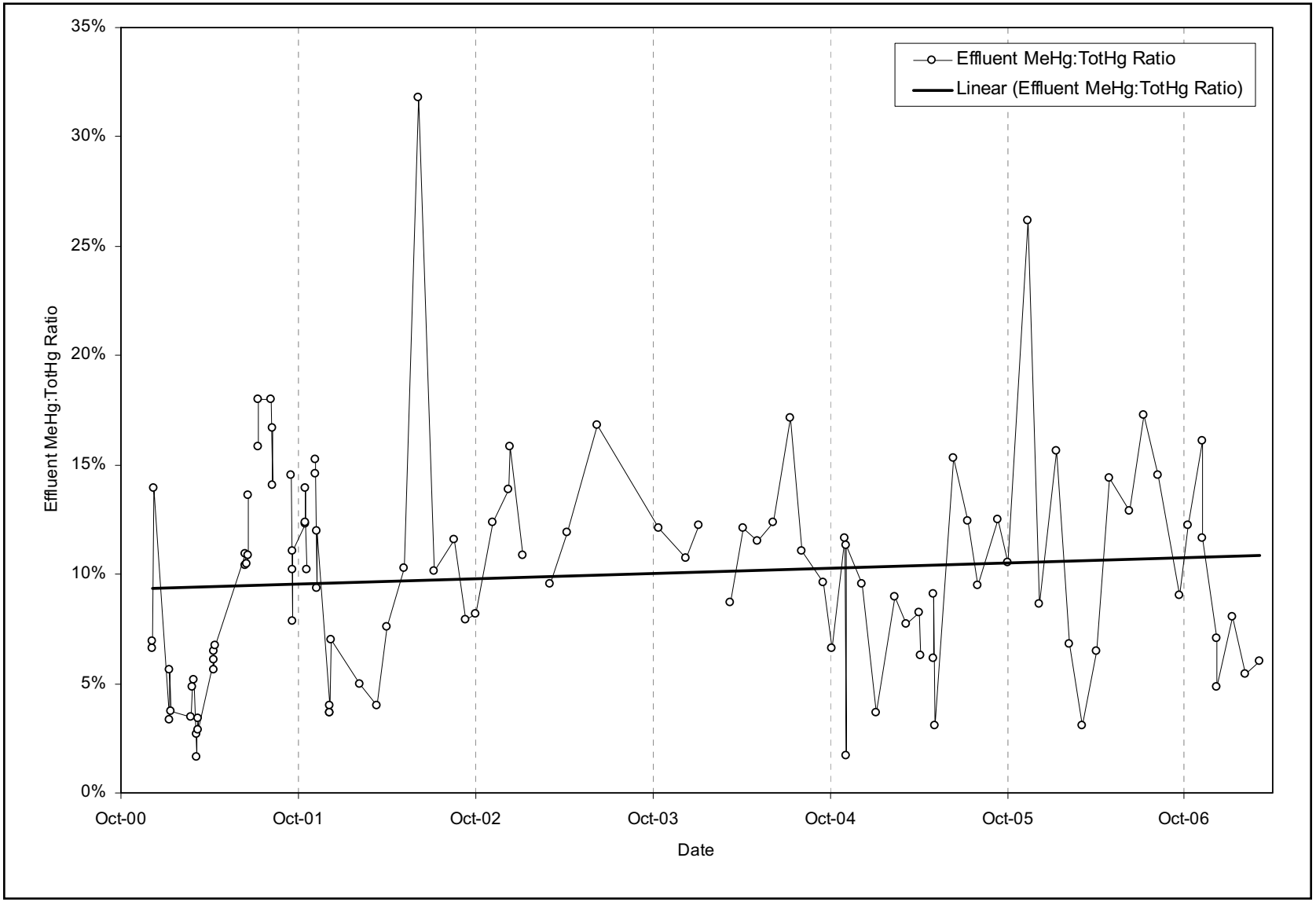

Figure 32: Time-series Graph of SRCSD Sacramento River WWTP Effluent MeHg:TotHg Concentration Ratios

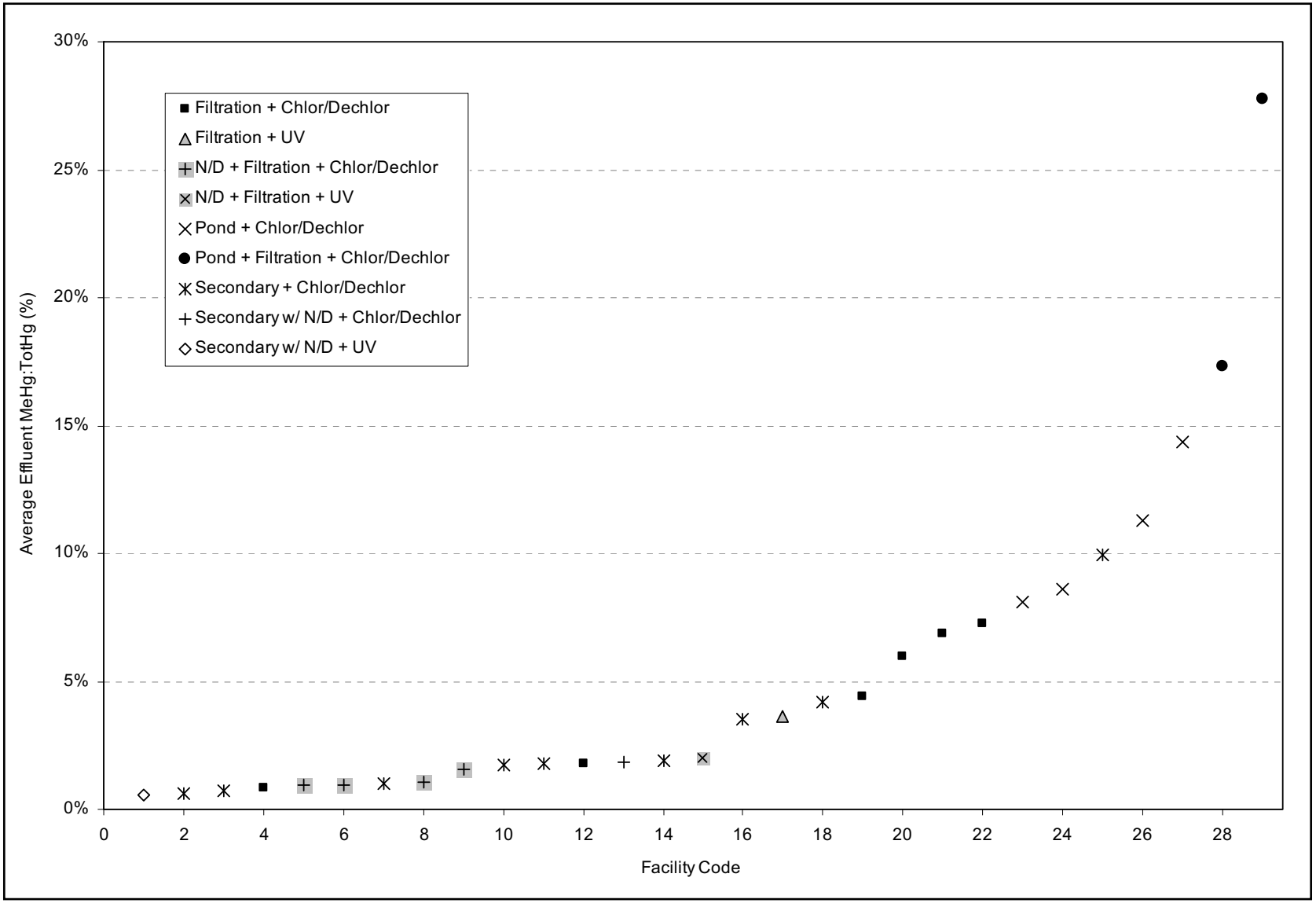

Figure 33: Average of Effluent MeHg:TotHg Concentration Ratios with the Secondary Treatment Category Defined for Each Municipal WWTP

Facility Codes Used in Figure 33

Facility Code	NPDES No.	Facility
1	CA0078590	Discovery Bay WWTP
2	CA0078948	Turlock WWTP
3	CA0084727	Tuolumne UD Sonora RWTP/ Jamestown SDWTP
4	CA0082589	Redding Stillwater WWTP
5	CA0082660	Brentwood WWTP
6	CA0078662	Deer Creek WWTP
7	CA0077691	Vacaville Easterly WWTP
8	CA0079502	Roseville Dry Creek WWTP
9	CA0084573	Roseville Pleasant Grove WWTP
10	CA0079219	Merced WWTP
11	CA0079154	Tracy WWTP
12	CA0079731	Redding Clear Creek WWTP
13	CA0079171	West Sacramento WWTP
14	CA0077950	Woodland WWTP
15	CA0084476	Lincoln WWTP
16	CA0079260	Yuba City WWTP
17	CA0079243	Lodi White Slough WWTP
18	CA0081558	Manteca WWTP
19	CA0077828	Nevada Co SD #1 Lake Wildwood WWTP
20	CA0079367	Placer Co. SMD #3 WWTP
21	CA0079316	Placer Co. SMD #1 WWTP
22	CA0082848	San Joaquin Co DPW - Flag City WWTP
23	CA0079049	Davis WWTP (Discharge 2)
24	CA0079049	Davis WWTP (Discharge 1)
25	CA0077682	SRCSD Sacramento River WWTP
26	CA0079341	Placer Co. SA #28 Zone #6 WWTP
27	CA0079103	Modesto WWTP
28	CA0079138	Stockton WWTP
29	CA0081612	Nevada Co SD #2 Lake of the Pines WWTP

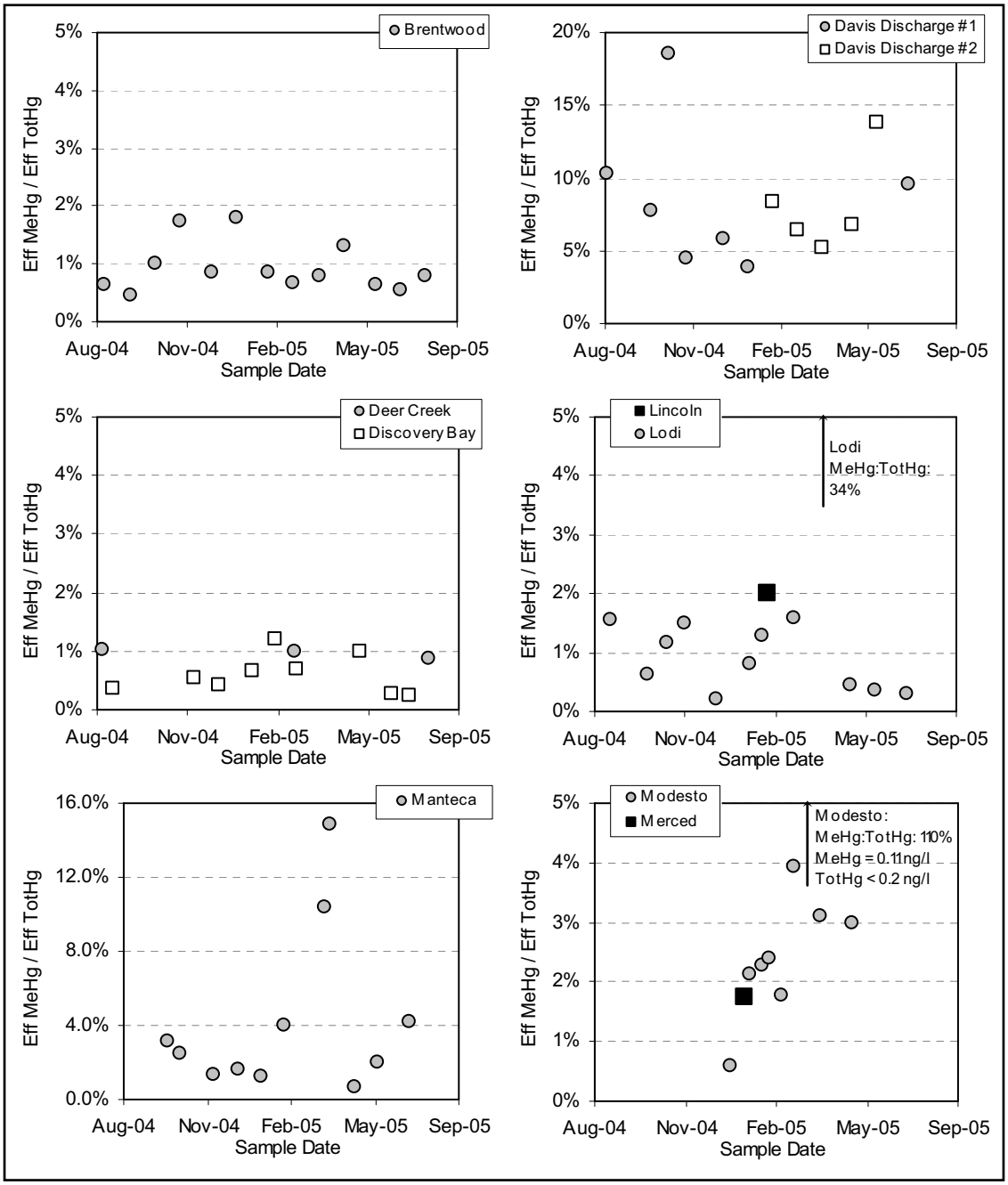

Figure 34a: Time-series Graphs of Municipal WWTP Effluent MeHg:TotHg Concentration Ratios

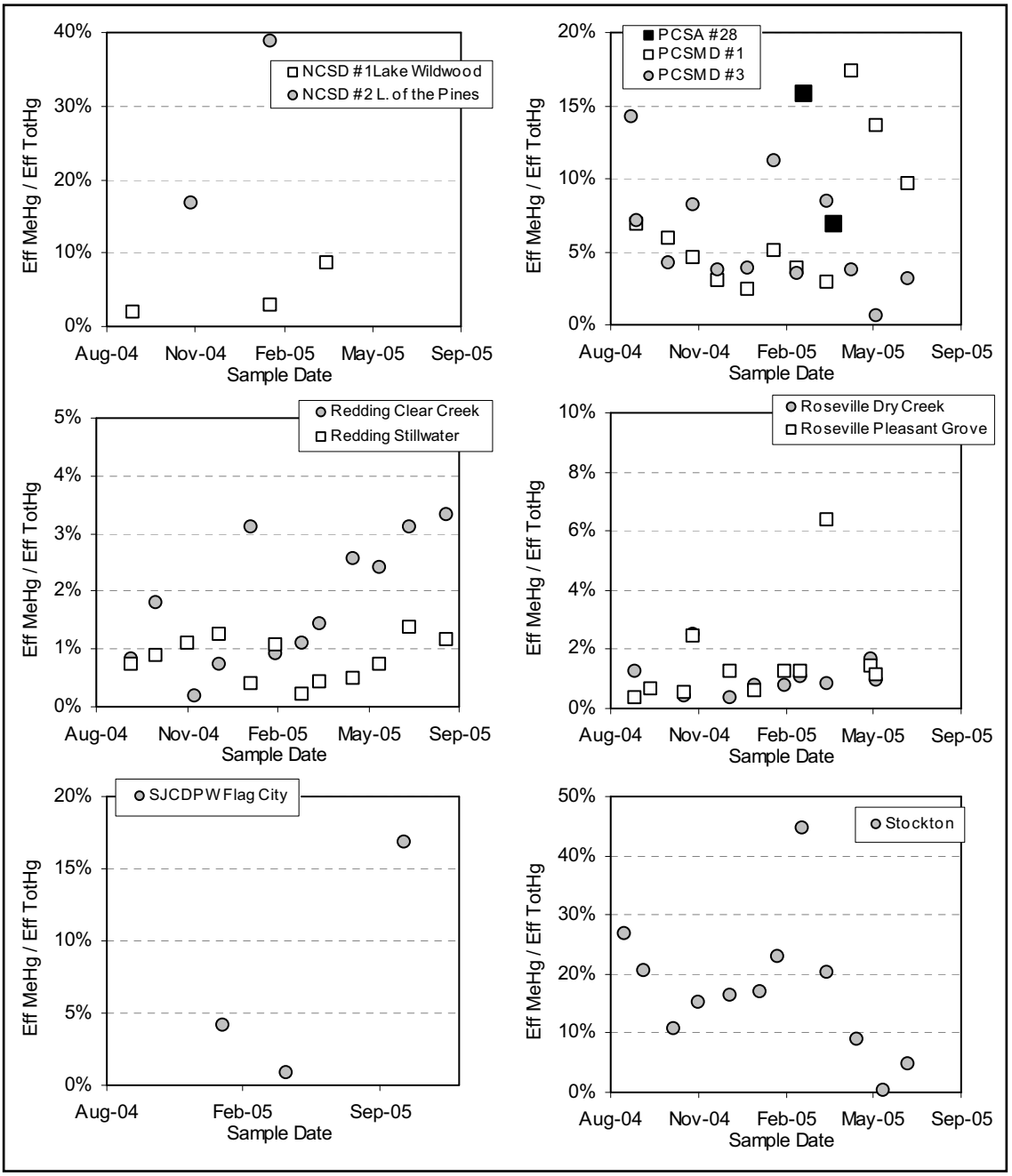

Figure 34b: Time-series Graphs of Municipal WWTP Effluent MeHg:TotHg Concentration Ratios

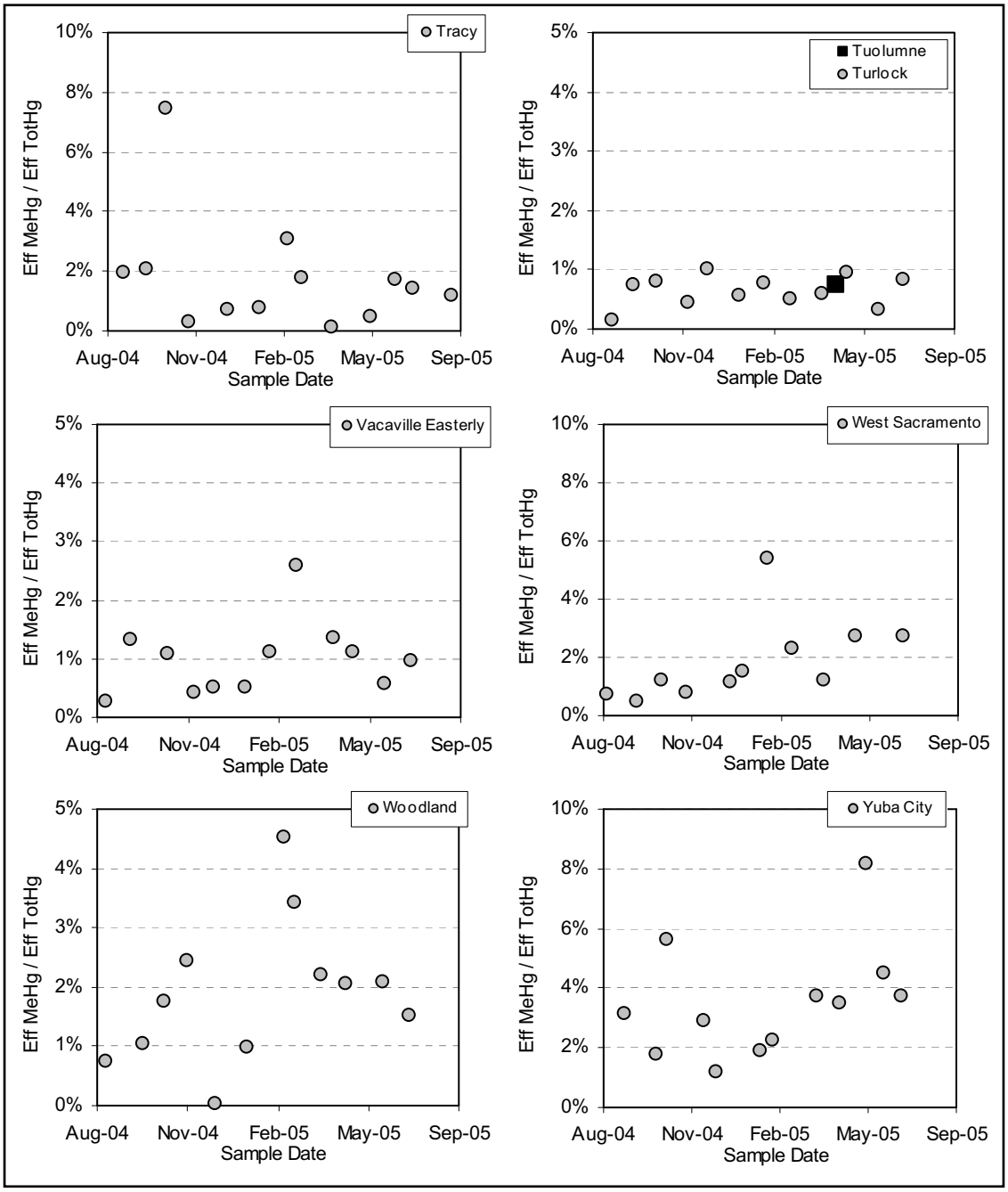

Figure 34c: Time-series Graphs of Municipal WWTP Effluent MeHg:TotHg Concentration Ratios

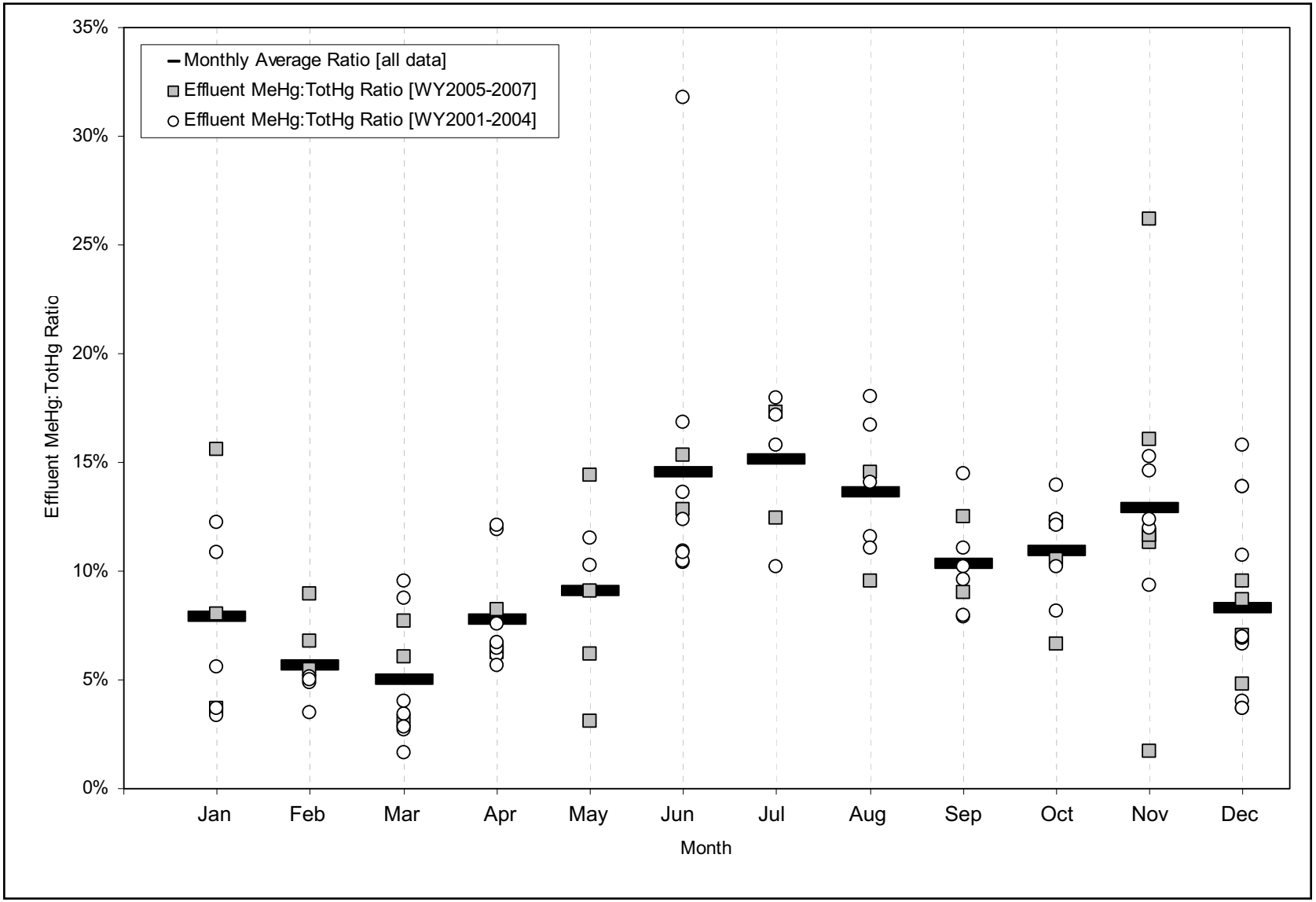

Figure 35: Monthly Effluent MeHg:TotHg Concentration Ratios for the SRCSD Sacramento River WWTP from WY2001-2007

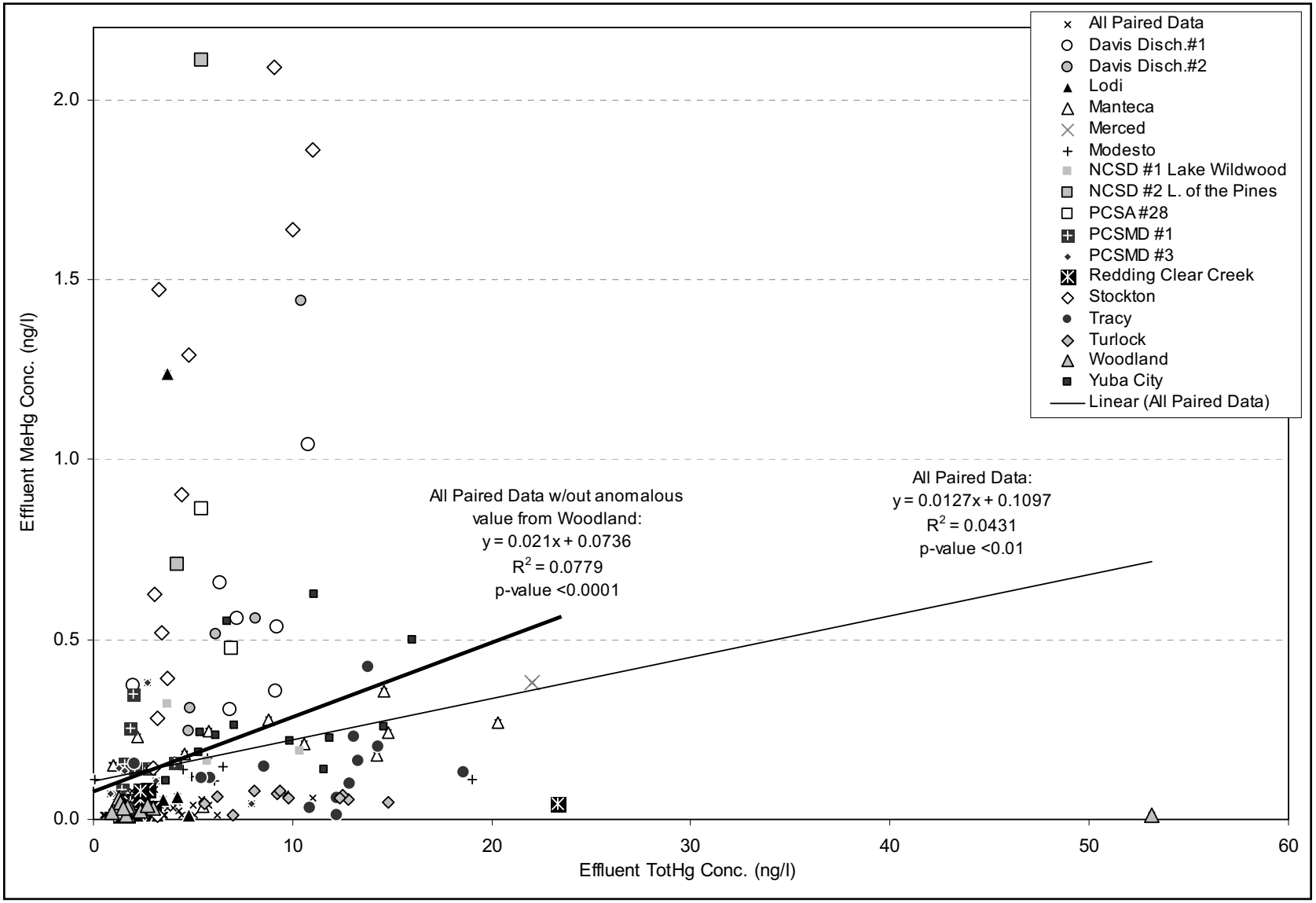

Figure 36a: Scatter-plot of Municipal WWTP Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for All Paired Data [excluding SRCSD Sacramento River WWTP data]

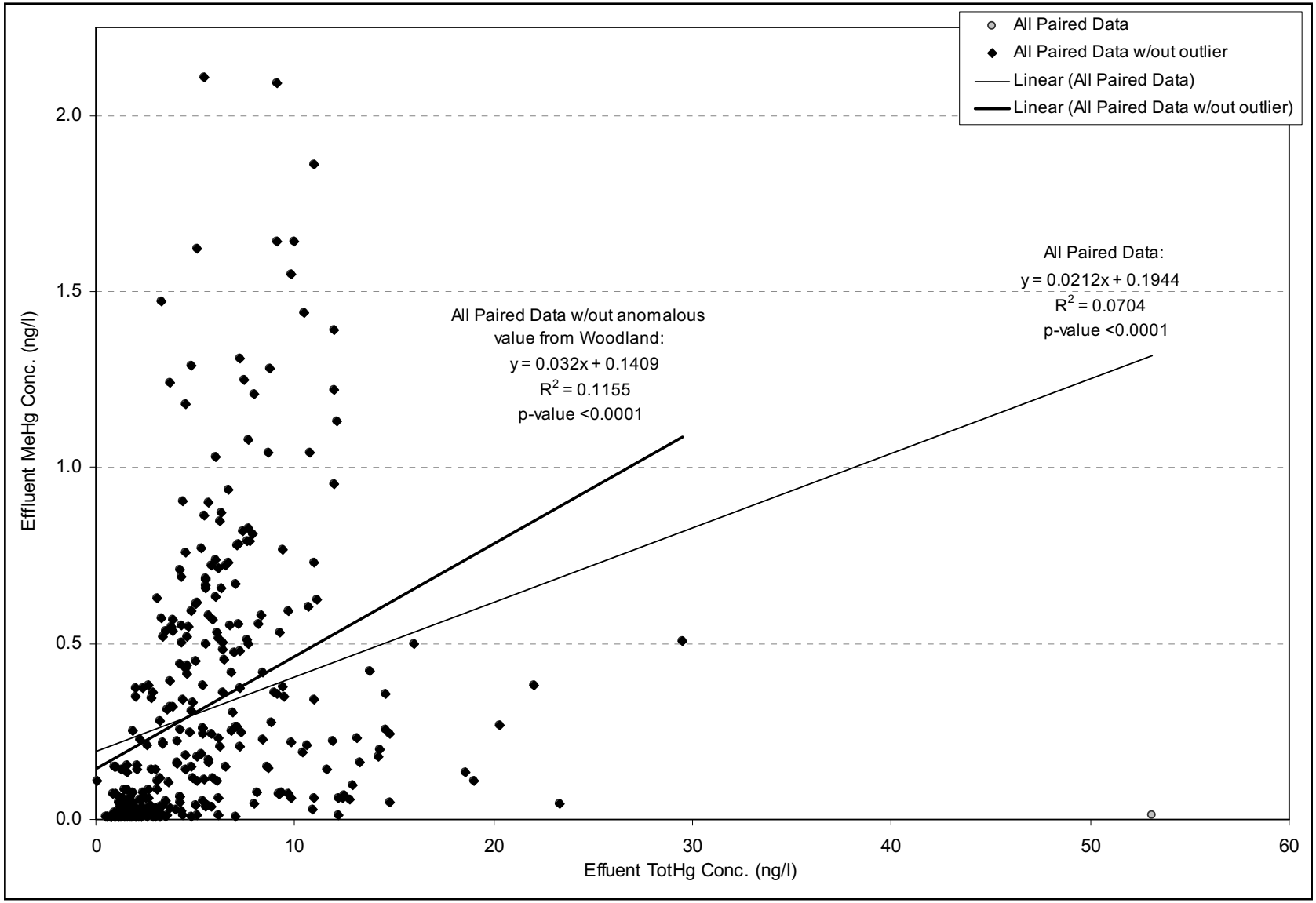

Figure 36b: Scatter-plot of Municipal WWTP Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for All Paired Data [including SRCSD Sacramento River WWTP data]

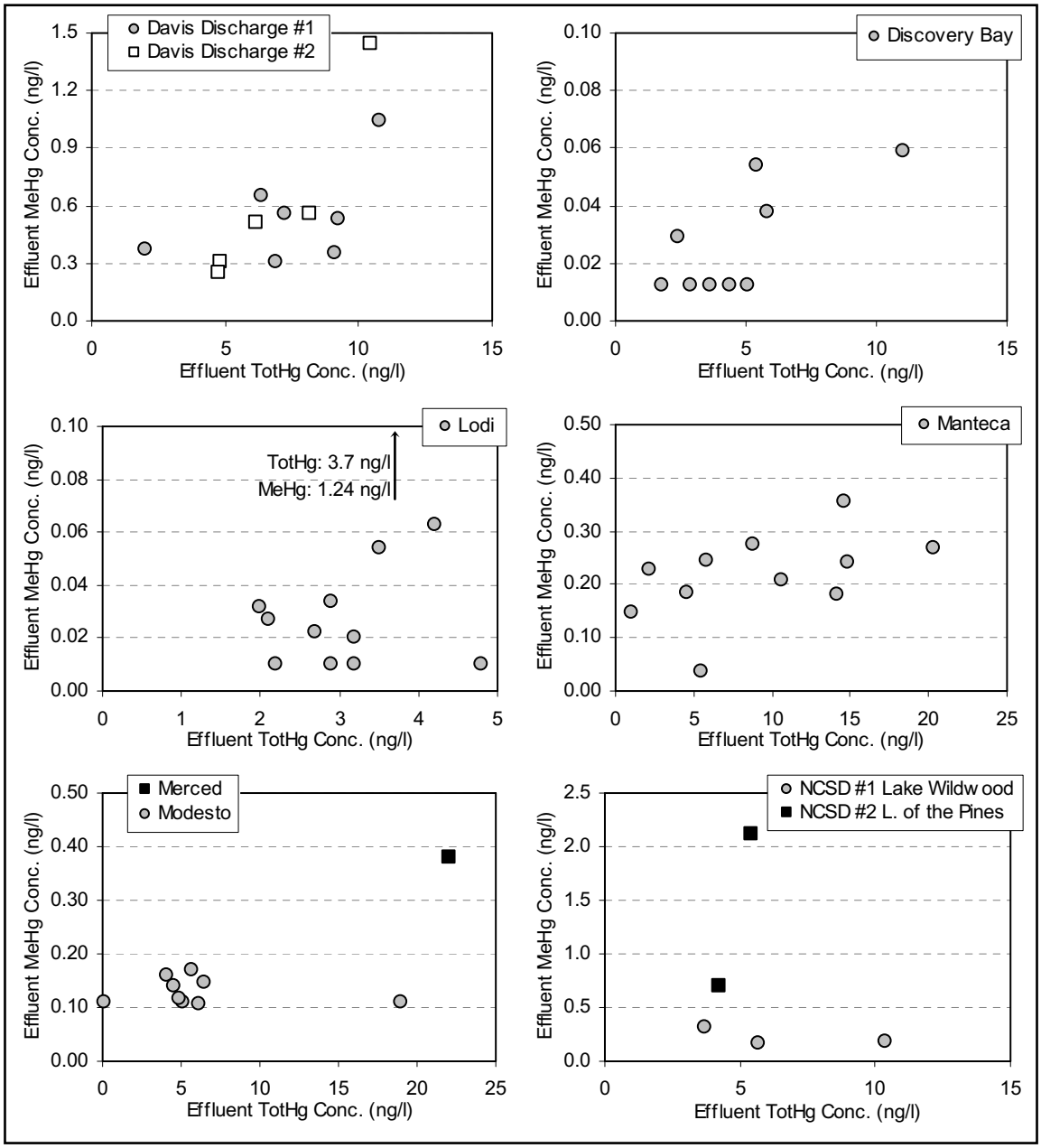

Figure 37a: Scatter-plots of Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for Each Municipal WWTP

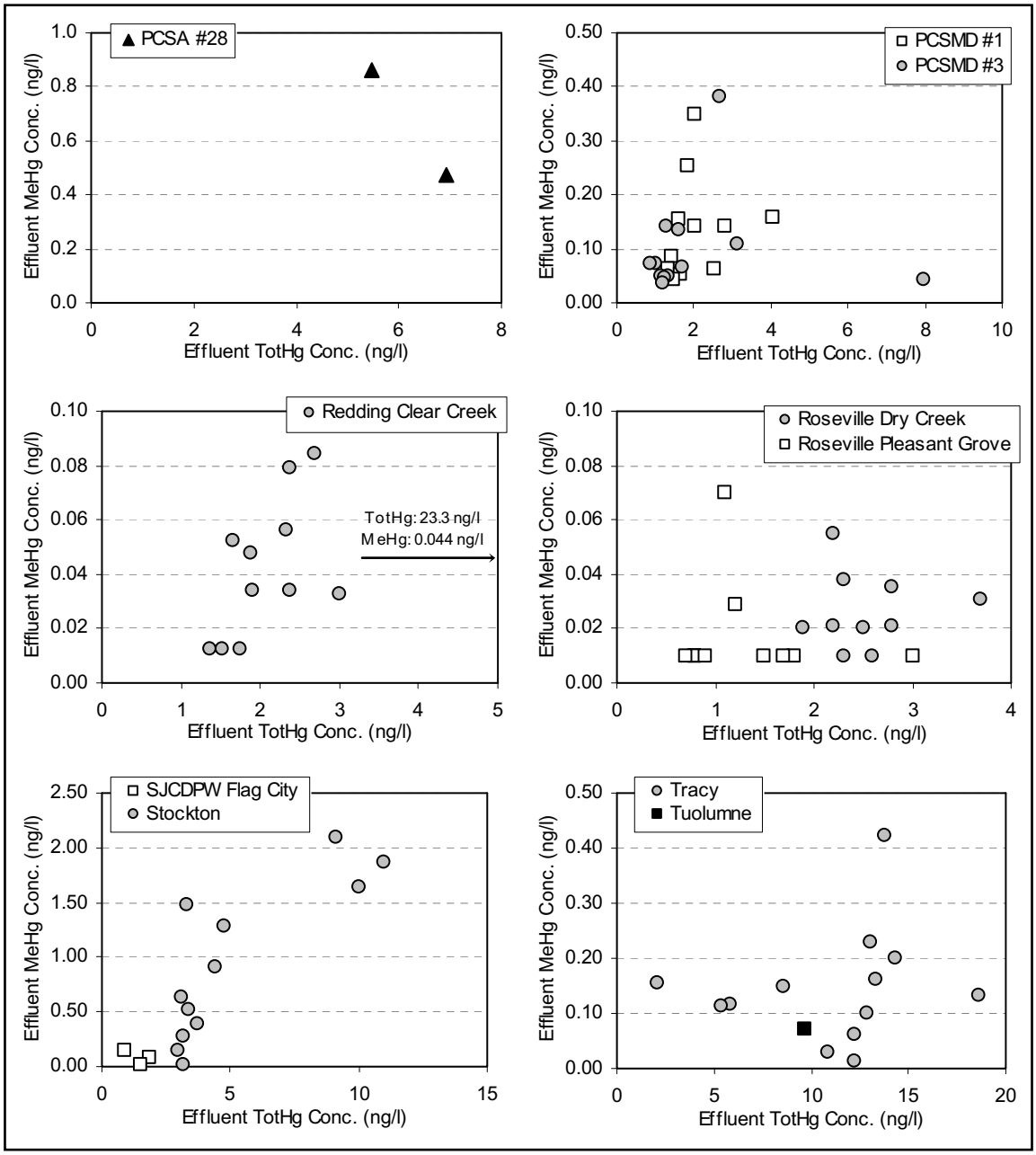

Figure 37b: Scatter-plots of Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for Each Municipal WWTP

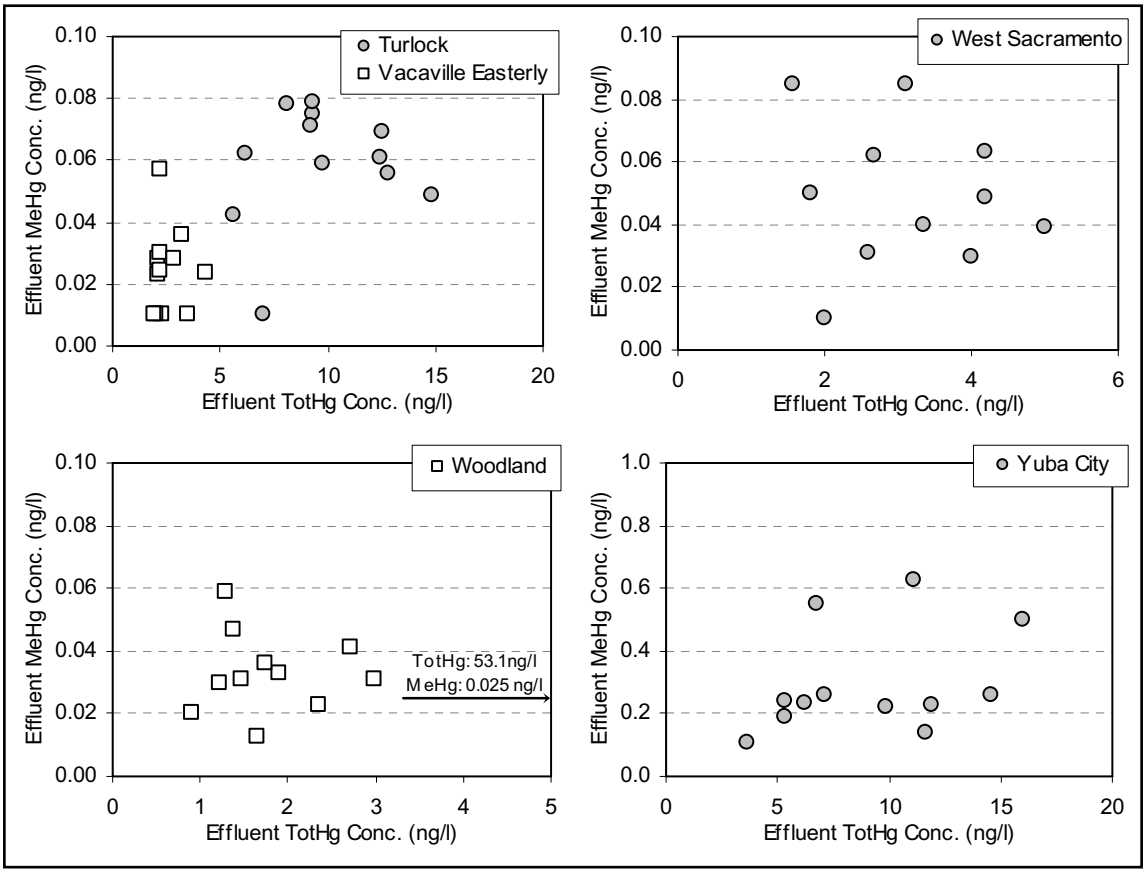

Figure 37c: Scatter-plots of Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for Each Municipal WWTP

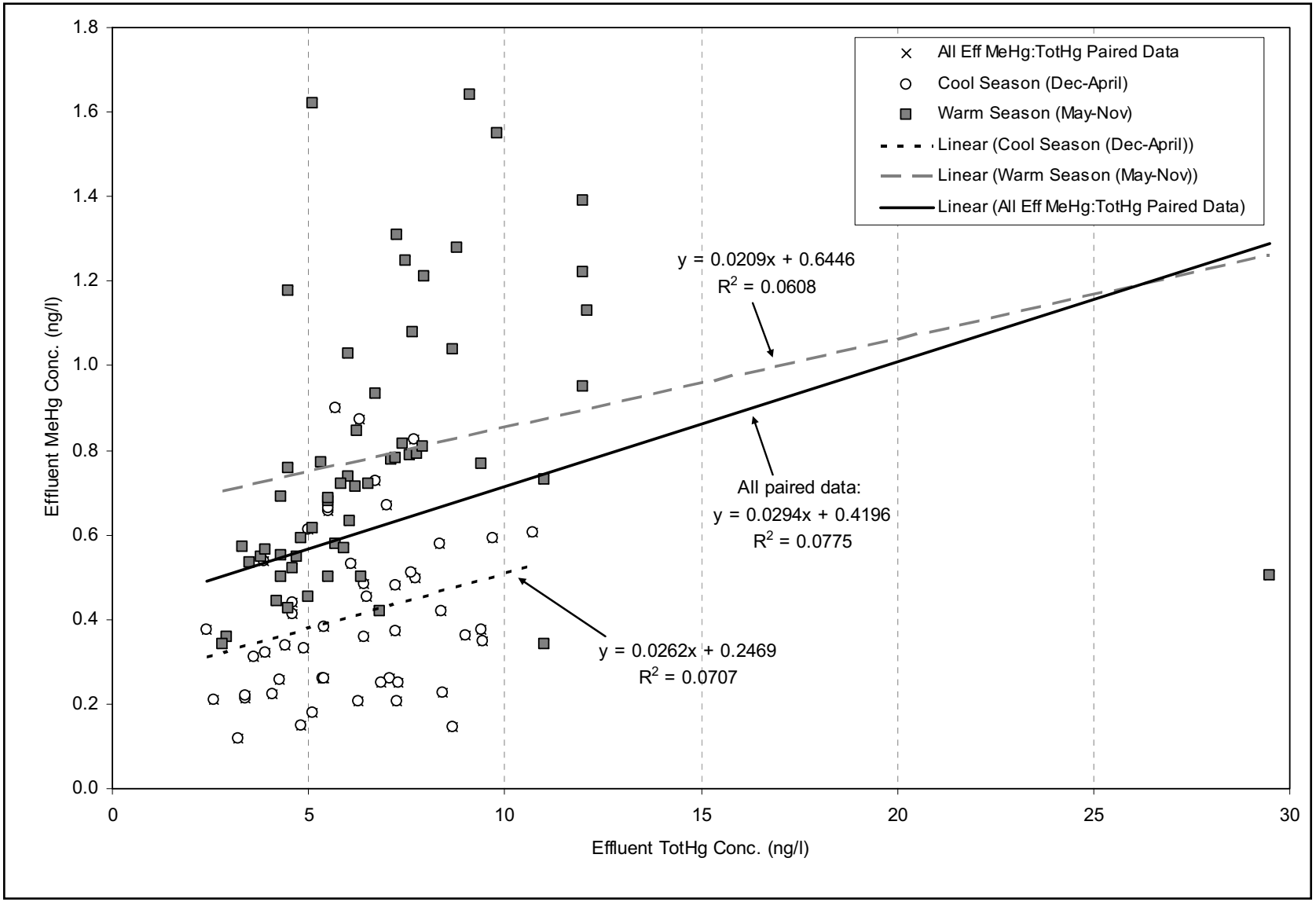

Figure 38: Scatter-plot of Effluent Inorganic Mercury versus Effluent Methylmercury Concentrations for the SRCSD Sacramento River WWTP

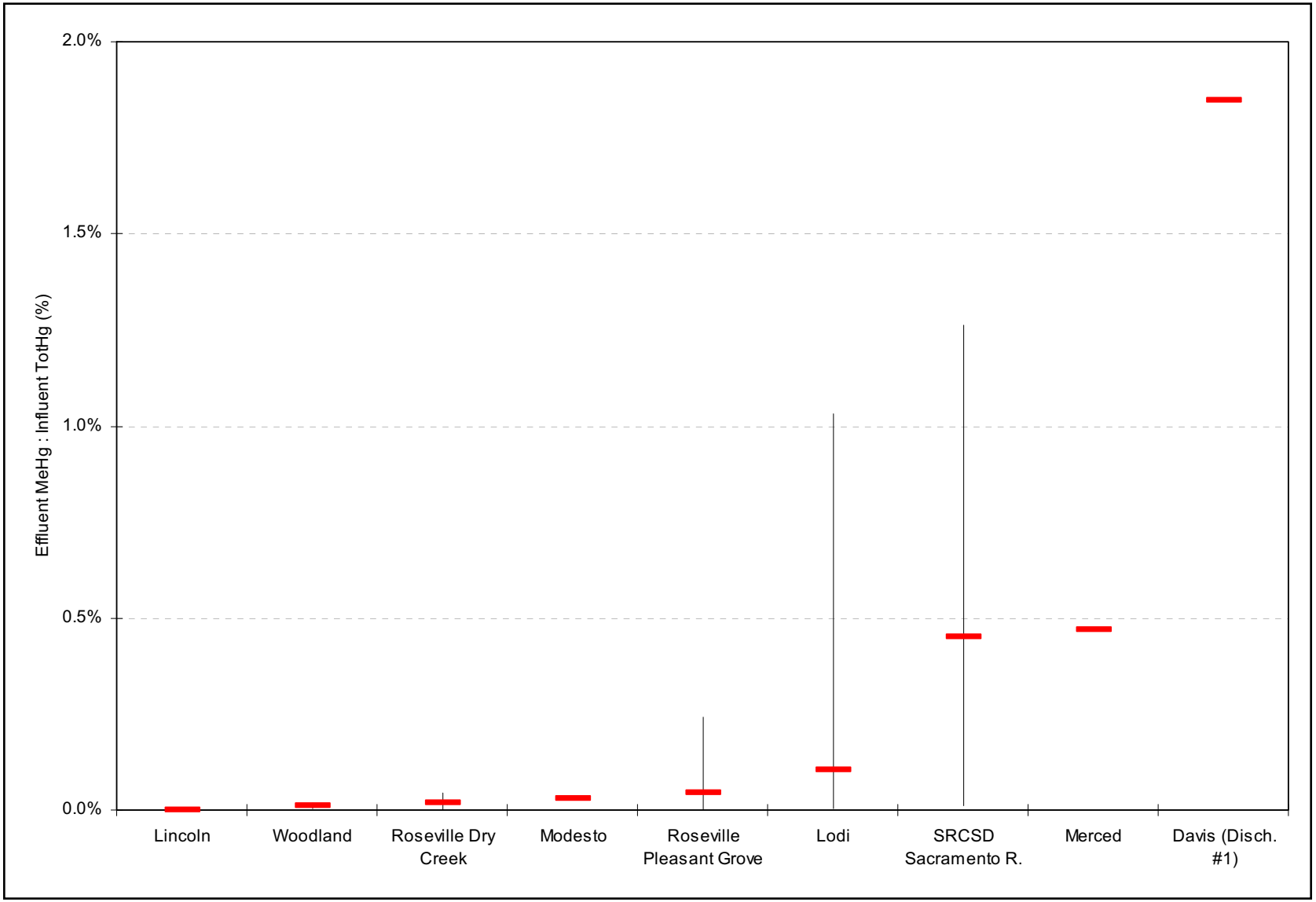

Figure 39: Average and Range of Effluent MeHg:Influent TotHg Concentration Ratios for Each Municipal WWTP

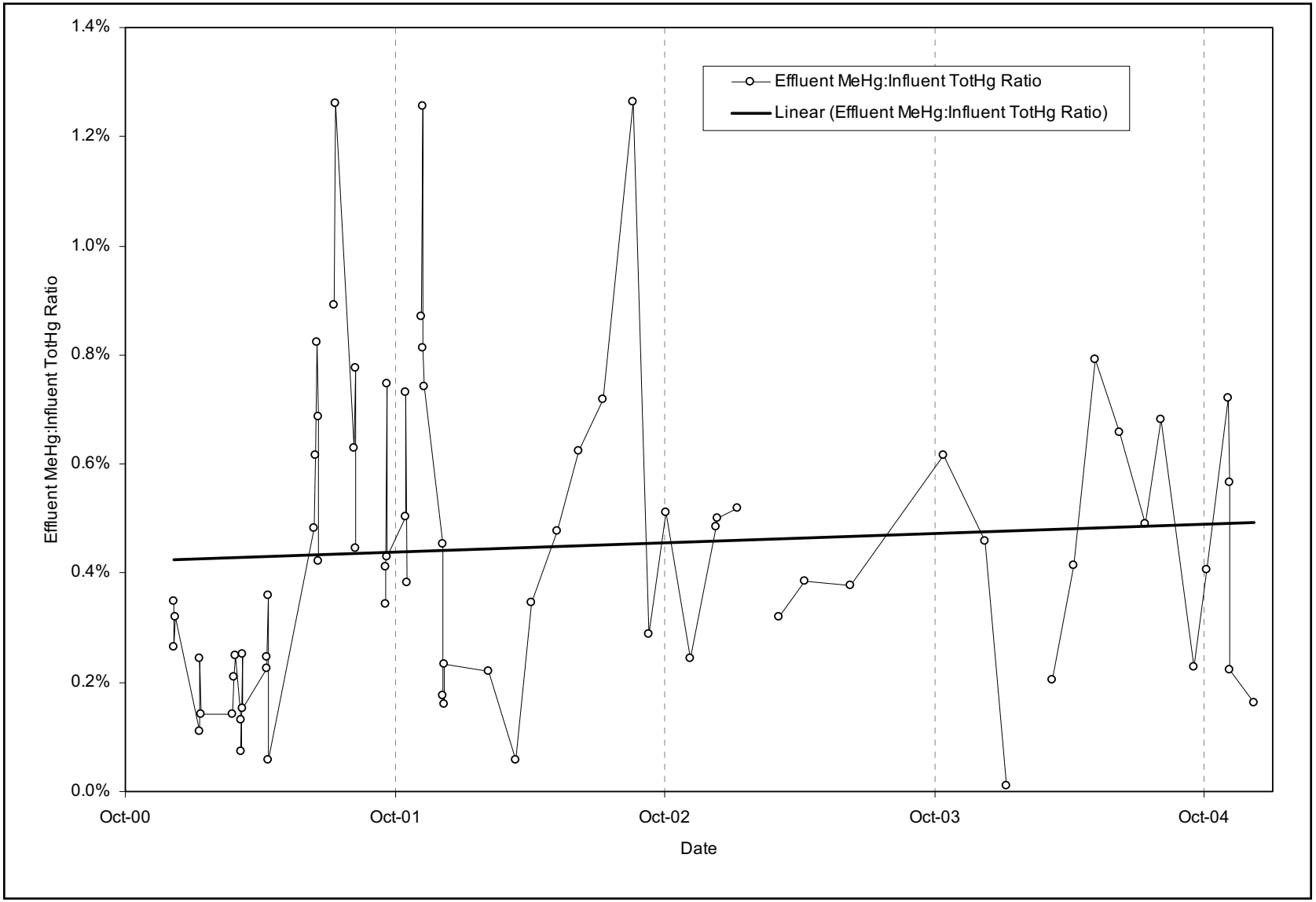

Figure 40: Time-series Graph of SRCSD Sacramento River WWTP Effluent MeHg:Influent TotHg Concentration Ratios

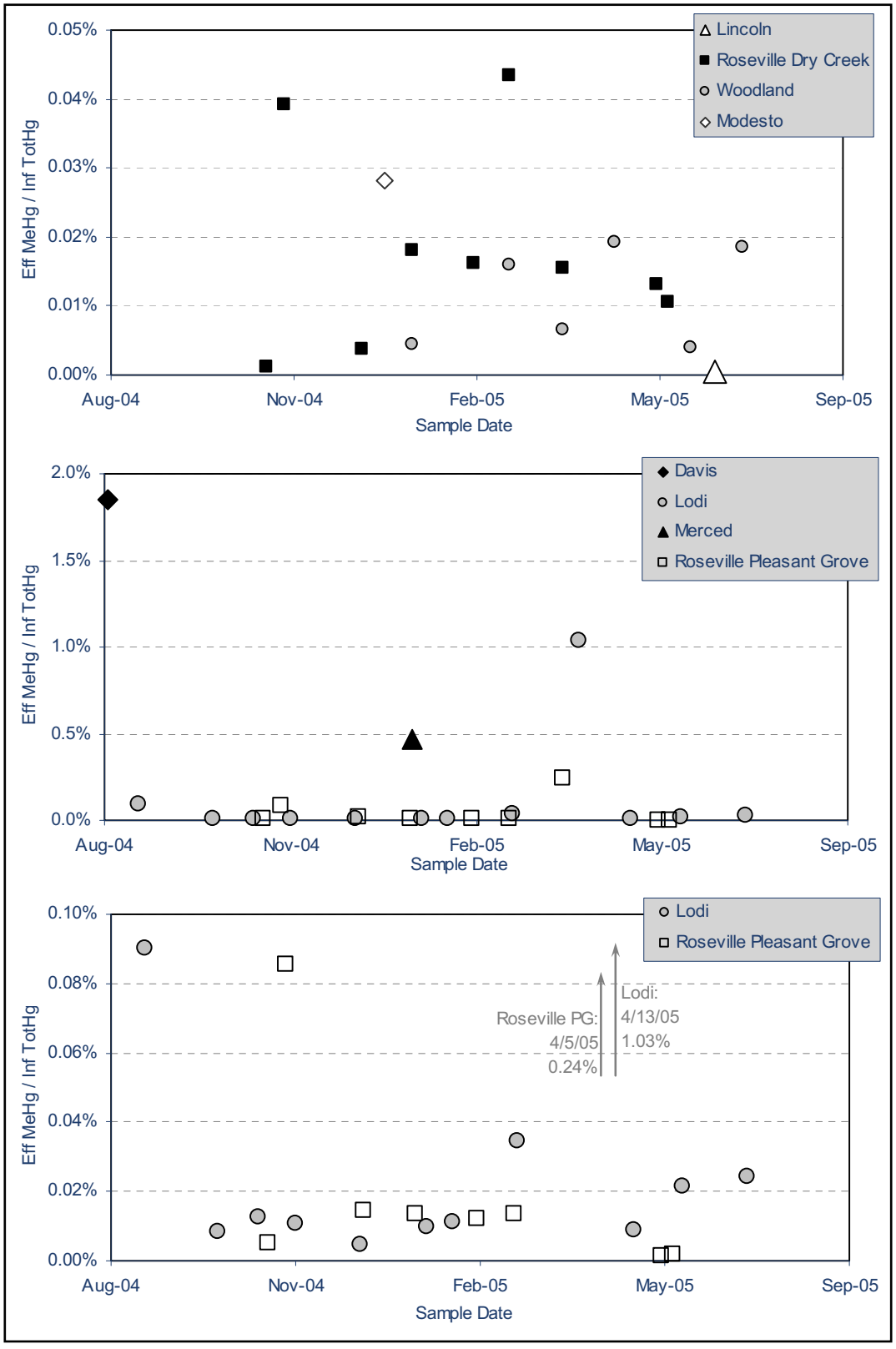

Figure 41: Time-series Graphs of Municipal WWTP Effluent MeHg:Influent TotHg Concentration Ratios

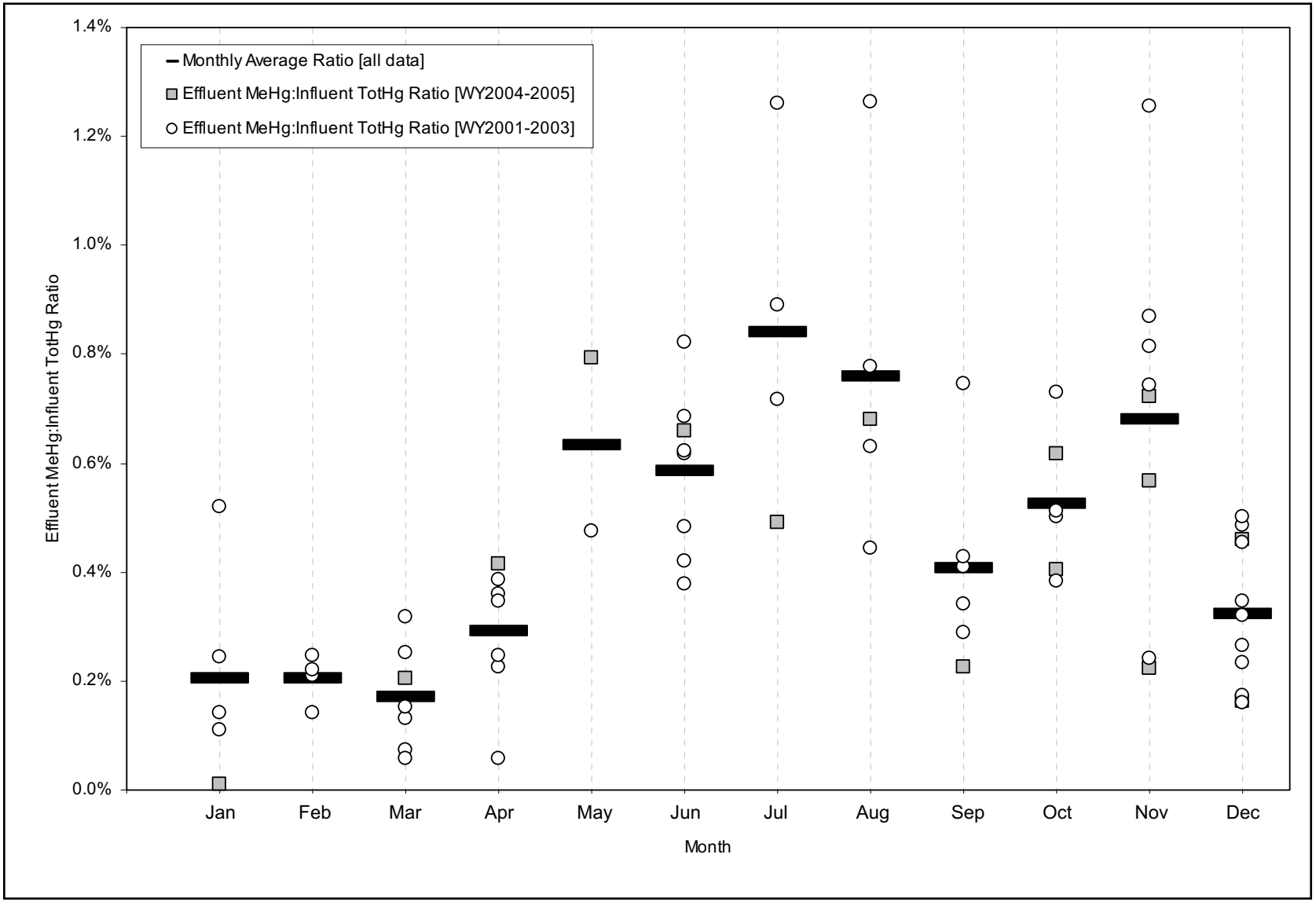

Figure 42: Monthly Effluent MeHg:Influent TotHg Concentration Ratios for the SRCSD Sacramento River WWTP from Dec. 2000 – Dec. 2004

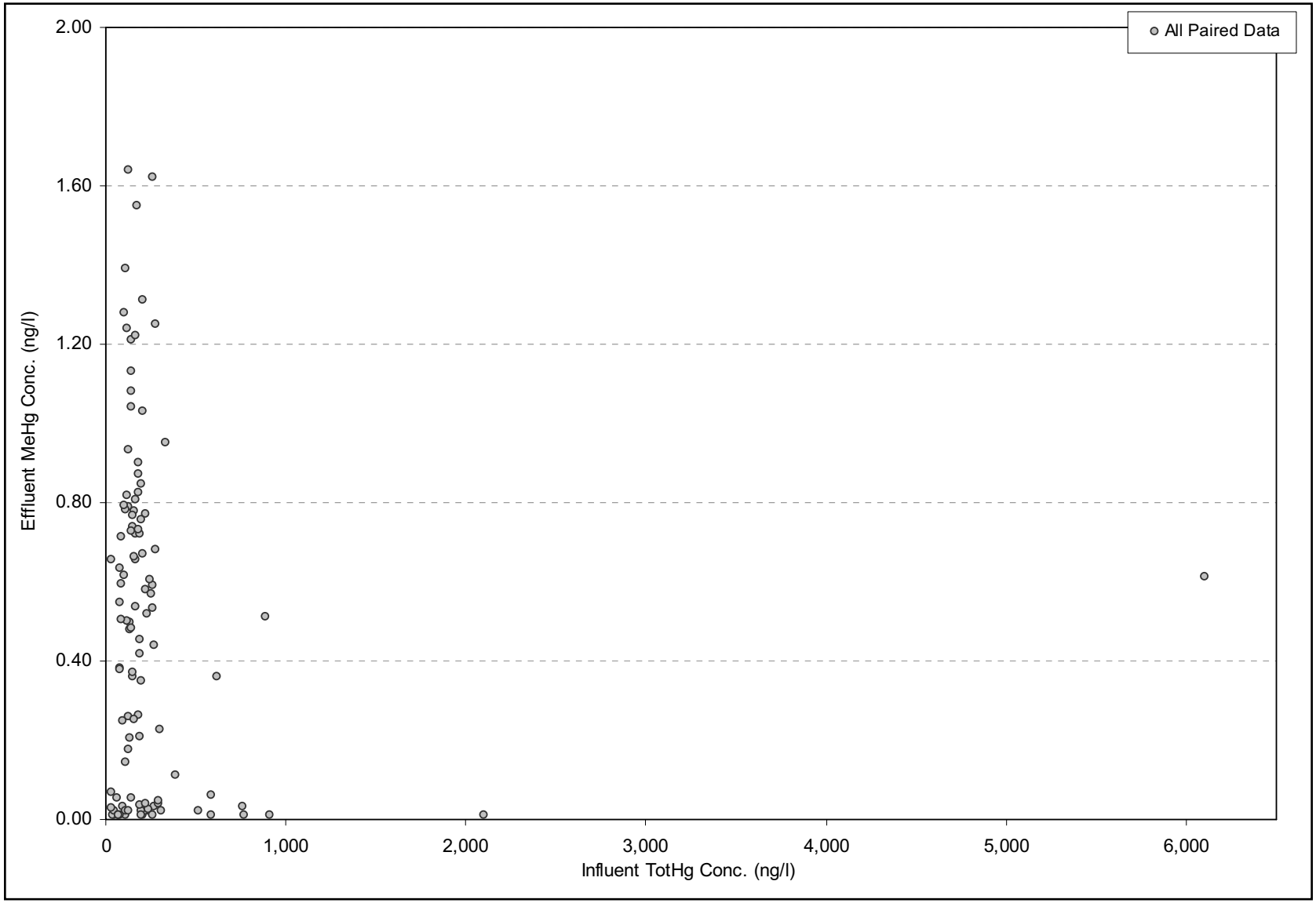

Figure 43a: Scatter-plot of Municipal WWTP Influent Inorganic Mercury versus Effluent Methylmercury Concentrations: All Paired Data [including SRCSD Sacramento WWTP data]

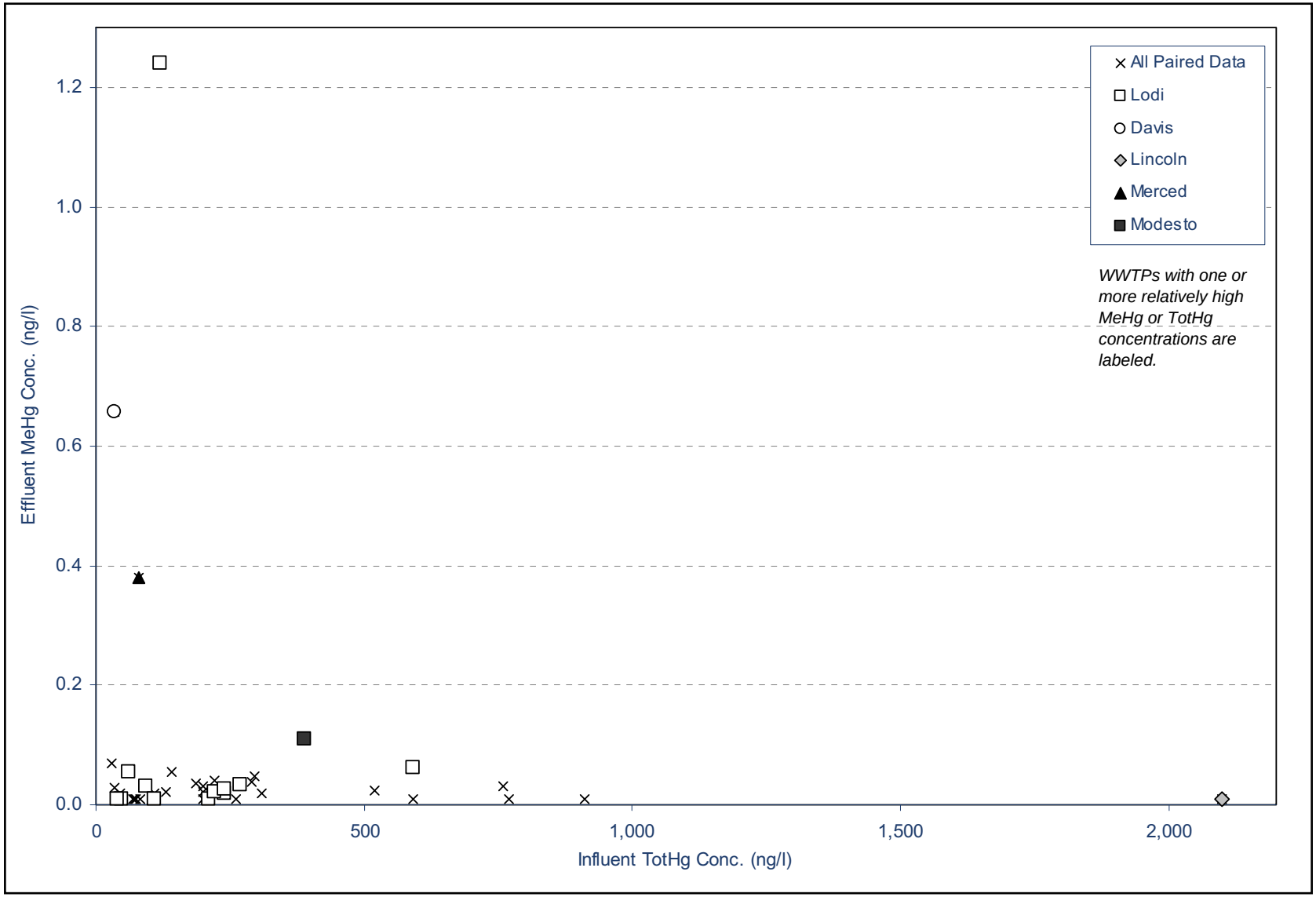

Figure 43b: Scatter-plot of Municipal WWTP Influent Inorganic Mercury versus Effluent Methylmercury Concentrations: All Paired Data [excluding SRCSD Sacramento WWTP data]

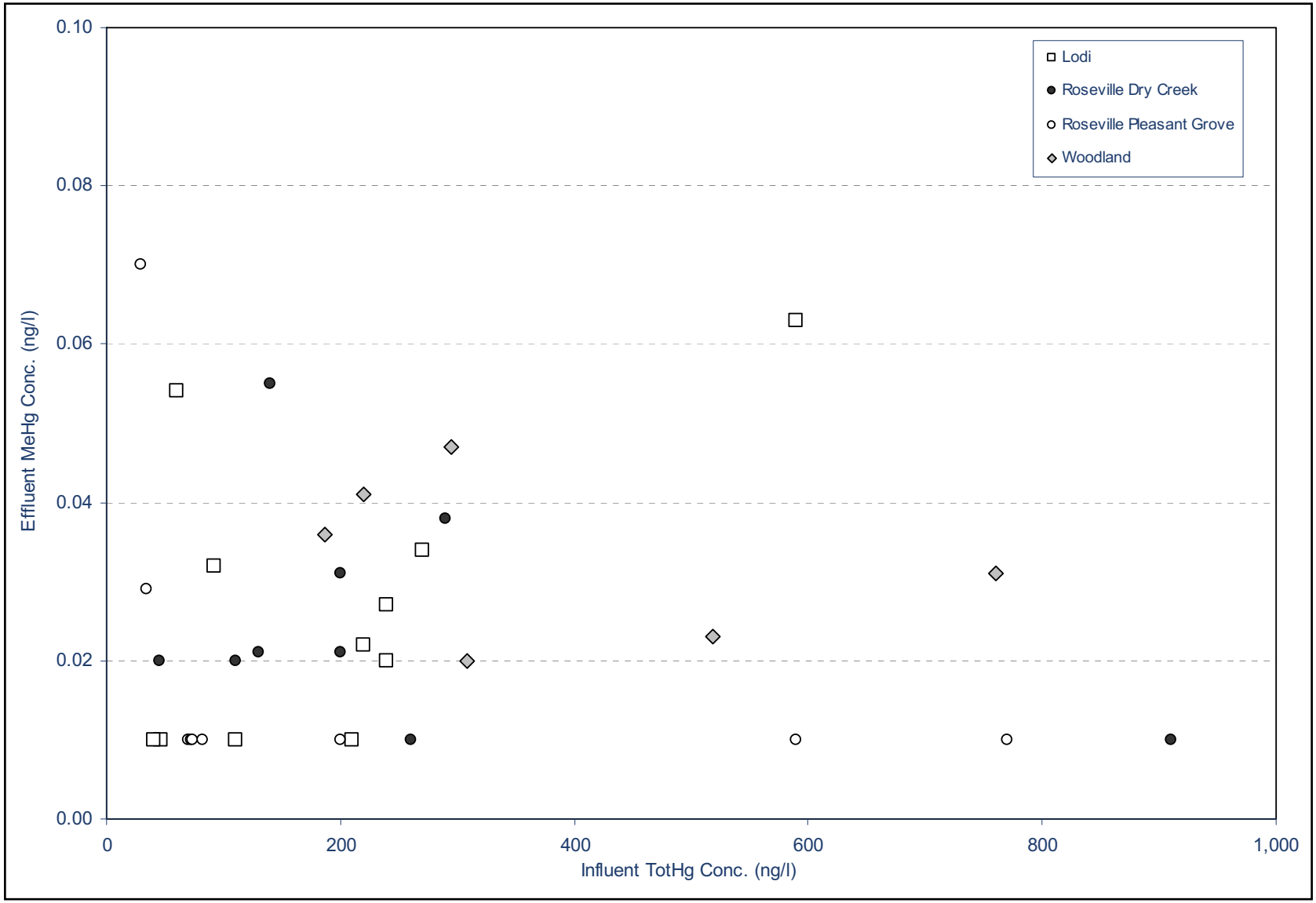

Figure 44: Scatter Plot of Municipal WWTP Influent Inorganic Mercury versus Effluent Methylmercury Concentrations: Zoomed to Show Typical Values

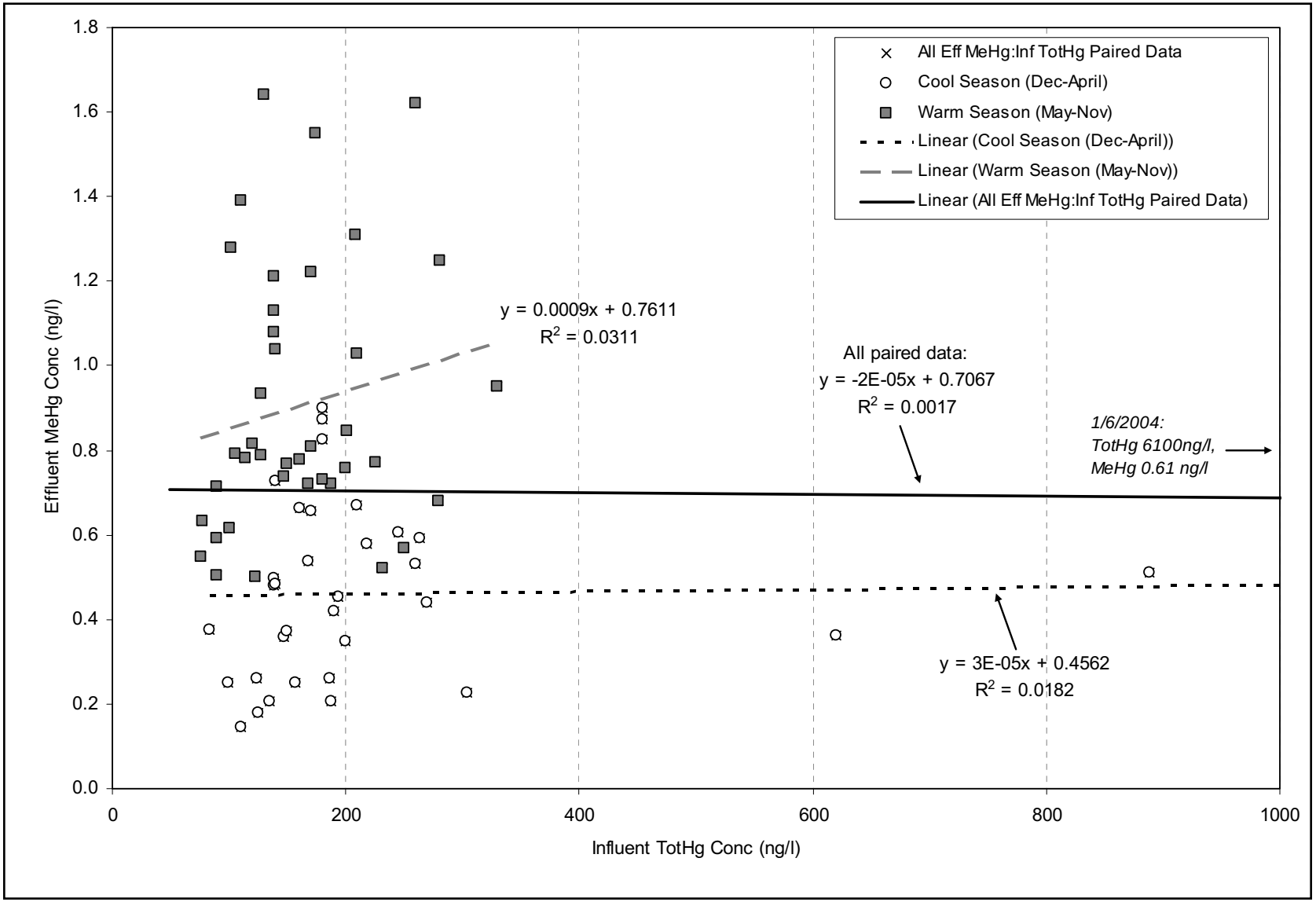

Figure 45a: Scatter-plot of Influent Inorganic Mercury versus Effluent Methylmercury Concentrations for the SRCSD Sacramento River WWTP

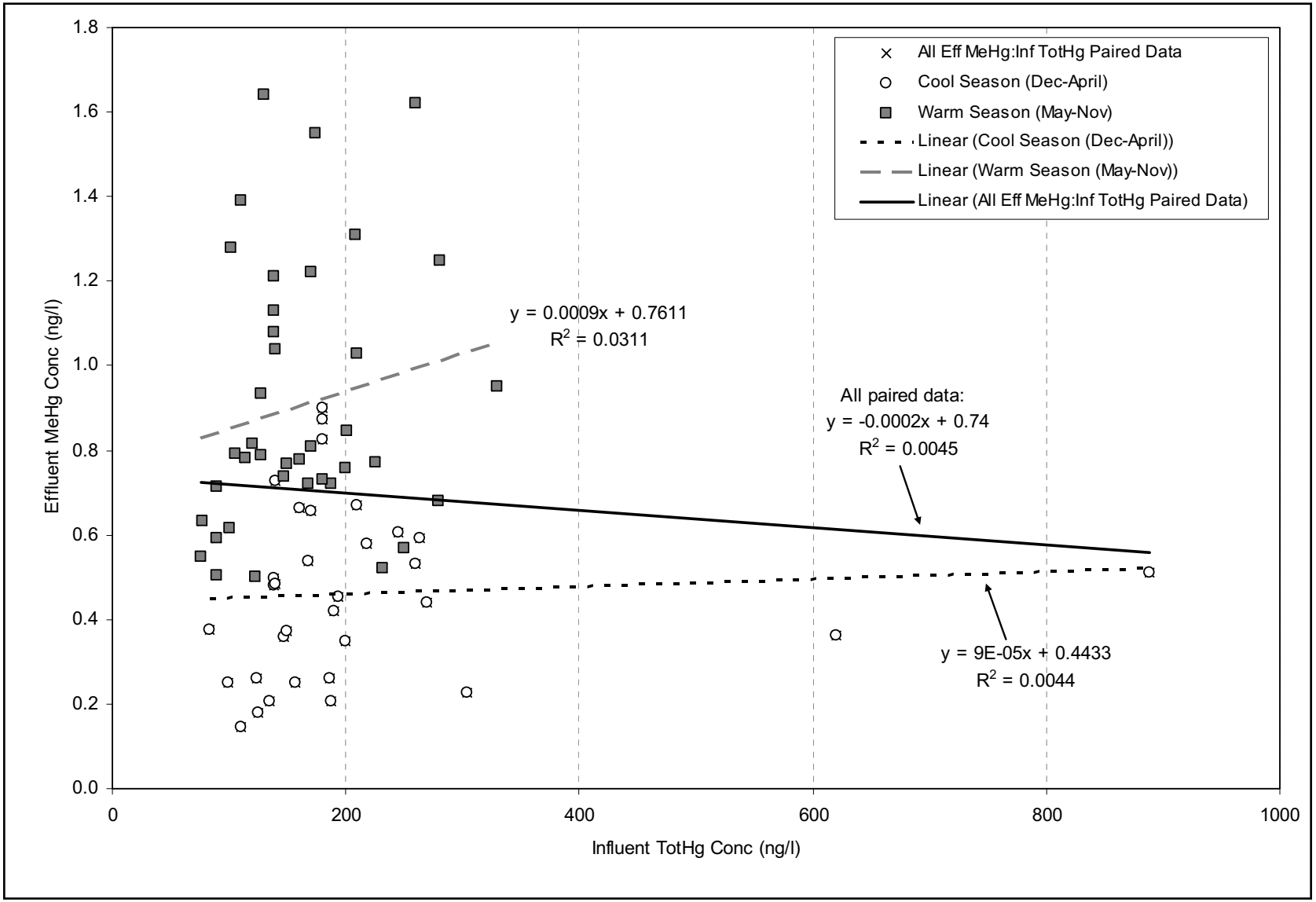

Figure 45b: Scatter-plot of Influent Inorganic Mercury versus Effluent Methylmercury Concentrations for the SRCSD Sacramento River WWTP (with the paired data that includes the anomalous value collected on 6 January 2004 removed)

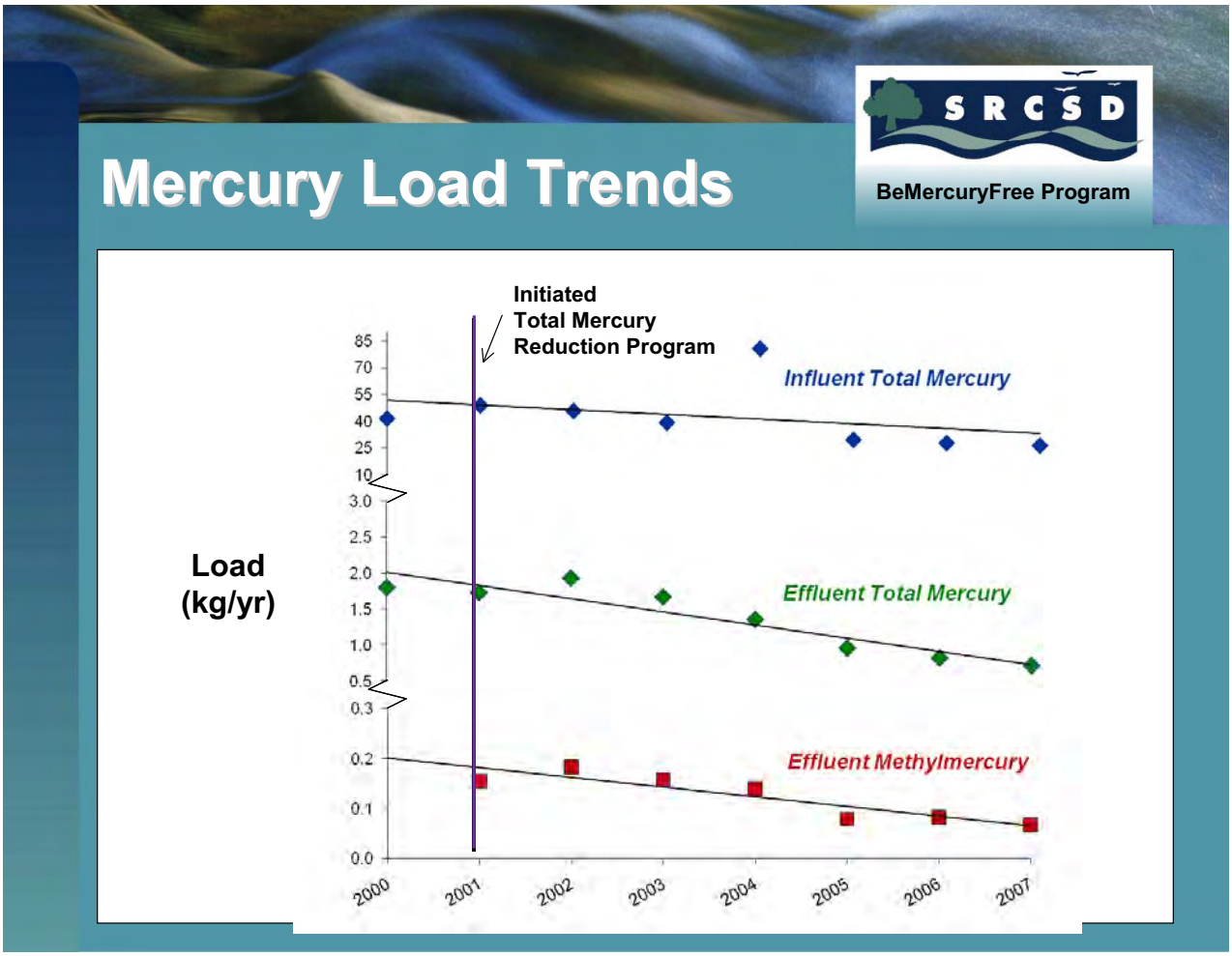

Figure 46: SRCSD Sacramento River WWTP Influent Inorganic Mercury and Effluent Inorganic Mercury and Methylmercury Loads

[Chart presented by the SRCSD District Engineer during testimony for the April 2008 Central Valley Water Board hearing for the Delta mercury control program.]

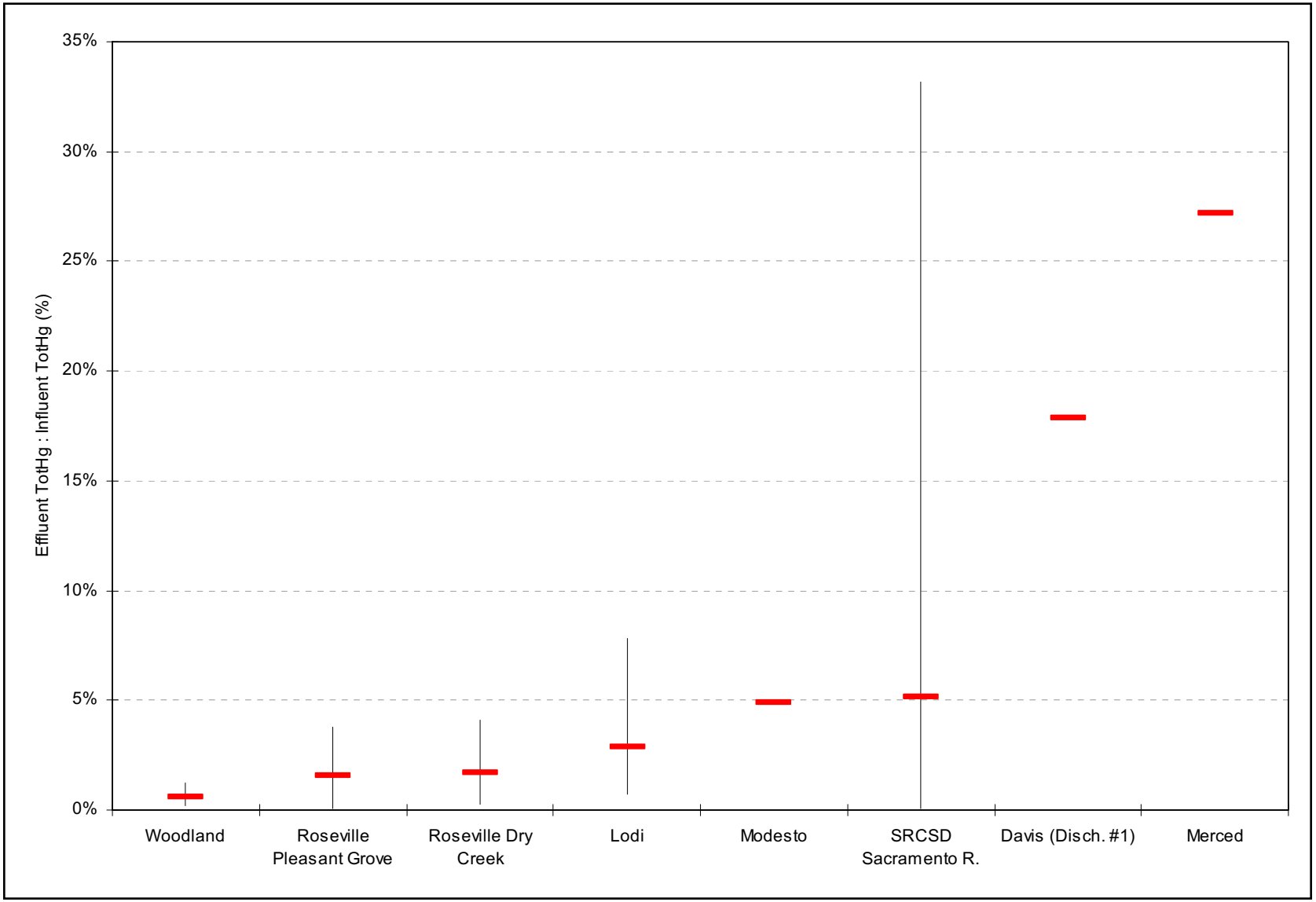

Figure 47: Average and Range of Effluent:Influent Inorganic Mercury Concentration Ratios for Each Municipal WWTP

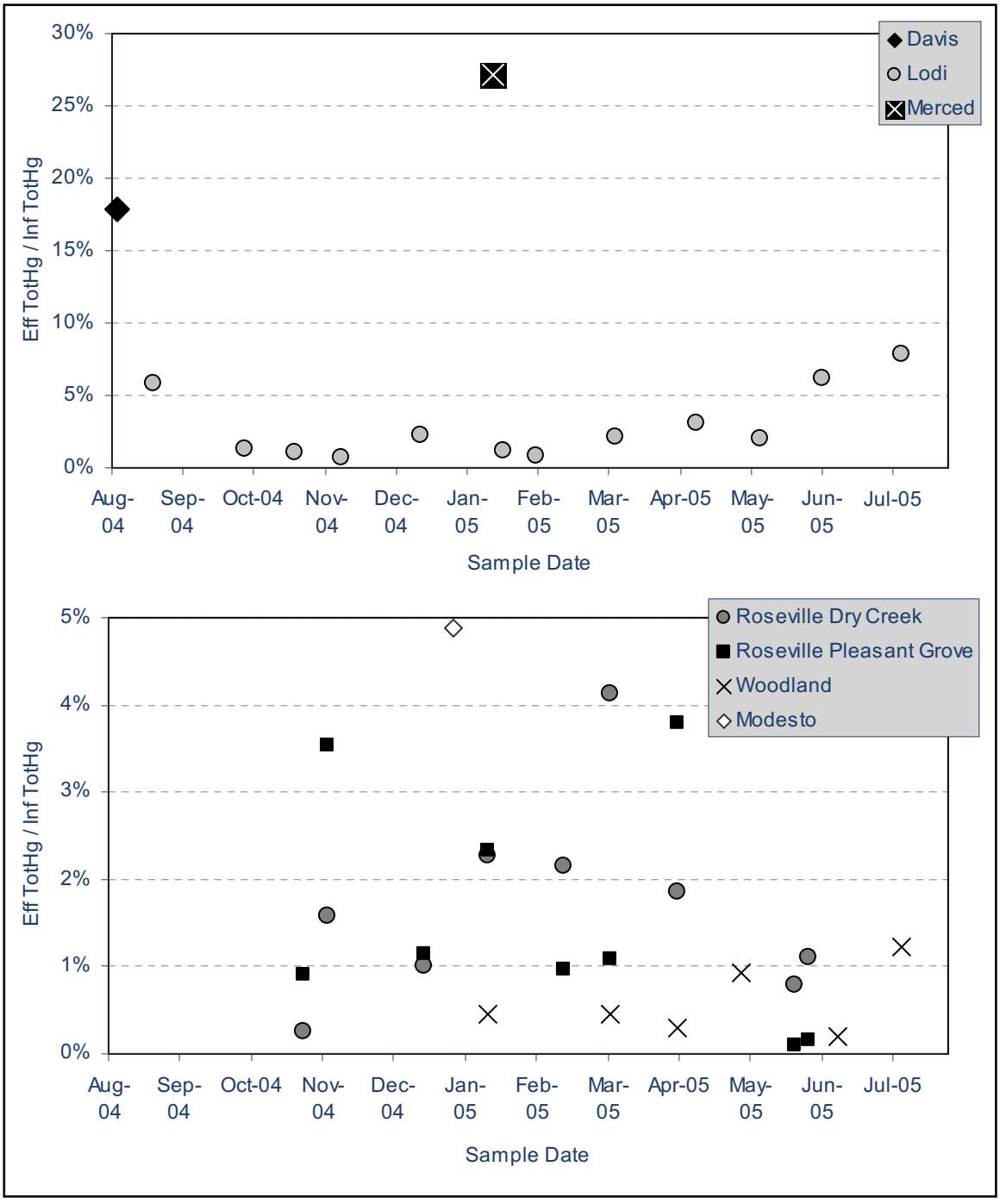

Figure 48: Time-series Graphs of Municipal WWTP Effluent:Influent Inorganic Mercury Concentration Ratios

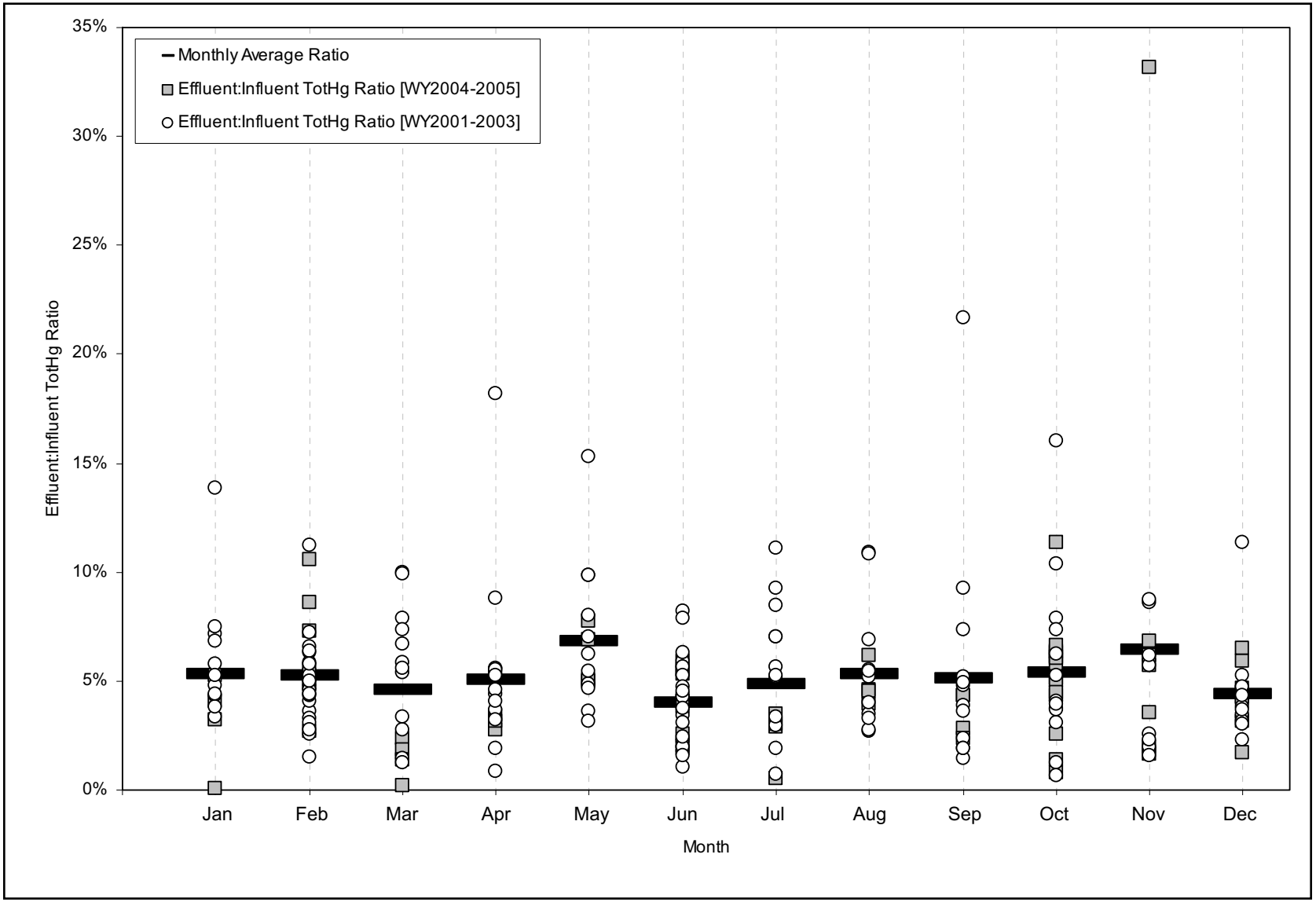

Figure 49: Monthly Effluent:Influent TotHg Concentration Ratios for the SRCSD Sacramento River WWTP from December 2000 – December 2004

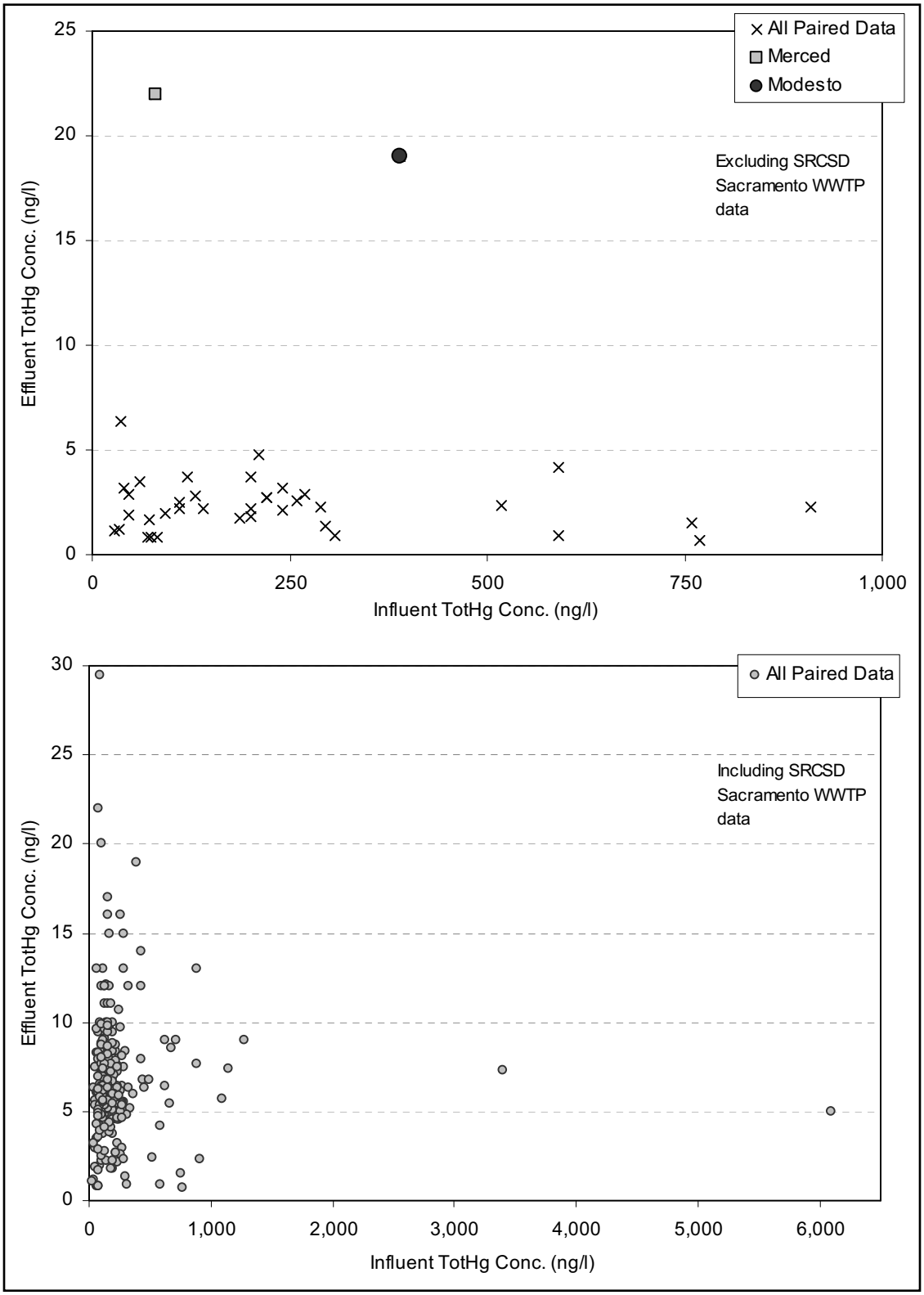

Figure 50: Scatter-plots of Municipal WWTP Influent Inorganic Mercury versus Effluent Inorganic Mercury Concentrations: All Paired Data

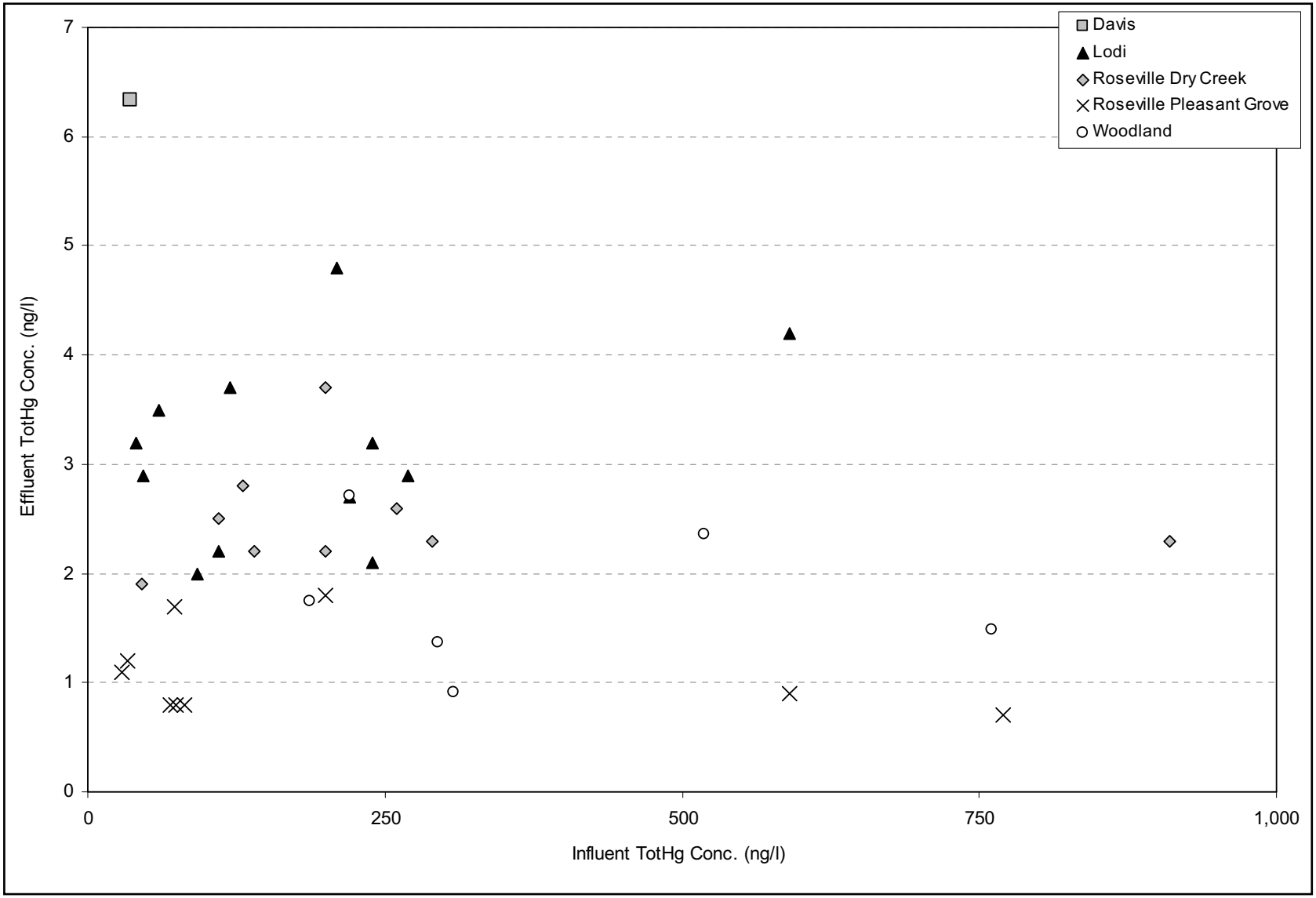

Figure 51: Scatter-plot of Municipal WWTP Influent Inorganic Mercury versus Effluent Inorganic Mercury Concentrations

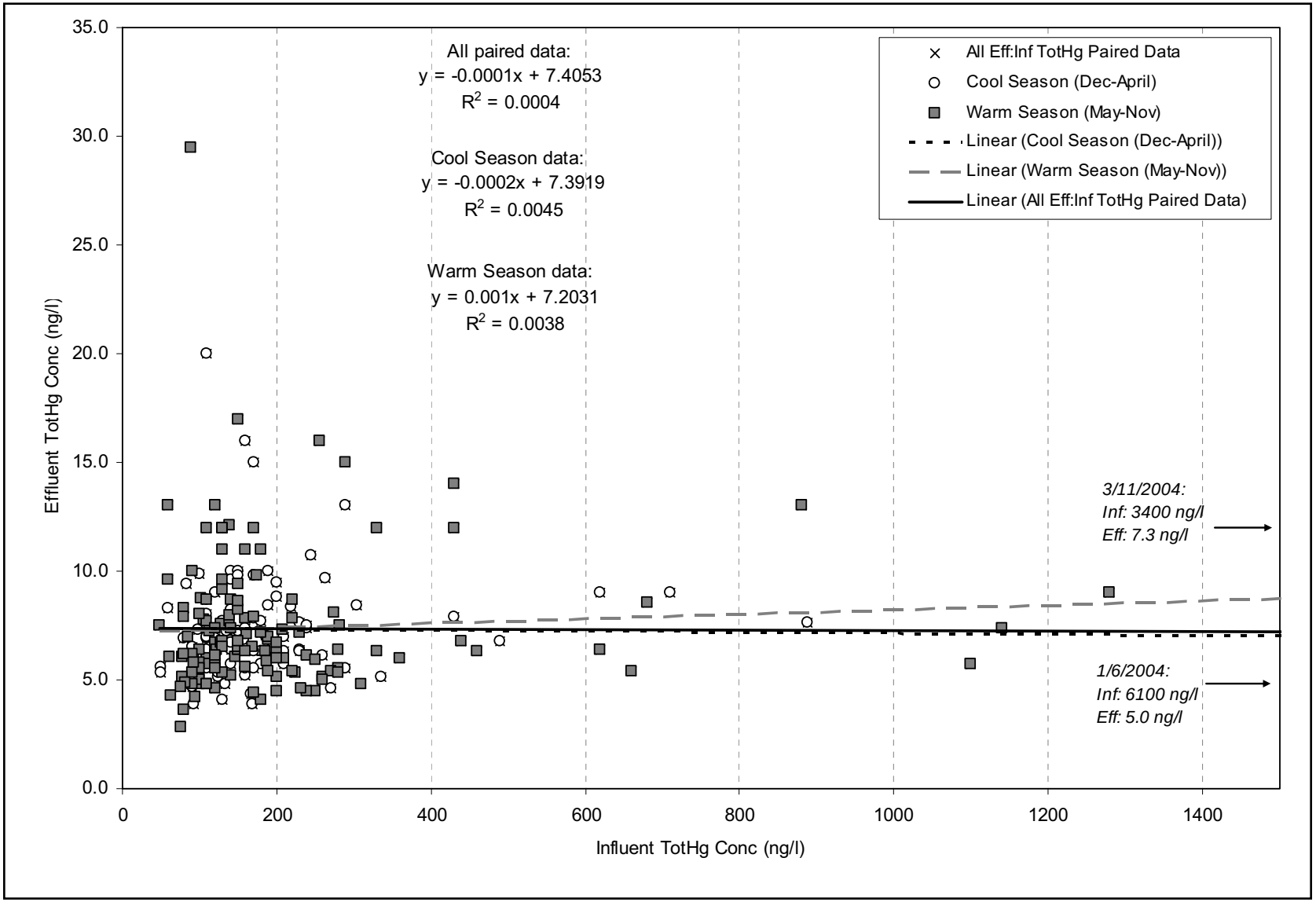

Figure 52: Scatter-plot of Influent Inorganic Mercury versus Effluent Inorganic Mercury Concentrations for the SRCSD Sacramento River WWTP

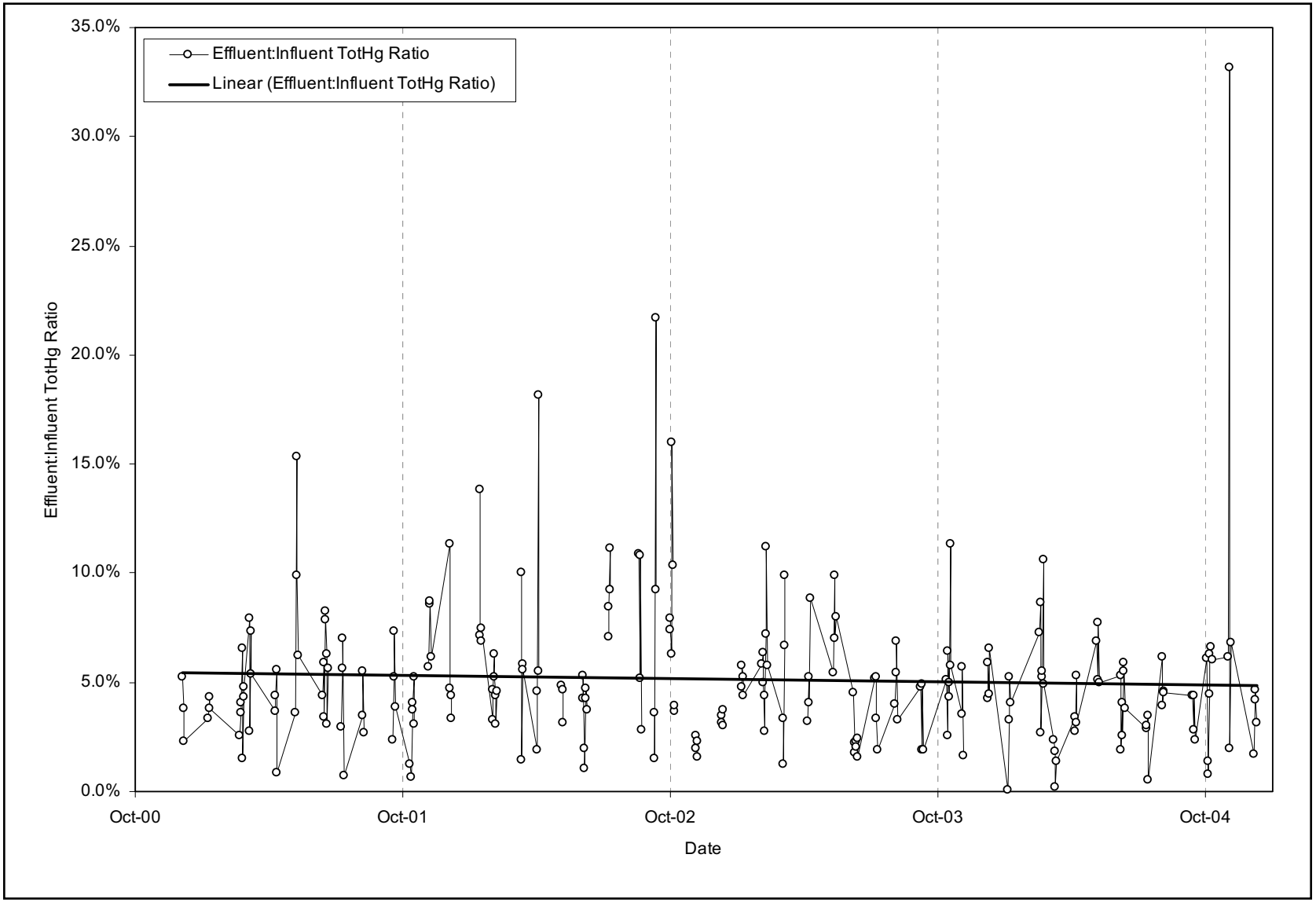

Figure 53: Time-series Graph of SRCSD Sacramento River WWTP Effluent:Influent Inorganic Mercury Concentration Ratios

APPENDIX A
EXAMPLE OF CALIFORNIA WATER CODE SECTION 13267 ORDER LETTER FOR EFFLUENT METHYLMERCURY MONITORING (4 PAGES) & DISCHARGERS TO WHICH A LETTER WAS SENT

California Regional Water Quality Control Board

Central Valley Region

Robert Schneider, Chair

Terry Tamminen
Secretary for
Environmental
Protection

Sacramento Main Office
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11020 Sun Center Drive #200 Rancho Cordova, CA 95670-6114
Phone (916) 464-3291

Arnold Schwarzenegger
Governor

16 June 2004

CERTIFIED MAIL
«Certified_Mail» «Cert_2»

«MAIL_CONTACT»
«MAIL_NAME»
«MAIL_STREET»
«MAIL_CITY», «MAIL_STATE» «MAIL_ZIP»

ORDER FOR UNFILTERED METHYLMERCURY WASTE DISCHARGE DATA PURSUANT TO CALIFORNIA WATER CODE SECTION 13267 (*MONTHLY* SAMPLING) NPDES NO. «NPDES_NO»

Section 303(d) of the federal Clean Water Act requires States to list water bodies that do not meet water quality objectives to protect their beneficial uses and to develop and implement Total Maximum Daily Load (TMDL) control programs to eliminate the impairment of beneficial uses.

The Sacramento and San Joaquin Rivers and associated Delta Estuary were placed on the 303(d) list because of elevated methylmercury concentrations in fish. Recent data demonstrate a statistically significant correlation between methylmercury concentrations in water and fish, i.e., as concentrations of methylmercury increase in the water column, concentrations of methylmercury also increase in fish resident in that water column. The data thus suggest that the annual median methylmercury concentration of a water body is a major factor determining resident fish tissue methylmercury levels. The proposed TMDL goal to protect Delta beneficial uses is 0.05 nanograms per liter (ng/l) methylmercury in water.

Limited methylmercury effluent data are available for local NPDES facilities. A recent survey by the Regional Board found considerable variability between facilities and demonstrated that some plants were discharging methylmercury above the proposed TMDL goal. Table 1 summarizes data collected by the Regional Board in February and March of 2004 as well as data collected by the Sacramento Regional County Sanitation District from a year-long study in 2001.

Section 13267 of the California Water Code states in part that a regional board may investigate the quality of waters within its region, and in doing so may require dischargers to furnish technical or monitoring reports which the regional board requires. The burden, including costs, of these reports must bear a reasonable relationship to the need for the report and the benefits to be obtained from the reports.

The monitoring reports required by this letter are necessary to determine the extent to which NPDES facilities are contributing methylmercury in concentrations that impair beneficial uses of receiving waters. Preliminary load calculations using the information shown in Table 1 estimate that POTWs discharge significant portions of the total methylmercury loading to the Delta. Accurate discharge information will be required from treatment facilities to complete the TMDL.

Table 1. Summary of unfiltered methylmercury concentrations in effluent from POTW's located in the Central Valley of California.

Facility	# of Sampling Events	Mean Concentration (ng/l)	Range (ng/l)
Sacramento Regional County Sanitation District	45	0.73	0.14-2.93
Stockton STP	2	0.34	0.13-0.59
Vacaville Easterly STP	2	0.10	0.09-0.11
West Sacramento STP	2	0.04	0.03-0.05
City of Roseville	2	0.01	0.01-0.01

Therefore pursuant to Section 13267 of the California Water Code, you are required to submit effluent methylmercury monitoring data for your facility. In most cases, this monitoring will be in addition to monitoring required in your NPDES Permit.

Instantaneous grab samples shall be collected monthly for one year (August 2004-July 2005) from the facility's effluent. Intermittent or seasonal dischargers shall collect monthly samples during those months for which a discharge occurs. The samples must be collected downstream from the last connection through which wastes can be admitted into the outfall, and shall be representative of the quality of the discharge from the treatment plant. Unfiltered methylmercury samples shall be taken using clean hands/dirty hands procedures[1] and shall be analyzed by U.S. EPA method 1630/1631 (Revision E) with a method detection limit of 0.02 ng/l. A matrix spike/matrix spike duplicate shall also be analyzed with either the first or second set of samples to insure an acceptable methylmercury recovery rate in your effluent. A travel-blank must also be collected and analyzed with every other set of samples. Any other methylmercury monitoring data collected by your plant during the above period shall also be reported to the Regional Board. If your facility is currently collecting total mercury data, methylmercury samples should be collected concurrently. A partial list of laboratories performing U.S. EPA method 1630/1631 is attached as Table 2.

While not required by this letter, we are also recommending that instantaneous grab samples be collected from the facility's upstream receiving water and the main influent to determine the methylmercury treatment efficiency of your facility.

Please submit quarterly reports summarizing the monitoring results to the Regional Board. The reports are due by 31 October 2004, 31 January 2005, 30 April 2005, and 31 July 2005. Your cooperation with this special discharge monitoring requirement is sincerely appreciated. However, we must advise that failure or refusal to comply with this request as required by Section 13267 of the California Water Code or falsifying any information provided may be subject to an administrative civil liability of up to $1,000 per day of violation in accordance with Section 13268.

[1] Described in U.S. EPA method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels for collection of equipment blanks (section 9.4.4.2)

Please contact your regular Regional Board staff representative if you have any questions regarding this order.

THOMAS R. PINKOS
Executive Officer

Attachment

Table 2. List of Analytical Laboratories Measuring Methylmercury by U.S. EPA Method 1630/1631

Presence on the list does not constitute endorsement by the Regional Board.

Facility	Contact	Phone
Battelle Marine Science Laboratory 1529 West Sequim Bay Road Sequim, WA 98382	Brenda Lasorsa	360-681-3650
Frontier GeoSciences 414 Pontius Ave N Seattle WA 98109 http://www.frontiergeosciences.com	Michelle Gauthier	206-622-6960
Brook-Rand Trace Metal Analysis and Products 3958 6th Ave N.W. Seattle WA 98107 http://www.brooksrand.com	Colin Davis	206-632-6206

Table A.1: NPDES-Permitted Facilities Required to Conduct Effluent Methylmercury Monitoring under California Water Code Section 13267.

AGENCY NAME	FACILITY NAME	NPDES NO	MONITORING FREQUENCY [a]
AEROJET GENERAL CORPORATION	INTERIM GROUNDWATER WTP	CA0083861	B
AEROJET GENERAL CORPORATION	SACRAMENTO FACILITY	CA0004111	B
AFB CONVERSION AGENCY	A C & W - GROUNDWATER TREATMENT	CA0083992	Q
ANDERSON, CITY OF	ANDERSON WWTP	CA0077704	M
ATWATER, CITY OF	ATWATER WWTP	CA0079197	M
AUBURN, CITY OF	AUBURN WWTP	CA0077712	M
BELL CARTER OLIVE COMPANY INC	BELL CARTER INDUSTRIAL WWTP	CA0083721	Q
BELL CARTER OLIVE COMPANY INC	PLANT 1	CA0081639	B
BELLA VISTA WD	BELLA VISTA WTP	CA0080799	B
BIGGS, CITY OF	BIGGS WWTP	CA0078930	Q
BRENTWOOD, CITY OF	BRENTWOOD WWTP	CA0082660	M
BROWN SAND, INC.	MANTECA AGGREGATE SAND PLANT [b]	CA0082783	Q
CA DEPT OF FISH & GAME	DARRAH SPRINGS HATCHERY	CA0004561	Q
CA DEPT OF FISH & GAME	FEATHER RIVER HATCHERY	CA0004570	Q
CA DEPT OF FISH & GAME	MERCED RIVER FISH HATCHERY	CA0080055	Q
CA DEPT OF FISH & GAME	MOCCASIN FISH HATCHERY	CA0004804	Q
CA DEPT OF FISH & GAME	MOKELUMNE RIVER FISH HATCHERY	CA0004791	Q
CA DEPT OF FISH & GAME	NIMBUS HATCHERY	CA0004774	Q
CA DEPT OF FISH & GAME	SAN JOAQUIN FISH HATCHERY	CA0004812	Q
CA DEPT OF FISH & GAME	THERMALITO ANNEX HATCHERY	CA0082350	Q
CA DEPT OF GENERAL SERVICES	STATE PRINTING & WAREHOUSES	CA0078875	Q
CA (STATE OF) CENTRAL PLANT	CENTRAL HEATING/COOLING FAC	CA0078581	Q
CALAVERAS TROUT FARM, INC	TROUT REARING FACILITY	CA0081752	Q
CALIF AMMONIA COMPANY	CALAMCO - STOCKTON TERMINAL	CA0083968	Q
CALIFORNIA DAIRIES, INC	LOS BANOS FOODS, INC	CA0082082	Q
CALPINE CORPORATION	GREENLEAF UNIT ONE COGEN PLANT	CA0081566	Q
CANADA COVE L.P.	FRENCH CAMP GOLF & RV PARK WWTP	CA0083682	Q
CHICO, CITY OF	CHICO REGIONAL WWTP	CA0079081	M
CLEAR CREEK CSD	CLEAR CREEK WTP	CA0083828	B
COLFAX, CITY OF	COLFAX WWTP	CA0079529	Q
COLUSA, CITY OF	COLUSA WWTP	CA0078999	Q
CORNING, CITY OF	CORNING INDUST/DOMESTIC WWTP	CA0004995	Q
CRYSTAL CREEK AGGREGATE INC	CRYSTAL CREEK AGGREGATE	CA0082767	B
DAVIS, CITY OF	CITY OF DAVIS WWTP	CA0079049	M
DEFENSE LOGISTICS AGENCY, ASCW	DDJC, SHARPE - GW CLEANUP	CA0081931	Q
DEUEL VOCATIONAL INSTITUTE	DEUEL VOCATNL INST. WWTP	CA0078093	Q
DISCOVERY BAY CSD	DISCOVERY BAY WWTP	CA0078590	M
DONNER SUMMIT PUBLIC UTILITY	DONNER SUMMIT WWTP	CA0081621	Q
EAST BAY MUD	CAMANCHE DAM POWER HOUSE	CA0082040	Q

Table A.1: NPDES-Permitted Facilities Required to Conduct Effluent Methylmercury Monitoring under California Water Code Section 13267.

AGENCY NAME	FACILITY NAME	NPDES NO	MONITORING FREQUENCY [(a)]
EL DORADO ID	DEER CREEK WWTP	CA0078662	M
EL DORADO ID	EL DORADO HILLS WWTP	CA0078671	M
FORMICA CORPORATION	SIERRA PLANT	CA0004057	Q
GALT, CITY OF	GALT SD WWTP	CA0081434	M
GAYLORD CONTAINER CORPORATION	ANTIOCH PULP & PAPER MILL	CA0004847	M
GENERAL ELECTRIC CO	GWCS	CA0081833	Q
GRASS VALLEY, CITY OF	GRASS VALLEY WWTP	CA0079898	M
GWF POWER SYSTEMS, INC.	GWF POWER SYSTEMS, SITE IV	CA0082309	Q
HERSHEY FOODS CORP	HERSHEY CHOCOLATE USA, OAKDALE	CA0004146	Q
JACKSON, CITY OF	CITY OF JACKSON WWTP	CA0079391	Q
LEHIGH SOUTHWEST CEMENT CO	LEHIGH SOUTHWEST CEMENT CO	CA0081191	B
LINCOLN, CITY OF	CITY OF LINCOLN WWTP	CA0084476	M
LINDA CO WATER DISTRICT	LINDA CO WTR DIST WWTP	CA0079651	Q
LIVE OAK, CITY OF	CITY OF LIVE OAK WWTP	CA0079022	Q
LODI, CITY OF	WHITE SLOUGH WWTP	CA0079243	M
MANTECA, CITY OF	MANTECA WWTP	CA0081558	M
MARIPOSA PUD	MARIPOSA WWTP	CA0079430	Q
MAXWELL P.U.D.	MAXWELL PUD WWTP	CA0079987	Q
MERCED, CITY OF	MERCED WWTP	CA0079219	M
MIRANT DELTA LLC	CONTRA COSTA POWER PLT ANTIOCH	CA0004863	M
MODESTO ID	MODESTO ID REGIONAL WTP	CA0083801	Q
MODESTO, CITY OF	GRAYSON PARK WELL NO.295	CA0083054	Q
MODESTO, CITY OF	MODESTO WWTP	CA0079103	M
MOUNTAIN HOUSE CSD	MOUNTAIN HOUSE WWTP	CA0084271	M
MT LASSEN TROUT FARMS INC	MEADOWBROOK FACILITY	CA0080373	Q
NEVADA CITY, CITY OF	NEVADA CITY WWTP	CA0079901	Q
NEVADA CO SD #1	CASCADE SHORES WWTP	CA0083241	Q
NEVADA CO SD #1	LAKE OF THE PINES WWTP	CA0081612	Q
NEVADA CO SD #1	LAKE WILDWOOD WWTP	CA0077828	M
OLIVEHURST PUD	OLIVEHURST WWTP	CA0077836	M
ORIGINAL SIXTEEN TO ONE MINE	SIXTEEN TO ONE MINE	CA0081809	Q
OROVILLE WYANDOTTE ID	MINERS RANCH WTP	CA0083143	B
PACIFIC COAST SPROUT FARMS	SACRAMENTO FACILITY	CA0082961	Q
PACTIV CORP	PACTIV MOLDED PULP MILL	CA0004821	M
PARADISE ID	PARADISE WTP	CA0083488	B
PLACER CO FACILITY SERVICES 1	PLACER CO SMD NO 1	CA0079316	M
PLACER CO FACILITY SERVICES 1	PLACER CO SMD NO 3	CA0079367	Q
PLACER CO FACILITY SERVICES 1	SA NO 28, ZONE NO.6	CA0079341	Q
PLACERVILLE, CITY OF	HANGTOWN CREEK WWTP	CA0078956	M

Table A.1: NPDES-Permitted Facilities Required to Conduct Effluent Methylmercury Monitoring under California Water Code Section 13267.

AGENCY NAME	FACILITY NAME	NPDES NO	MONITORING FREQUENCY [(a)]
PLANADA CSD	WWTP	CA0078950	Q
PROCTER AND GAMBLE COMPANY	PROCTER & GAMBLE CO WWTP	CA0004316	Q
RED BLUFF, CITY OF	RED BLUFF WWTP	CA0078891	M
REDDING, CITY OF	CLEAR CREEK WWTP	CA0079731	M
REDDING, CITY OF	STILLWATER WWTP	CA0082589	M
RIO ALTO WD	LAKE CALIFORNIA WWTP	CA0077852	B
RIO VISTA, CITY OF	RIO VISTA WWTP	CA0079588	Q
RIO VISTA, CITY OF	TRILOGY WWTP	CA0083771	Q
RIVER HIGHLANDS CSD	HAMMONTON GOLD VILLAGE WWTP	CA0081574	Q
RIVIERA WEST MUTUAL WATER CO	RIVIERA WEST WATER SUPPLY TP	CA0083925	Q
ROSEVILLE, CITY OF	DRY CREEK WWTP	CA0079502	M
ROSEVILLE, CITY OF	PLEASANT GROVE WWTP	CA0084573	M
S.M.U.D.	RANCHO SECO NUCLEAR GEN STA 1	CA0004758	M
SACRAMENTO CO AIRPORT SYSTEM	SACRAMENTO INTERNATIONAL AIRPT	CA0034841	Q
SACRAMENTO COGENERATION AUTH.	PROCTOR & GAMBLE COGEN. PLANT	CA0083569	Q
SACRAMENTO MUNICIPAL UTILITY D	SMUD COGENERATION PLANT	CA0083658	Q
SACRAMENTO REGIONAL CSD-ELK GV	WALNUT GROVE WWTP	CA0078794	Q
SACRAMENTO, CITY OF	COMBINED WW COLLECTION/TRT SYS	CA0079111	M
SAN ANDREAS SANITARY DIST.	SAN ANDREAS WWTP	CA0079464	Q
SAN JOAQUIN CO DPW	CSA 31 - FLAG CITY WWTP	CA0082848	Q
SEWER COMM - OROVILLE REGION	OROVILLE WWTP	CA0079235	M
SHASTA CSA #17	COTTONWOOD WWTP	CA0081507	Q
SHASTA LAKE, CITY OF	SHASTA LAKE WTP	CA0004693	B
SHASTA LAKE, CITY OF	SHASTA LAKE WWTP	CA0079511	Q
SHEA, J F COMPANY INC	FAWNDALE ROCK & ASPHALT	CA0083097	B
SIERRA PACIFIC INDUSTRIES	CAMINO SAWMILL	CA0078841	Q
SIERRA PACIFIC INDUSTRIES	MARTELL COMPLEX/SIERRA PINE	CA0004219	Q
SIERRA PACIFIC INDUSTRIES	SIERRA PACIFIC, ANDERSON DIV	CA0082066	Q
SIERRA PACIFIC INDUSTRIES	SIERRA PACIFIC, SHASTA LAKE DV	CA0081400	Q
STIMPEL-WIEBELHAUS ASSOCIATES	SWA AT MOUNTAIN GATE	CA0084140	B
STOCKTON COGENERATION COMPANY	STOCKTON COGENERATION FACILITY	CA0081965	Q
STOCKTON, CITY OF	STOCKTON WWTP	CA0079138	M
THE BOEING COMPANY	INTERIM GW TREATMENT SYSTEM	CA0084891	B
TRACY, CITY OF	TRACY WWTP	CA0079154	M
TUOLUMNE UD/JAMESTOWN SD	SONORA WWTP/JAMESTOWN WWTP	CA0084727	M
TURLOCK, CITY OF	TURLOCK WWTP	CA0078948	M
U.A. LOCAL 38 TRUST FUND	KONOCTI HARBOR INN	CA0083551	Q
U.S. BUREAU OF RECLAMATION	SLIGER MINE	CA0084905	Q
UNIVERSITY OF CALIFORNIA, DAVIS	AQUATIC CENTER/ANIMAL SCIENCE	CA0083348	Q

Table A.1: NPDES-Permitted Facilities Required to Conduct Effluent Methylmercury Monitoring under California Water Code Section 13267.

AGENCY NAME	FACILITY NAME	NPDES NO	MONITORING FREQUENCY [(a)]
UNIVERSITY OF CALIFORNIA, DAVIS	HYDRAULICS LABORATORY	CA0084182	Q
UNIVERSITY OF CALIFORNIA, DAVIS	UC DAVIS WWTP	CA0077895	M
UNITED AUBURN INDIAN COMMUNITY	AUBURN RANCHERIA CASINO WWTP	CA0084697	Q
US AIR FORCE - BEALE AFB	BEALE AFB WWTP	CA0110299	B
US AIR FORCE - MCCLELLAN AFB	GW EXTR & TRMT SYSTEM	CA0081850	B
US DEPT OF AGRICULTURE	UCD AQUATIC WEED LABORATORY	CA0083364	Q
USDI BUREAU OF RECLAMATION	WINTER RUN REARING FACILITY	CA0084298	Q
USDI FISH & WILDLIFE SERVICE	COLEMAN FISH HATCHERY	CA0004201	Q
VACAVILLE, CITY OF	EASTERLY WWTP	CA0077691	M
WASTE MANAGEMENT OF ALAMEDA CO	ALTAMONT LANDFILL & RESOURCE	CA0083763	Q
WEST SACRAMENTO, CITY OF	WEST SACRAMENTO WWTP	CA0079171	M
WHEELABRATOR SHASTA ENERGY CO	WHEELABRATOR SHASTA ENERGY CO	CA0081957	Q
WILLIAMS, CITY OF	WILLIAMS WWTP	CA0077933	Q
WILLOWS, CITY OF	WILLOWS WWTP	CA0078034	M
WOODLAND, CITY OF - DOMESTIC	WOODLAND WWTP	CA0077950	M
YUBA CITY	YUBA CITY WWTP	CA0079260	M
YUBA CWD	FORBESTOWN WTP	CA0084824	B

[(a)] Key: Biannual (B); Monthly (M); and Quarterly (Q).
[(b)] The Manteca Aggregate Sand Plant is now known as Oakwood Lake Subdivision Mining Reclamation.

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APPENDIX B
SUMMARY OF NPDES FACILITY EFFLUENT AND INFLUENT METHYLMERCURY AND TOTAL MERCURY CONCENTRATIONS

Many facilities have multiple discharge locations and influent sources (intakes). Therefore, there are separate tables that summarize the methylmercury concentrations for each discharge and intake:

- Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations
- Table B.2: Summary of Effluent 3 and Effluent 4 Methylmercury Concentrations
- Table B.3: Summary of Influent/Intakes 1 and 2 Methylmercury Concentrations
- Table B.4: Summary of Influent/Intakes 3 and 4 Methylmercury Concentrations

Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

Facility	Footnotes	# of EFF 1 MeHg Samples	# of EFF 1 Nondetect Samples	Ave. EFF 1 MeHg Conc. (ng/l) (p)	Min. EFF 1 MeHg Conc (ng/l)	Max. EFF 1 MeHg Conc (ng/l)	# of EFF 2 MeHg Samples	# of EFF 2 Nondetect Samples	Ave. EFF 2 MeHg Conc. (ng/l) (p)	Min. EFF 2 MeHg Conc (ng/l)	Max. EFF 2 MeHg Conc (ng/l)
Aggregate											
Crystal Creek Aggregate	a	1	1	0.010	0.010	0.010					
J.F. Shea CO Fawndale Rock and Asphalt	a	1	1	0.010	0.010	0.010	1	1	0.010	0.010	0.010
Lehigh Southwest Cement Co.	a, b	1	1	0.010	0.010	0.010	1	1	0.010	0.010	0.010
Oakwood Lake Subdivision Mining Reclamation	a	2	1	0.027	0.010	0.043					
Stimpel Wiebelhaus Assoc. SWA at Mountain Gate		1		0.081	0.081	0.081					
Aquaculture											
Calaveras Trout Farm (Rearing Facility)		2		0.060	0.027	0.092					
DFG Darrah Springs Fish Hatchery	a, c	4	1	0.024	0.010	0.031	4	1	0.028	0.010	0.043
DFG Merced River Fish Hatchery		1		0.037	0.037	0.037					
DFG Moccasin Creek Fish Hatchery	a	1	1	0.010	0.010	0.010					
DFG Mokelumne River Fish Hatchery	a	4	1	0.041	0.010	0.059					
DFG Nimbus Fish Hatchery		3		0.065	0.053	0.085	1		0.129	0.129	0.129
DFG San Joaquin Fish Hatchery		2		0.060	0.047	0.073					
Pacific Coast Sprout Farms (Sacramento Facility)	a	1	1	0.010	0.010	0.010					
UC Davis Center for Aquatic Biology & Aquaculture	a, d	4	2	0.030	0.010	0.067	4	1	0.082	0.010	0.243
USDI BR Winter Run Rearing Facility	a	4	4	0.010	0.010	0.010					
USDI FWS Coleman Fish Hatchery		3		0.030	0.023	0.043					
Drinking Water Treatment											
Bella Vista Water District		1		0.027	0.027	0.027					
Clear Creek CSD WTP		2		0.036	0.028	0.043	1		0.041	0.041	0.041
Modesto ID Regional WTP	k	3 [2]		0.056	0.045	0.066					
Paradise Irrigation District	a	1	1	0.013	0.013	0.013					
Shasta Lake WTP	a	2	1	0.025	0.010	0.040					
South Feather Water & Power Agency Miners Ranch WTP	a, k	2 [1]	2 [1]	0.013	0.013	0.013					

Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

Facility	Footnotes	# of EFF 1 MeHg Samples	# of EFF 1 Nondetect Samples	Ave. EFF 1 MeHg Conc. (ng/l) (p)	Min. EFF 1 MeHg Conc (ng/l)	Max. EFF 1 MeHg Conc (ng/l)	# of EFF 2 MeHg Samples	# of EFF 2 Nondetect Samples	Ave. EFF 2 MeHg Conc. (ng/l) (p)	Min. EFF 2 MeHg Conc (ng/l)	Max. EFF 2 MeHg Conc (ng/l)
Food Processing											
Bell Carter Olive Company Inc.	a	4	2	0.017	0.010	0.027					
CA Dairies, Inc. Los Banos Foods	a	4	3	0.016	0.013	0.026					
Hershey Chocolate USA, Oakdale	a	4	4	0.010	0.010	0.010					
Groundwater Remediation											
Aerojet Interim GW WTP	a, k	2 [1]	2 [1]	0.013	0.013	0.013	1	1	0.013	0.013	0.013
Boeing Company Interim Treat. System	a	1	1	0.010	0.010	0.010					
Defense Logistics Agency Sharpe GW Cleanup	a, i	3	2	0.018	0.010	0.033	1	1	0.010	0.010	0.010
General Electric Co. GWCS	a, j, m	3	3	0.010	0.010	0.010	3	3	0.010	0.010	0.010
Heating/Cooling											
Aerojet Sacramento Facility	f, k	1 [0]		(k)	(k)	(k)					
CA (State of) Central Heating/Cooling Facility	a	4	3	0.015	0.010	0.029					
CALAMCO - Stockton Terminal		4		0.293	0.030	0.919					
Gaylord Container Corp. Antioch Pulp and Paper Mill		3		0.055	0.048	0.061					
Sacramento International Airport		2		0.035	0.023	0.046					
UA Local 38 Trust Fund Konocti Harbor Resort		1		0.079	0.079	0.079					
Manufacturing											
Formica Corporation Sierra Plant		1		0.050	0.050	0.050					
Proctor & Gamble Co. WWTP	a, e	3	3	0.010	0.010	0.010	1		0.033	0.033	0.033
Mines											
Sliger Mine	a	4	1	0.064	0.025	0.091					
Miscellaneous											
DGS Office of State Publishing	a, k	4 [3]	4 [3]	0.010	0.010	0.010					
UC Davis Hydraulics Laboratory		3		0.057	0.038	0.082					
Municipal WWTPs											
Anderson WWTP	a	12	2	0.090	0.010	0.271					

Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

Facility	Footnotes	# of EFF 1 MeHg Samples	# of EFF 1 Nondetect Samples	Ave. EFF 1 MeHg Conc. (ng/l) (p)	Min. EFF 1 MeHg Conc (ng/l)	Max. EFF 1 MeHg Conc (ng/l)	# of EFF 2 MeHg Samples	# of EFF 2 Nondetect Samples	Ave. EFF 2 MeHg Conc. (ng/l) (p)	Min. EFF 2 MeHg Conc (ng/l)	Max. EFF 2 MeHg Conc (ng/l)
Atwater WWTP	a	12	3	0.034	0.010	0.084					
Auburn WWTP	a	12	6	0.028	0.010	0.072					
Biggs WWTP		2		1.605	0.150	3.060					
Brentwood WWTP	a	13	13	0.010	0.010	0.010					
Canada Cove LP French Camp Golf & RV Park WWTP		4		0.147	0.029	0.291					
Chico Regional WWTP		12		0.126	0.057	0.178					
Colfax WWTP		3		0.197	0.115	0.350					
Colusa WWTP		4		2.863	1.970	4.020					
Corning Industries/ Domestic WWTP	k	3 [2]		0.044	0.034	0.053					
Cottonwood WWTP		5		0.096	0.045	0.245					
Davis WWTP	o	7		0.546	0.305	1.040	5		0.613	0.247	1.440
Deer Creek WWTP	a	13	11	0.015	0.013	0.032					
Deuel Vocational Institute WWTP	a, k	4 [3]	4 [3]	0.010	0.010	0.010					
Discovery Bay WWTP	a	12	7	0.191	0.013	2.030					
El Dorado Hills WWTP	a, k, l	13 [12]	10	0.018	0.013	0.055	2	2	0.013	0.013	0.013
Galt WWTP		6		0.139	0.027	0.220					
Grass Valley WWTP	a	16	2	0.160	0.010	0.938					
Jackson WWTP		4		0.108	0.061	0.161					
Lincoln WWTP	a, k	8 [7]	6	0.018	0.010	0.068					
Live Oak WWTP		4		0.591	0.427	0.785					
Lodi White Slough WWTP	a, n	12	4	0.128	0.010	1.240					
Manteca WWTP		11		0.216	0.037	0.356					
Mariposa PUD WWTP		4		0.393	0.040	0.912					
Maxwell PUD WWTP		4		0.993	0.044	1.720					
Merced WWTP		12		0.386	0.130	0.672					
Modesto WWTP		9		0.130	0.108	0.170					

Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

Facility	Footnotes	# of EFF 1 MeHg Samples	# of EFF 1 Nondetect Samples	Ave. EFF 1 MeHg Conc. (ng/l) (p)	Min. EFF 1 MeHg Conc (ng/l)	Max. EFF 1 MeHg Conc (ng/l)	# of EFF 2 MeHg Samples	# of EFF 2 Nondetect Samples	Ave. EFF 2 MeHg Conc. (ng/l) (p)	Min. EFF 2 MeHg Conc (ng/l)	Max. EFF 2 MeHg Conc (ng/l)
Nevada City WWTP	a	4	2	0.048	0.010	0.146					
Nevada Co SD #1 Cascade Shores WWTP	a	3	1	0.142	0.010	0.286					
Nevada Co SD #1 Lake Wildwood WWTP	a	12	1	0.109	0.010	0.320					
Nevada Co SD #2 Lake of the Pines WWTP		2		1.409	0.708	2.110					
Olivehurst PUD WWTP	a	13	1	0.144	0.013	0.268					
Oroville WWTP		12		0.147	0.061	0.280					
Placer Co. SA #28 Zone #6 WWTP		2		0.668	0.474	0.862					
Placer Co. SMD #1 WWTP		12		0.141	0.042	0.350					
Placer Co. SMD #3 WWTP		12		0.100	0.037	0.381					
Placerville Hangtown Creek WWTP	a	12	1	0.058	0.013	0.170					
Planada Comm. Service Dist. WWTP		4		1.168	0.374	2.040					
Red Bluff WWTP	a	12	6	0.027	0.010	0.057					
Redding Clear Creek WWTP	a	12	3	0.042	0.013	0.084					
Redding Stillwater WWTP	a	12	12	0.013	0.013	0.013					
Rio Alto WD- Lake CA WWTP		2		1.746	0.141	3.350					
Rio Vista Main WWTP		4		0.164	0.035	0.522					
Roseville Dry Creek WWTP	a	12	4	0.023	0.010	0.055					
Roseville Pleasant Grove WWTP	a	12	10	0.017	0.010	0.070					
San Andreas SD WWTP		4		0.249	0.178	0.293					
San Joaquin Co DPW - Flag City WWTP	a	3	1	0.081	0.013	0.152					
Shasta Lake WWTP	a	2	1	0.022	0.010	0.034					
SRCSD Sacramento River WWTP		108		0.613	0.118	1.640					
SRCSD Walnut Grove WWTP (CSD1)	k	3 [2]		2.155	0.949	3.360					
Stockton WWTP	a	12	1	0.935	0.010	2.090					
Tracy WWTP	a	13	1	0.145	0.013	0.422					
Tuolumne UD Sonora WWTP/ Jamestown WWTP		3		0.182	0.071	0.262					

Table B.1: Summary of Effluent 1 and Effluent 2 Methylmercury Concentrations

Facility	Footnotes	# of EFF 1 MeHg Samples	# of EFF 1 Nondetect Samples	Ave. EFF 1 MeHg Conc. (ng/l) (p)	Min. EFF 1 MeHg Conc (ng/l)	Max. EFF 1 MeHg Conc (ng/l)	# of EFF 2 MeHg Samples	# of EFF 2 Nondetect Samples	Ave. EFF 2 MeHg Conc. (ng/l) (p)	Min. EFF 2 MeHg Conc (ng/l)	Max. EFF 2 MeHg Conc (ng/l)
Turlock WWTP	a, g	12	1	0.059	0.010	0.079					
UC Davis WWTP	a	12	3	0.038	0.010	0.078					
United Auburn Indian Community Casino WWTP	a	2	2	0.010	0.010	0.010					
Vacaville Easterly WWTP	a	12	4	0.024	0.010	0.057					
West Sacramento WWTP	a	12	1	0.050	0.010	0.085					
Williams WWTP		4		1.553	0.560	2.100					
Woodland WWTP	a	12	2	0.031	0.013	0.059					
Yuba City WWTP		12		0.295	0.106	0.625					
Paper & Saw Mills											
Pactiv Molded Pulp Mill	a	12	5	0.039	0.010	0.085					
SPI Anderson Division		4		0.106	0.036	0.140	3		0.120	0.052	0.177
SPI Shasta Lake							2		0.607	0.023	1.190
Power Generation											
Calpine Corp. Greenleaf Unit One Cogen Plant		4		0.064	0.020	0.117					
Camanche Dam Powerhouse	a	4	3	0.020	0.010	0.039					
GWF Power Systems	a	4	4	0.013	0.013	0.013					
Mirant Delta CCPP	h	12		0.075	0.020	0.121	10		0.086	0.042	0.150
Sacramento Cogen Authority Procter & Gamble Plant	a	4	1	0.052	0.013	0.070					
Stockton Congeneration Co.	a	4	3	0.017	0.013	0.029					
Wheelabrator Shasta Energy Co.		4		0.104	0.055	0.178					
Power Generation/ Domestic WWTP											
SMUD Rancho Seco Nuclear Generating Station	a	12	4	0.040	0.013	0.104					

Table B.1 Footnotes:

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.

b. Lehigh Southwest Cement Co. EFF 1: Outfall #1, Shale Quarry Tunnel Road. Effluent 2: Lehigh Southwest Cement Co., 002B: Shale Quarry

c. Darrah Springs Fish Hatchery EFF 1: Upper Springs. EFF 2: Darrah Springs Fish Hatchery - Lower Springs

d. UCD Center for Aquatic Biology & Aquaculture, EFF 1: CABA Aquatic Center. EFF 2: CABA Putah Creek Facility

e. Proctor & Gamble, Pond EFF 2: Effluent PTI-660

f. Aerojet Sacramento Facility, EFF 1 Sample collected from West Detention Pond because there was no discharge to the American River during the rainy season.

g. City of Turlock WWTP, EFF 1: R5

h. Mirant Delta CCPP EFF 1:Outfall 001, EFF 2: Outfall 002

i. Defense Logistics Agency, Sharp Groundwater Cleanup; EFF 1: CBCGWTPEFF = Central Area B/C Aquifer Zone, EFF 2: NBGWTPEFF = North GWTP effluent

j. General Electric Co., GWCS: EFF 1: Air Stripper Effluent, EFF 2: 100-foot Zone Effluent

k. Results for the following facilities and sample dates were not incorporated in the calculations due to sample preservation hold times exceeding EPA recommendations: Aerojet Interim GW WTP (18 November 2005, EFF 1 and EFF 2 were both <MDL); Aerojet Sacramento Facility (18 March 2005, 0.057 ng/l); Corning Industries/ Domestic WWTP (22 September 2004, 0.041 ng/l); Deuel Vocational Institute WWTP (26 October 2004, <MDL); DGS Office of State Publishing (8 July 2005, <MDL); El Dorado Hills WWTP (9 August 2005, 0.057 ng/l); Lincoln WWTP (25 August 2005, 0.034 ng/l); Modesto ID Regional WWTP (8 October 2004, 0.038 ng/l); South Feather Water & Power Agency Miners Ranch WTP (9 September 2004, <MDL); and SRCSD Walnut Grove WWTP (CSD1) (29 December 2004, 0.759 ng/l).

l. El Dorado Hills WWTP sampled effluent when discharging to land and to surface water. Only samples collected when the plant discharged to surface water (December 2004 through April 2005) were used in the February 2008 Delta TMDL Report (Wood *et al.*, 2008b). However, this summary includes samples that were collected when the plant discharged to land and to surface water.

m. General Electric Co. GWCS conducted four sampling events. However, results for samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations.

n. Lodi White Slough WWTP sampled effluent when discharging to land and to surface water. Only samples collected when the plant discharged to surface water (September 2004 through June 2005) were used in the TMDL Report. However, this summary includes samples that were collected when the plant discharged to land and to surface water.

o. Davis WWTP: EFF 1: Willow Slough, EFF 2: Conaway Ranch Toe Drain in the Yolo Bypass

p. Tables 6.5 and 8.4 in the main text of the February 2008 TMDL Report and Tables B and C in the draft Basin Plan amendment provide average concentration values rounded to two decimal places based on un-rounded calculations. For example, the Tracy WWTP had an average methylmercury concentration of 0.014465 ng/l, which rounds to 0.0145 ng/l in this table, and 0.14 ng/l in Table 6.5.

Table B.2: Summary of Effluent 3 and Effluent 4 Methylmercury Concentrations

Facility	Footnotes	# of EFF 3 MeHg Samples	# of EFF 3 Nondetect Samples	Ave. EFF 3 MeHg Conc. (ng/l)	Min. EFF 3 MeHg Conc. (ng/l)	Max. EFF 3 MeHg Conc. (ng/l)	# of EFF 4 MeHg Samples	# of EFF 4 Nondetect Samples	Ave. EFF 4 MeHg Conc. (ng/l)	Min. EFF 4 MeHg Conc. (ng/l)	Max. EFF 4 MeHg Conc. (ng/l)
Aggregate											
Lehigh Southwest Cement Co.	a, b	1	1	0.010	0.010	0.010	1		0.062	0.062	0.062
Groundwater Remediation											
Aerojet Interim GW WTP	a, e	2 [1]	2 [1]	0.013	0.013	0.013	2 [1]	2 [1]	0.013	0.013	0.013
Defense Logistics Agency Sharpe GW Cleanup	a, c	2	2	0.010	0.010	0.010					
General Electric Co. GWCS	a, d, f	3	3	0.010	0.010	0.010					

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.
b. Lehigh Southwest Cement Co., EFF 3: 001A: Limestone Quarry, EFF 4: 00X: Cement Plant
c. Defense Logistics Agency, Sharp Groundwater Cleanup, EFF 3: SBGWTPEFF= South GWTP effluent, EFF 4: SSJCUPST = South San Joaquin Irrigation District Canal (upstream sample).
d. General Electric Co. EFF 3: GWCS: Multizone Effluent
e. Aerojet Interim Groundwater WTP results for samples collected on 18 November 2005 (both <MDL) were not incorporated in the calculations due to sample preservation hold time exceeding EPA recommendations.
f. General Electric Co. GWCS conducted four sampling events. However, results for General Electric Co. GWCS samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations.

Table B.3: Summary of Influent/Intakes 1 and 2 Methylmercury Concentrations

Facility	Footnotes	# of INF 1 MeHg Samples	# of INF 1 Nondetect Samples	Ave. INF 1 MeHg Conc. (ng/l)	Min. INF 1 MeHg Conc. (ng/l)	Max. INF 1 MeHg Conc. (ng/l)	# of INF 2 MeHg Samples	# of INF 2 Nondetect Samples	Ave. INF 2 MeHg Conc. (ng/l)	Min. INF 2 MeHg Conc. (ng/l)	Max. INF 2 MeHg Conc. (ng/l)
Aquaculture											
Calaveras Trout Farm (Rearing Facility)		1		0.067	0.067	0.067					
DFG Darrah Springs Fish Hatchery	a, b	1	1	0.010	0.010	0.010	1	1	0.010	0.010	0.010
DFG Mokelumne River Fish Hatchery	a	1	1	0.010	0.010	0.010					
DFG Nimbus Fish Hatchery		2		0.052	0.051	0.052	1		0.031	0.031	0.031
DFG San Joaquin Fish Hatchery		1		0.021	0.021	0.021					
Drinking Water Treatment											
Bella Vista Water District		1		0.084	0.084	0.084					
Modesto ID Regional WTP	a, h	3 [2]	2 [1]	0.022	0.010	0.033					
Groundwater Remediation											
General Electric Co. GWCS	a, g	3	3	0.010	0.010	0.010	3	3	0.010	0.010	0.010
Heating/Cooling											
CALAMCO - Stockton Terminal		1		0.026	0.026	0.026					
Manufacturing											
Proctor & Gamble Co. WWTP	a, c	3	3	0.010	0.010	0.010	3	2	0.015	0.010	0.026
Municipal WWTPs											
Atwater WWTP		1		1.940	1.940	1.940					
Auburn WWTP		1		2.720	2.720	2.720					
Chico Regional WWTP		11		1.167	0.527	1.590					
Colusa WWTP		1		1.580	1.580	1.580					
Davis WWTP	d	1		1.660	1.660	1.660					
Deer Creek WWTP		13		1.154	0.335	1.570					
El Dorado Hills WWTP	h	13 [12]		1.139	0.388	2.020					
Grass Valley WWTP		16		1.897	0.588	5.010					
Jackson WWTP		1		0.854	0.854	0.854					
Lodi White Slough WWTP		12		1.396	0.730	2.740					

Table B.3: Summary of Influent/Intakes 1 and 2 Methylmercury Concentrations

Facility	Footnotes	# of INF 1 MeHg Samples	# of INF 1 Nondetect Samples	Ave. INF 1 MeHg Conc. (ng/l)	Min. INF 1 MeHg Conc. (ng/l)	Max. INF 1 MeHg Conc. (ng/l)	# of INF 2 MeHg Samples	# of INF 2 Nondetect Samples	Ave. INF 2 MeHg Conc. (ng/l)	Min. INF 2 MeHg Conc. (ng/l)	Max. INF 2 MeHg Conc. (ng/l)
Mariposa PUD WWTP		1		0.068	0.068	0.068					
Maxwell PUD WWTP		1		14.600	14.600	14.600					
Nevada City WWTP		4		3.140	1.090	6.230					
Placer Co. SMD #1 WWTP		1		2.590	2.590	2.590					
Planada Comm. Service Dist. WWTP		1		3.390	3.390	3.390					
Rio Vista Main WWTP		4		2.903	1.570	4.790					
Roseville Dry Creek WWTP		9		1.360	0.600	2.860					
Roseville Pleasant Grove WWTP		9		0.808	0.120	2.160					
SRCSD Sacramento River WWTP		111		1.624	0.746	2.840					
SRCSD Walnut Grove WWTP (CSD1)	h	3 [2]		3.683	0.626	6.740					
UC Davis WWTP		12		2.991	0.074	11.100					
Williams WWTP		4		7.133	4.530	11.900					
Woodland WWTP		12		2.309	0.767	7.070					
Power Generation											
Camanche Dam Powerhouse	e	1		0.095	0.095	0.095					
GWF Power Systems	a	4	3	0.075	0.013	0.263					
Mirant Delta CCPP	a, f	12	1	0.096	0.010	0.296					
Sacramento Cogen Authority Procter & Gamble Plant	a	4	3	0.029	0.010	0.080					

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.
b. Darrah Springs Fish Hatchery, INF 1 & 2 Upper Springs
c. Proctor & Gamble, INF 2: Well #2 BR-226
d. City of Davis Plant, INF 1 -Head: Influent coming to the plant, collected at head-gate
e. Camache Dam Powerhouse, INF 1: receiving water received 200 feet upstream of discharge
f. Mirant Delta CCPP, INF 1: Intake 002
g. General Electric Co., INF 1: GWCS: Air Stripper Influent, INF 2: 100-foot Zone Influent. General Electric Co. GWCS conducted four sampling events. However, results for General Electric Co. GWCS samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations.
h. Results for the following facilities and sample dates were not incorporated in the calculations due to sample preservation hold times exceeding EPA recommendations: El Dorado Hills WWTP (9 August 2005, 1.41 ng/l); Modesto ID Regional WWTP (8 October 2004, <MDL); and SRCSD Walnut Grove WWTP (CSD1) (29 December 2004, 1.15 ng/l).

Table B.4: Summary of Influent/Intakes 3 and 4 Methylmercury Concentrations

Facility	Footnotes	# of INF 3 MeHg Samples	# of INF 3 Nondetect Samples	Ave. INF 3 MeHg Conc. (ng/l)	Min. INF 3 MeHg Conc. (ng/l)	Max. INF 3 MeHg Conc. (ng/l)	# of INF 4 MeHg Samples	# of INF 4 Nondetect Samples	Ave. INF 4 MeHg Conc. (ng/l)	Min. INF 4 MeHg Conc. (ng/l)	Max. INF 4 MeHg Conc. (ng/l)
Groundwater Remediation											
General Electric Co. GWCS	a, c	3	3	0.010	0.010	0.010					
Manufacturing											
Proctor & Gamble Co. WWTP	a, b	3	3	0.010	0.010	0.010	3	3	0.010	0.010	0.010

a. Sample MeHg concentration <MDL; half the detection limit was used for calculations.
b. Proctor & Gamble, INF 3: Well #3 BR-2025, INF 4:Well #4 BRL-341
c. General Electric Co., INF 3: Multizone Influent. General Electric Co. GWCS conducted four sampling events. However, results for General Electric Co. GWCS samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations.

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Aerojet Interim GW WTP	CA0083861	WTP (GW)	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	5.00	average			2.6*	18	0.013		0.090
Aerojet Sacramento Facility WWTP	CA0004111	Heating / Cooling	U/S of Delta / Yolo Bypass	Sacra-mento			X			0.024	WY2005					0.057		
AFB Conversion Agency A C & W GW Treatment	CA0083992	WTP (GW)	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.39	average			2.6*	1.4	0.013		0.0070
Agricultural Mgmt & Production Afterthought Mine	CA0084166	Mines	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.054	peak flow					0.064*	Mines	0.0048
Altamont Landfill and Resource	CA0083763	Landfill	U/S of Delta / Yolo Bypass	San Joaquin	X	Jun-07			X	0.15	(c)			23.1				
Anderson WWTP	CA0077704	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.4	dry weather average		Tertiary	4.1*	7.9	0.090		0.17
Atwater WWTP	CA0079197	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	3.4	dry weather average		Secondary	8.7*	41	0.034		0.16
Auburn WWTP	CA0077712	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.17	WY2005	Tertiary		1.5	2.4	0.028		0.045
Beale Air Force Base WWTP	CA0110299	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.7	baseline	Secondary		15.9	15	0.105*	Mun WWTP: Filtration + Chlor./ Dechlor.	0.10
Bell Carter Olive Company Inc.	CA0083721	Food	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.38	maximum flow allowed					0.017		0.0089
Bell Carter Olive Company Inc. Plant 1	CA0081639	Food	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.15	baseline					0.014*	Food	0.0029

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Bella Vista Water District	CA0080799	Water Filtration	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.5	baseline			4.6*	3.200	0.027		0.019
Biggs WWTP	CA0078930	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.38	average		Secondary	8.7*	4.6	1.605		0.84
Boeing Company, Interm. Treat. System	CA0084891	WTP (GW)	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.56	WY2005			2.6*	5.2	0.010		0.0077
Brentwood WWTP	CA0082660	Mun. WWTP	Delta/Yolo Bypass	Marsh Creek			X	X	X	3.09	WY2005	Tertiary		1.3	5.5	0.010		0.086
CA Dairies, Inc. Los Banos Foods	CA0082082	Food	U/S of Delta / Yolo Bypass	San Joaquin	X	Oct-07		X	X	0.5						0.016		0.011
CALAMCO - Stockton Terminal	CA0083968	Heating / Cooling	Delta/Yolo Bypass	Central	X	Oct-06				5.06	WY2005			6.6		0.293		
Calaveras Trout Farm (Rearing Facility)	CA0081752	Aqua-culture	U/S of Delta / Yolo Bypass	San Joaquin			X			19.4	average					0.060		
Calpine Corp. Greenleaf Unit One Cogen Plant	CA0081566	Power	U/S of Delta / Yolo Bypass	Sacra-mento	X	Apr-08				0.11	WY2005			2.3		0.064		
Camache Dam Powerhouse	CA0082040	Power	U/S of Delta / Yolo Bypass	Mokelumne	X	Oct-08				0.04	average			0.8		0.020		
Canada Cove LP French Camp Golf & RV Park WWTP	CA0083682	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	0.04	average		Tertiary	4.1*	0.23	0.147		0.0081
Chester WWTP	CA0077747	Mun. WWTP	U/S of Major Dam	Sacra-mento								Secondary		8.9				
Chico Regional WWTP	CA0079081	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	7.2	average		Secondary	8.7*	86	0.126		1.3
Clear Creek CSD WTP	CA0083828	Water Filtration	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.16	average			4.6*	1.000	0.036		0.0080
Colfax WWTP	CA0079529	Mun. WWTP	U/S of Major Dam	Sacra-mento						0.024	average seepage rate	Secondary		7.0		0.197		0.0065

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Collins and Aikman	CA0081531	WTP (GW)	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	0.022	average			2.6	0.079	0.013		0.00040
Collins Pine Company Chester Sawmill	CA0004391	Paper Mill / Saw Mills	U/S of Major Dam	Sacra-mento										5.9				
Colusa WWTP	CA0078999	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.66	WY2005		Secondary	8.7*	7.9	2.863		2.6
Corning Industries/ Domestic WWTP	CA0004995	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1	average		Secondary	8.7*	12	0.044		0.061
Cottonwood WWTP	CA0081507	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.29	2002 average		Tertiary	4.1*	1.6	0.096		0.038
Crystal Creek Aggregate	CA0082767	Aggregate	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.002	average			4.8	0.013	0.010		2.8×10^{-5}
Davis WWTP Discharge 001	CA0079049	Mun. WWTP	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	2.8	WY2005	Secondary		7.4	17	0.550		1.3
Davis WWTP Discharge 002	CA0079049	Mun. WWTP	Delta/Yolo Bypass	Yolo Bypass			X	X	X	2.4	WY2005	Secondary		6.9	23	0.610		0.78
Defense Logistics Agency Sharpe GW Cleanup	CA0081931	WTP (GW)	U/S of Delta / Yolo Bypass	San Joaquin	X	Apr-08		X	X	1.9				2.6*	6.8	0.018		0.047
Deuel Vocational Institute WWTP	CA0078093	Mun. WWTP	Delta/Yolo Bypass	San Joaquin			X	X	X	0.47	WY2005	Tertiary		3.3	2.1	0.010		0.013
DFG Darrah Springs Fish Hatchery	CA0004561	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			18.7	average					0.024		
DFG Feather River Fish Hatchery	CA0004570	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			25.8	baseline			1.4				
DFG Merced River Fish Hatchery	CA0080055	Aqua-culture	U/S of Delta / Yolo Bypass	San Joaquin			X			4.55	average					0.037		
DFG Moccasin Creek Fish Hatchery	CA0004804	Aqua-culture	U/S of Delta / Yolo Bypass	San Joaquin			X			19.62	WY2005					0.010		

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
DFG Mokelumne River Fish Hatchery	CA0004791	Aqua-culture	U/S of Delta / Yolo Bypass	Mokelumne			X			21	average					0.041		
DFG Nimbus Fish Hatchery	CA0004774	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			40	baseline			26.8		0.065		
DFG San Joaquin Fish Hatchery	CA0004812	Aqua-culture	U/S of Delta / Yolo Bypass	San Joaquin			X			22.6	average					0.060		
DFG Thermalito Annex Fish Hatchery	CA0082350	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			7.8	average			1.5				
DGS Office of State Publishing	CA0078875	Publishing	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.3	WY2005			1.5	0.62	0.010		0.0041
Discovery Bay WWTP	CA0078590	Mun. WWTP	Delta/Yolo Bypass	Central			X	X	X	1.5	WY2005	Secondary		5.0	10	0.178		0.37
Donner Summit WWTP	CA0081621	Mun. WWTP	U/S of Major Dam	Sacra-mento								Tertiary		7.8				
El Dorado ID Deer Creek WWTP	CA0078662	Mun. WWTP	U/S of Delta / Yolo Bypass	Mokelumne			X	X	X	2.52	WY2005	Tertiary		5.1	18	0.015		0.052
El Dorado ID El Dorado Hills WWTP Discharge 1	CA0078671	Mun. WWTP	U/S of Delta / Yolo Bypass	Mokelumne			X	X	X	1.08	WY2005	Tertiary		2.0	3.0	0.018		0.027
Formica Corporation Sierra Plant	CA0004057	Manufactu ring	U/S of Delta / Yolo Bypass	Sacra-mento	X	Apr-09		X	X	0.88	average			3.5	4.3	0.050		0.061
Galt WWTP	CA0081434	Mun. WWTP	U/S of Delta / Yolo Bypass	Mokelumne			X	X	X	1.92	WY2005	Secondary		3.7	9.8	0.139		0.37
Gaylord Container Corp. Antioch Pulp and Paper Mill	CA0004847	Heating / Cooling	Delta/Yolo Bypass	West	X	Jun-06								7.1		0.055		
General Electric Co. GWCS	CA0081833	WTP (GW)	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	1.6	average			2.6*	5.7	0.010		0.022

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Grass Valley WWTP	CA0079898	Mun. WWTP	U/S of Major Dam	Sacra-mento						2.1	WY2005	Secondary		5.0		0.160		0.46
Grizzly Lake Resort Dellecker WWTP	CA0081744	Mun. WWTP	U/S of Major Dam	Sacra-mento								Secondary		8.6				
GWF Power Systems	CA0082309	Power	Delta/Yolo Bypass	West			X	X	X	0.05	WY2005			4.3	0.27	0.020		0.0019
Hershey Chocolate USA, Oakdale	CA0004146	Food	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	1.03	WY2005					0.010		0.014
J.F. Enterprises Worm Farm	CA0081949	Aqua-culture	U/S of Delta / Yolo Bypass	San Joaquin			X			5.44	maximum flow							
J.F. Shea CO Fawndale Rock and Asphalt	CA0083097	Aggregate	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	3.87	average			4.8*	26	0.010		0.053
Jackson WWTP	CA0079391	Mun. WWTP	U/S of Major Dam	Mokelumne						0.56	WY2005	Tertiary		6.1		0.108		0.11
Kinder Morgan Elmira Remediation Project	CA0084719	WTP (GW)	U/S of Delta / Yolo Bypass	Yolo Bypass	X	Jun-08		X	X	0.07				2.6*	0.25	0.013		0.0013
Kinder Morgan Fox Rd Pipeline Release Site	CA0084760	WTP (GW)	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	0.072	average			2.6*	0.26	0.013		0.0013
Kinder Morgan Holt Ground Water Recovery	CA0084701	WTP (GW)	Delta/Yolo Bypass	Central	X	Jun-05		X	X	0.044	monthly average			2.5	0.15	0.013		0.00079
Land O'Lakes, Inc., Valley Gold LLC	CA0084808	Food	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	0.152	baseline					0.014*	Food	0.0029
Lehigh Southwest Cement Co.	CA0081191	Aggregate	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X		typically little discharge							

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Lincoln Center Groundwater Treatment Facility	CA0084255	WTP (GW)	Delta/Yolo Bypass	Central			X	X	X	0.25				0.6	0.21	0.03*	WTP (GW)	0.010
Lincoln WWTP	CA0084476	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.13	WY2005	Tertiary		1.4	2.2	0.018		0.028
Linda Co Water Dist WWTP	CA0079651	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.3	baseline	Secondary		20.7	37	0.018*	Mun WWTP: N/D + Filtration + Chlor./ Dechlor.	0.032
Live Oak WWTP	CA0079022	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.7	Nov04-Oct05		Secondary	8.7*	20	0.591		1.4
LLNL Site 300 GW Treatment	CA0082651	WTP (GW)	U/S of Delta / Yolo Bypass	San Joaquin	X	Aug-05			X	0.065	average			2.6*	0.23	0.013		
Lodi White Slough WWTP	CA0079243	Mun. WWTP	Delta/Yolo Bypass	Central			X	X	X	4.5	WY2005	Tertiary		3.3	21	0.128		0.93
Manteca WWTP	CA0081558	Mun. WWTP	Delta/Yolo Bypass	San Joaquin			X	X	X	4.63	WY2005	Secondary		10.6	68	0.216		1.4
Mariposa PUD WWTP	CA0079430	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	0.245	average		Secondary	8.7*	2.9	0.393		0.13
Maxwell PUD WWTP	CA0079987	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.14	average		Secondary	8.7*	1.7	0.993		0.19
Merced WWTP	CA0079219	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	8.5	baseline	Secondary		9.3	109	0.386		4.5
Metropolitan Stevedore	CA0084174	Port Terminal	Delta/Yolo Bypass	Central			X	X	X		(g)							
Mirant Delta LLC Contra Costa Power Plant, Outfall 1	CA0004863	Power	Delta/Yolo Bypass	West			X			2.9	WY2005			6.1		0.075		

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Mirant Delta LLC Contra Costa Power Plant, Outfall 2	CA0004863	Power	Delta/Yolo Bypass	West			X			121.0	WY2005			7.1		0.086		
Modesto ID Regional WTP	CA0083801	Water Filtration	U/S of Delta / Yolo Bypass	San Joaquin	X	Sep-07		X	X	0.04	WY2005			4.6*	0.25	0.056		0.0031
Modesto WWTP	CA0079103	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	11.8	WY2005	Secondary		5.7	93	0.130		2.1
Mountain House CSD WWTP	CA0084271	Mun. WWTP	Delta/Yolo Bypass	San Joaquin			X			0.45	(h)	Tertiary	Tertiary	0.8	0.50	0.050		0.031
Mt Lassen Trout Farms Dales Facility	CA0080381	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			2.4	average							
Mt Lassen Trout Farms Jeffcoat Facility	CA0082104	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			2	baseline							
Mt Lassen Trout Farms Jeffcoat West Facility	CA0082813	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			4.5	average							
Mt Lassen Trout Farms Meadowbrook Facility	CA0080373	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			2.76	average							
Mt Lassen Trout Farms Millseat Facility	CA0082279	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			14	average							
Mt Lassen Trout Farms Volta Facility	CA0083879	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			1.9	average							
Mt Lassen Trout Farms Willow Springs Facility	CA0082163	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			3	average							
Nevada City WWTP	CA0079901	Mun. WWTP	U/S of Major Dam	Sacra-mento						0.43	average			7.1		0.048		0.029

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Nevada Co SD #1 Cascade Shores WWTP	CA0083241	Mun. WWTP	U/S of Major Dam	Sacra-mento						0.026	average					0.142		0.0051
Nevada Co SD #1 Lake Wildwood WWTP	CA0077828	Mun. WWTP	U/S of Major Dam	Sacra-mento						0.5	1999-2002 annual average					0.109		0.075
Nevada Co SD #2 Lake of the Pines WWTP	CA0081612	Mun. WWTP	U/S of Major Dam	Sacra-mento						0.54	baseline					1.409		1.1
Oakwood Lake Subdivision Mining Reclamation	CA0082783	Lake Dewatering	Delta/Yolo Bypass	San Joaquin			X	X	X	9.15	WY2005			2.9	37	0.030		0.38
Olivehurst PUD WWTP	CA0077836	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.2	WY2005		Secondary	8.7*	22	0.144		0.24
Oroville WWTP	CA0079235	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	3	average	Tertiary		3.7	15	0.147		0.61
Pacific Coast Sprout Farms, Inc. (Sacramento Facility)	CA0082961	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			0.1	baseline			1.8		0.010		
Pactiv Molded Pulp Mill	CA0004821	Paper Mill / Saw Mills	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.9	average			2.0	5.3	0.039		0.10
Paradise Irrigation District	CA0083488	Water Filtration	U/S of Major Dam	Sacra-mento						1.5	design flow			4.7	9.7	0.013		
Placer Co. SA #28 Zone #6 WWTP	CA0079341	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.01	WY2005	Secondary		9.3	0.13	0.668		0.0092
Placer Co. SMD #1 WWTP	CA0079316	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.90	WY2005	Tertiary		2.1	5.7	0.141		0.37
Placer Co. SMD #3 WWTP	CA0079367	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.12	WY2005	Tertiary		2.1	0.35	0.100		0.017
Placerville Hangtown Creek WWTP	CA0078956	Mun. WWTP	U/S of Major Dam	Sacra-mento						1.3	average	Tertiary		11.6		0.058		0.10

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Planada Comm. Service Dist. WWTP	CA0078950	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	0.38	average		Tertiary	4.1*	2.2	1.168		0.61
Pliant Corp Vitafilm Plant	CA0080071	Heating / Cooling	U/S of Delta / Yolo Bypass	San Joaquin	X	Dec-06				0.338								
Portola WWTP	CA0077844	Mun. WWTP	U/S of Major Dam	Sacra-mento								Secondary		4.9				
Proctor & Gamble Co. WWTP	CA0004316	Manufactu ring	U/S of Delta / Yolo Bypass	Sacra-mento	X	Jun-06		X	X	5.5				1.9	14	0.010		0.076
Quincy WWTP	CA0078981	Mun. WWTP	U/S of Major Dam	Sacra-mento								Secondary		15.8				
Red Bluff WWTP	CA0078891	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.4	baseline		Tertiary	4.1*	7.9	0.027		0.052
Redding Clear Creek WWTP	CA0079731	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	7.5	baseline	Tertiary		3.7	38	0.042		0.44
Redding Stillwater WWTP	CA0082589	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	3.46	WY2000-02 average	Tertiary		2.1	10	0.013		0.062
Rio Alto WD- Lake CA WWTP	CA0077852	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.15	dry weather average		Tertiary	4.1*	0.85	1.746		0.36
Rio Vista Northwest WWTP	CA0083771	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X			1	(i)		Tertiary	4.1*	5.7	0.05*	Mun WWTP: N/D + Filtration + UV	0.069
Rio Vista Trilogy WWTP	CA0083771	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento	X	Replaced by Rio Vista Northwest WWTP in 2007.		X	X	0.1	seasonal discharge (181 days)	Secondary		3.7	0.52	0.06*	Mun WWTP: Filtration + Chlor./ Dechlor. + Activated Sludge + Trickling Filter	0.0041

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Rio Vista WWTP	CA0079588	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X	X	X	0.47	WY2005	Secondary		9.5	6.2	0.164		0.10
River Highlands CSD Hammonton Gold Village WWTP	CA0081574	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.008	baseline	Secondary		6.9	0.076	0.902*	Mun WWTP: Pond + Chlor./ Dechlor.	0.010
Roseville Dry Creek WWTP	CA0079502	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	10.19	WY2005	Tertiary		10.9	196	0.023		0.41
Roseville Pleasant Grove WWTP	CA0084573	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X			5.90	WY2005 (j)	Tertiary		1.3	8.7	0.017		0.11
Sacramento Cogen Authority Procter & Gamble Plant	CA0083569	Power	U/S of Delta / Yolo Bypass	Sacra-mento	X	Sep-06				1.5				5.5		0.052		
Sacramento Combined WWTP (CWTP)	CA0079111	Combined Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X	X	X	0.59		Primary		66	54	0.536		0.44
Sacramento Combined WWTP (Pioneer)	CA0079111	Combined Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X	X	X	0.27				104	60	0.536		0.20
Sacramento Combined WWTP (Sump 2)	CA0079111	Combined Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X	X	X	0.42				101	38	0.536		0.31
Sacramento International Airport	CA0034841	Heating / Cooling	U/S of Delta / Yolo Bypass	Sacra-mento	X	Jun-06				1.5	design flow					0.035		
Sacramento Power Authority Campbells Cogen Plant	CA0083658	Power	U/S of Delta / Yolo Bypass	Sacra-mento	X	Mar-05								18.8				
San Andreas SD WWTP	CA0079464	Mun. WWTP	U/S of Major Dam	Central						0.3	baseline					0.249		0.10

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
San Joaquin Co DPW CSA 31 Flag City WWTP	CA0082848	Mun. WWTP	Delta/Yolo Bypass	Central	X	Jun-08		X	X	0.06	WY2005	Tertiary		9.1	0.27	0.081		0.0066
Shasta Lake WTP	CA0004693	Water Filtration	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.05	average			4.6*	0.32	0.025		0.0017
Shasta Lake WWTP	CA0079511	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.64	baseline		Tertiary	4.1*	3.6	0.022		0.019
Shasta Paper Co Shasta Mill	CA0004065	Paper Mill / Saw Mills	U/S of Delta / Yolo Bypass	Sacra-mento	X	Jan-05		X	X		(d)							
Sliger Mine	CA0084905	Mines	U/S of Major Dam	Sacra-mento						0.0646	average portal discharge					0.064		0.0057
SMUD Rancho Seco Nuclear Generating Station	CA0004758	Power/Domestic WWTP	U/S of Delta / Yolo Bypass	Mokelumne	X	Aug-09		X	X	0.09	average			0.8	0.10	0.040		0.0050
South Feather Water & Power Agency Miners Ranch WTP	CA0083143	Water Filtration	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.25	baseline			4.6	1.6	0.013		0.0045
SPI Anderson Division	CA0082066	Paper Mill / Saw Mills	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X		typically no discharge					0.106		
SPI Camino Sawmill	CA0078841	Paper Mill / Saw Mills	U/S of Major Dam	Sacra-mento										3.3				
SPI Martell Complex/Sierra Pine	CA0004219	Paper Mill / Saw Mills	U/S of Delta / Yolo Bypass	Mokelumne			X	X	X	0.57	baseline			11.7	9.2	0.117*	Paper Mill /Saw Mills	0.092
SPI Quincy Division	CA0080357	Paper Mill / Saw Mills	U/S of Major Dam	Sacra-mento										6.2				
SPI Shasta Lake	CA0081400	Paper Mill / Saw Mills	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.15	baseline			5.8*	1.4	0.117*	Paper Mill /Saw Mills	0.024
SRCSD Sacramento River WWTP	CA0077682	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento			X	X	X	162	WY2001-2003	Secondary		7.3	1,634	0.718		161

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
SRCSD Walnut Grove WWTP	CA0078794	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento	X	(e)		X	X	0.08		Secondary		21.5	2.4	2.155		0.24
State of California Central Heating/Cooling Plant	CA0078581	Heating / Cooling	Delta/Yolo Bypass	Sacra-mento			X			5.26	WY2005			2.8		0.015		
Stimpel Wiebelhaus Assoc. SWA at Mountain Gate Quarry	CA0084140	Aggregate	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.02	average			4.8*	0.13	0.081		0.0022
Stockton Congeneration Co.	CA0081965	Power	U/S of Delta / Yolo Bypass	San Joaquin	X	Oct-06				1.17				0.3		0.017		
Stockton WWTP	CA0079138	Mun. WWTP	Delta/Yolo Bypass	San Joaquin			X	X	X	28	WY2005	Tertiary		5.1	201	0.935		36
Tehama Co SD 1 Mineral WWTP	CA0084069	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.027	baseline		Tertiary	4.1*	0.15	1.04*	Mun WWTP: Pond + Filtration + Chlor./ Dechlor.	0.039
The Vendo Co GW Cleanup System	CA0083046	WTP (GW)	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	0.72	baseline			2.6*	2.6	0.013		0.013
Tracy WWTP	CA0079154	Mun. WWTP	Delta/Yolo Bypass	San Joaquin			X	X	X	9.49	WY2005	Secondary		11.0	145	0.145		1.8
Tuolumne UD Sonora WWTP/ Jamestown WWTP	CA0084727	Mun. WWTP	U/S of Major Dam	San Joaquin						0.16	WY2005					0.182		0.040
Turlock WWTP	CA0078948	Mun. WWTP	U/S of Delta / Yolo Bypass	San Joaquin			X	X	X	11.7	WY2005	Secondary		9.3	151	0.059		0.95
U.S. Army Corp of Engineers Titan 1-A Missile Facility	CA0084743	WTP (GW)	U/S of Delta / Yolo Bypass	Sacra-mento	X	Jun-07		X	X	0.0432				2.6*	0.16	0.013		0.00078

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
UC Davis Center for Aquatic Biology & Aquaculture Aquatic Center	CA0083348	Aqua-culture	U/S of Delta / Yolo Bypass	Yolo Bypass			X			0.67	WY2005					0.030		
UC Davis Center for Aquatic Biology & Aquaculture Putah Creek Facility	CA0083348	Aqua-culture	U/S of Delta / Yolo Bypass	Yolo Bypass			X			0.14	WY2005					0.082		
UC Davis Hydraulics Laboratory	CA0084182	Laboratory	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	0.01	average					0.057		0.00079
UC Davis WWTP	CA0077895	Mun. WWTP	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	1.93	WY2005		Tertiary	4.1*	11	0.038		0.10
United Auburn Indian Community Casino WWTP	CA0084697	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.15	WY2005		Tertiary	4.1*	0.85	0.010		0.0021
USAF McClellan AFB GW Ext & Trt Sys	CA0081850	WTP (GW)	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	2.12	average			2.6*	7.6	0.013		0.038
USDI BR Winter Run Rearing Facility	CA0084298	Aqua-culture	U/S of Major Dam	Sacra-mento												0.010		
USDI FWS Coleman Fish Hatchery	CA0004201	Aqua-culture	U/S of Delta / Yolo Bypass	Sacra-mento			X			40.08	average					0.030		
USDI UC Davis Aquatic Weed Laboratory	CA0083364	Laboratory	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	0.05	baseline					0.057*	Labor-atory	0.0039
Vacaville Easterly WWTP	CA0077691	Mun. WWTP	U/S of Delta / Yolo Bypass	Yolo Bypass			X	X	X	9.26	WY2005	Secondary		3.1	40	0.024		0.31
West Sacramento WWTP	CA0079171	Mun. WWTP	Delta/Yolo Bypass	Sacra-mento	X	Apr-08		X	X	5.6		Secondary		3.1	26	0.050		0.39

Table B.5: Summary of Facility Discharge Volumes and Effluent Total Mercury and Methylmercury Concentrations and Loads

Facility	NPDES No.	Facility Type	Proximity to Delta / Yolo Bypass [a]	Delta Subarea that Receives Discharge	NPDES Permit Rescinded During or After TMDL Study Period	NPDES Permit Rescinsion Date	Discharged in Sept. 2009 d/s Major Dams	Include in Sum of MeHg Source Loads d/s Major Dams for TMDL Period	Include in Sum of TotHg Source Loads d/s Major Dams for 20-yr Period	Annual Discharge (mgd)	Annual Discharge Type	Maximum Level of Mun. WWTP Treatment When EFF TotHg Data Were Collected	Treatment Category for Mun WWTPs d/s Major Dams w/o EFF TotHg Data	Ave. EFF TotHg Conc. [b] (ng/l)	EFF TotHg Load (g/yr)	Ave. EFF MeHg Conc. [b] (ng/l)	Treatment Category for EFF MeHg Conc. Estimate	EFF MeHg Load (g/yr)
Wheelabrator Shasta Energy Co.	CA0081957	Power	U/S of Delta / Yolo Bypass	Sacra-mento			X			0.02	average					0.104		
Williams WWTP	CA0077933	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.44	WY2005		Secondary	8.7*	3.6	1.553		0.94
Willows WWTP	CA0078034	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	1.22	average		Secondary	8.7*	15	0.105*	Mun WWTP: Filtration + Chlor./ Dechlor.	0.18
Woodland WWTP	CA0077950	Mun. WWTP	Delta/Yolo Bypass	Yolo Bypass			X	X	X	6.05	WY2005	Secondary		6.1	51	0.031		0.25
Yuba City WWTP	CA0079260	Mun. WWTP	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	5.5	(f)	Secondary		9.1	69	0.295		2.2
Yuba CWD Forbestown WTP	CA0084824	Water Filtration	U/S of Delta / Yolo Bypass	Sacra-mento			X	X	X	0.07	design flow			0.6	0.058	0.033*	Water Filtration	0.0032

Footnotes for Table B.5:

(a) U/S: Upstream.

(b) An asterisk (*) indicates that effluent total mercury and/or methylmercury concentration date were not available for these facilities. Average effluent concentrations observed at similar facilities were used to estimate their effluent loads. The average concentrations shown in this table for non-municipal WWTPs for which effluent total mercury and/or methylmercury concentration data were not available are based on the average of average effluent concentrations observed at facilities within their respective facility categories. Average total mercury concentrations for municipal WWTPs with tertiary and secondary treatment processes for which effluent data were not available are based on the average of the average total mercury concentrations observed at tertiary and secondary municipal WWTPs, 4.1 and 8.7 ng/l, respectively. Average methylmercury concentrations for municipal WWTPs for which effluent data were not available are based on the average concentrations observed at municipal treatment plants with a similar suite of treatment processes, as shown in Tables 17, 23 and 26.

(c) Altamont Landfill and Resource discharge: average wet weather/dry weather design prior to 1999; there has been no discharge since 1999.

(d) Shasta Paper Co Shasta Mill discharge: stormwater discharges only; there has been no discharge of treated process and domestic wastewater from the treatment plant to Sacramento River since 31 August 2001.

(e) SRCSD Walnut Grove WWTP discharge: The WWTP no longer discharges; as of March 2010, the NPDES permit has not yet been rescinded.

(f) Yuba City WWTP discharge: average daily flow for dates effluent was sampled for methylmercury.

(g) Metropolitan Stevedore discharge: the facility's discharge volume was not specified by its permit.

(h) Mountain House CSD WWTP discharge: Phase 1 dry weather design capacity; the WWTP began to discharge to surface water in 2007.

(i) Rio Vista Northwest WWTP discharge: start-up capacity; the WWTP began to discharge to surface water in 2007.

(j) Roseville Pleasant Grove WWTP discharge: the WWTPbegan to discharge to surface water in June 2004.

APPENDIX C
SUMMARY OF NPDES FACILITY EFFLUENT, INFLUENT, AND RECEIVING WATER MATRIX SPIKES AND MATRIX SPIKE DUPLICATES

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0083861	AEROJET INTERIM GROUND WTP	11/17/05	Effluent	99.1%	107.4%	8.0%
CA0083861	AEROJET INTERIM GROUND WTP	06/06/06	Effluent	90.3%	98.4%	8.6%
CA0004111	AEROJET SACRAMENTO FACILITY	03/18/05	Effluent	86.5%	97.6%	12.1%
CA0004847	ANTIOCH PULP & PAPER MILL	09/23/04	Effluent	106.8%	103.9%	2.8%
CA0004847	ANTIOCH PULP & PAPER MILL	10/14/04	Effluent	118.9%	114.9%	3.4%
CA0083721	BELL CARTER INDUSTRIAL WWTP	03/02/05	Effluent	119.4%	103.4%	14.4%
CA0083721	BELL CARTER INDUSTRIAL WWTP	12/15/04	Effluent	100.3%	92.1%	8.5%
CA0080799	BELLA VISTA WTP	09/21/04	Effluent	105.7%	107.6%	1.8%
CA0084891	BOEING COMPANY INTERIM GW TRT SYSTEM	08/17/04	Effluent	86.8%	85.6%	1.4%
CA0078581	CA CENTRAL HEATING/COOLING FAC	12/15/04	Effluent	103.0%	108.6%	5.3%
CA0078581	CA CENTRAL HEATING/COOLING FAC	03/07/05	Effluent	102.4%	95.3%	7.2%
CA0078581	CA CENTRAL HEATING/COOLING FAC	08/25/04	Effluent	114.4%	101.2%	12.2%
CA0078581	CA CENTRAL HEATING/COOLING FAC	06/06/05	Effluent	117.0%	103.0%	12.7%
CA0078875	CA STATE PRINTING & WAREHOUSES	08/30/04	Effluent	98.5%	86.5%	13.0%
CA0083968	CALAMCO - STOCKTON TERMINAL	07/11/05	Effluent	120.0%	117.9%	1.8%
CA0083968	CALAMCO - STOCKTON TERMINAL	08/04/05	Effluent	125.5%	119.6%	4.8%
CA0083968	CALAMCO - STOCKTON TERMINAL	08/26/04	Effluent	122.3%	107.4%	13.0%
CA0081752	CALAVERAS TROUT FARM, INC TROUT REARING FAC.	09/30/04	Effluent	103.0%	107.9%	4.6%
CA0083828	CLEAR CREEK WTP	12/09/04	Effluent	111.6%	105.3%	5.8%
CA0083828	CLEAR CREEK WTP	06/27/05	Effluent	91.0%	106.7%	15.9%
CA0082767	CRYSTAL CREEK AGGREGATE	01/04/05	Effluent	100.1%	112.5%	11.7%
CA0081931	DEFENSE LOGISTICS AGENCY GW CLEANUP	09/27/04	Effluent	115.6%	115.6%	0.0%
CA0004561	DFG DARRAH SPRINGS HATCHERY	09/15/04	Effluent	115.5%	105.6%	9.0%
CA0004561	DFG DARRAH SPRINGS HATCHERY	09/14/04	Effluent	96.2%	111.4%	14.6%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0080055	DFG MERCED RIVER FISH HATCHERY	05/26/05	Effluent	120.2%	117.3%	2.4%
CA0004804	DFG MOCCASIN FISH HATCHERY	08/24/04	Effluent	92.0%	86.5%	6.2%
CA0004812	DFG SAN JOAQUIN FISH HATCHERY	09/28/04	Effluent	109.7%	108.8%	0.8%
CA0083097	FAWNDALE ROCK & ASPHALT	10/20/04	Effluent	102.3%	100.9%	1.4%
CA0083097	FAWNDALE ROCK & ASPHALT	10/20/04	Effluent	99.6%	119.9%	18.5%
CA0081833	GENERAL ELECTRIC CO GWCS	01/24/05	Effluent	120.6%	119.1%	1.3%
CA0081833	GENERAL ELECTRIC CO GWCS	07/05/05	Effluent	111.8%	108.1%	3.4%
CA0081833	GENERAL ELECTRIC CO GWCS	10/08/04	Effluent	114.0%	122.4%	7.1%
CA0082309	GWF POWER SYSTEMS, SITE IV	02/03/05	Effluent	97.8%	96.4%	1.4%
CA0082309	GWF POWER SYSTEMS, SITE IV	08/11/04	Effluent	94.8%	92.5%	2.5%
CA0004146	HERSHEY CHOCOLATE USA, OAKDALE	10/12/04	Effluent	111.5%	109.2%	2.1%
CA0004146	HERSHEY CHOCOLATE USA, OAKDALE	02/07/05	Effluent	100.9%	91.9%	9.3%
CA0083551	KONOCTI HARBOR INN	10/13/04	Effluent	110.8%	100.1%	10.1%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	12/08/04	Effluent	111.3%	111.1%	0.2%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	10/19/04	Effluent	107.0%	116.5%	8.5%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	10/19/04	Effluent	116.7%	100.9%	14.5%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	12/08/04	Effluent	121.6%	97.9%	21.6%
CA0082082	LOS BANOS FOODS, INC	09/07/04	Effluent	103.7%	89.9%	14.3%
CA0082783	MANTECA AGGREGATE SAND PLANT [b]	08/26/04	Effluent	96.5%	92.0%	4.8%
CA0083143	MINERS RANCH WTP	09/09/04	Effluent	106.6%	97.7%	8.7%
CA0004863	MIRANT CCPP ANTIOCH	11/02/04	Effluent	115.3%	122.6%	6.1%
CA0004863	MIRANT CCPP ANTIOCH	11/02/04	Effluent	123.5%	106.3%	15.0%
CA0083801	MODESTO ID REGIONAL WTP	01/18/05	Effluent	113.6%	111.3%	2.0%
CA0083801	MODESTO ID REGIONAL WTP	10/08/04	Effluent	113.8%	108.1%	5.1%
CA0083801	MODESTO ID REGIONAL WTP	04/11/05	Effluent	104.2%	95.8%	8.4%
CA0004821	PACTIV MOLDED PULP MILL	04/06/05	Effluent	116.8%	117.1%	0.3%
CA0004821	PACTIV MOLDED PULP MILL	08/03/05	Effluent	88.8%	100.5%	12.4%
CA0004821	PACTIV MOLDED PULP MILL	09/16/04	Effluent	123.5%	86.6%	35.1%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0083488	PARADISE WTP	09/08/04	Effluent	96.1%	103.7%	7.6%
CA0004316	PROCTER & GAMBLE CO WWTP	08/30/04	Effluent	124.6%	108.9%	13.4%
CA0083569	PROCTOR & GAMBLE COGEN. PLANT	08/11/04	Effluent	94.4%	93.2%	1.3%
CA0083569	PROCTOR & GAMBLE COGEN. PLANT	08/11/04	Effluent	100.0%	97.5%	2.5%
CA0034841	SACRAMENTO INTERNATIONAL AIRPT	08/31/04	Effluent	116.3%	110.6%	5.0%
CA0034841	SACRAMENTO INTERNATIONAL AIRPT	05/20/05	Effluent	103.0%	118.1%	13.7%
CA0004693	SHASTA LAKE WTP	11/12/04	Effluent	107.8%	104.1%	3.5%
CA0004693	SHASTA LAKE WTP	08/23/04	Effluent	80.5%	103.0%	24.5%
CA0082066	SIERRA PACIFIC, ANDERSON DIV	01/26/05	Effluent	95.2%	91.7%	3.7%
CA0082066	SIERRA PACIFIC, ANDERSON DIV	12/26/04	Effluent	102.6%	107.0%	4.2%
CA0082066	SIERRA PACIFIC, ANDERSON DIV	12/26/04	Effluent	112.7%	117.7%	4.3%
CA0082066	SIERRA PACIFIC, ANDERSON DIV	01/26/05	Effluent	93.8%	86.7%	7.9%
CA0081400	SIERRA PACIFIC, SHASTA LAKE DV	03/23/05	Effluent	103.2%	100.1%	3.0%
CA0081400	SIERRA PACIFIC, SHASTA LAKE DV	12/30/04	Effluent	91.2%	86.1%	5.8%
CA0084905	SLIGER MINE	12/20/05	Effluent	92.4%	99.1%	7.0%
CA0081965	STOCKTON COGENERATION FACILITY	08/18/04	Effluent	104.3%	96.1%	8.2%
CA0084182	UC DAVIS HYDRAULICS LABORATORY	09/22/04	Effluent	113.4%	110.3%	2.8%
CA0083348	UCDAVIS AQUATIC CENTER/ANIMAL SCIENCE	11/05/04	Effluent	103.7%	100.0%	3.6%
CA0083348	UCDAVIS AQUATIC CENTER/ANIMAL SCIENCE	09/22/04	Effluent	118.8%	124.6%	4.8%
CA0083348	UCDAVIS AQUATIC CENTER/ANIMAL SCIENCE	09/22/04	Effluent	116.7%	126.3%	7.9%
CA0004201	USDI FWS COLEMAN FISH HATCHERY	11/24/04	Effluent	112.8%	108.4%	4.0%
CA0084298	USDI FWS WINTER RUN REARING FACILITY	10/28/04	Effluent	118.1%	116.7%	1.2%
CA0081957	WHEELABRATOR SHASTA ENERGY CO	10/07/04	Effluent	91.0%	91.0%	0.0%
CA0077704	ANDERSON WWTP	10/06/04	Effluent (Mun-WW)	120.2%	128.4%	6.6%
CA0079197	ATWATER WWTP	09/28/04	Effluent (Mun-WW)	102.70%	107.70%	4.8%
CA0079219	ATWATER WWTP	09/14/04	Effluent (Mun-WW)	106.80%	106.60%	0.2%
CA0077712	AUBURN WWTP	10/06/04	Effluent (Mun-WW)	115.4%	115.9%	0.4%
CA0077712	AUBURN WWTP	08/31/04	Effluent (Mun-WW)	120.7%	115.1%	4.7%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0077712	AUBURN WWTP	07/12/05	Effluent (Mun-WW)	96.2%	117.8%	20.2%
CA0078930	BIGGS WWTP	08/23/04	Effluent (Mun-WW)	55.5%	56.0%	0.9%
CA0082660	BRENTWOOD WWTP	12/06/04	Effluent (Mun-WW)	107.6%	107.2%	0.4%
CA0082660	BRENTWOOD WWTP	11/01/04	Effluent (Mun-WW)	117.9%	119.3%	1.2%
CA0082660	BRENTWOOD WWTP	03/07/05	Effluent (Mun-WW)	115.9%	118.1%	1.9%
CA0082660	BRENTWOOD WWTP	10/04/04	Effluent (Mun-WW)	108.8%	110.9%	1.9%
CA0082660	BRENTWOOD WWTP	09/08/04	Effluent (Mun-WW)	109.5%	116.7%	6.4%
CA0082660	BRENTWOOD WWTP	01/03/05	Effluent (Mun-WW)	107.4%	99.7%	7.4%
CA0082660	BRENTWOOD WWTP	08/09/04	Effluent (Mun-WW)	99.4%	73.5%	30.0%
CA0079081	CHICO REGIONAL WWTP	05/10/05	Effluent (Mun-WW)	107.60%	107.60%	0.0%
CA0079081	CHICO REGIONAL WWTP	09/07/04	Effluent (Mun-WW)	106.10%	107.50%	1.3%
CA0079081	CHICO REGIONAL WWTP	06/14/05	Effluent (Mun-WW)	89.40%	91.70%	2.5%
CA0079731	CLEAR CREEK WWTP	06/09/05	Effluent (Mun-WW)	95.5%	95.5%	0.0%
CA0079731	CLEAR CREEK WWTP	09/08/04	Effluent (Mun-WW)	108.5%	105.5%	2.8%
CA0079529	COLFAX WWTP	11/10/04	Effluent (Mun-WW)	122.1%	117.0%	4.3%
CA0078999	COLUSA WWTP	08/26/04	Effluent (Mun-WW)	133.2%	91.9%	13.3%
CA0078999	COLUSA WWTP	12/02/04	Effluent (Mun-WW)	89.5%	90.7%	0.3%
CA0004995	CORNING INDUST/DOMESTIC WWTP	09/22/04	Effluent (Mun-WW)	122.3%	107.4%	13.0%
CA0081507	COTTONWOOD WWTP	09/30/04	Effluent (Mun-WW)	101.0%	106.8%	5.6%
CA0081507	COTTONWOOD WWTP	04/01/05	Effluent (Mun-WW)	98.7%	84.6%	15.4%
CA0079049	DAVIS WWTP	09/22/04	Effluent (Mun-WW)	102%	96%	6.1%
CA0078662	DEER CREEK WWTP	12/07/04	Effluent (Mun-WW)	92.5%	91.1%	1.5%
CA0078662	DEER CREEK WWTP	02/08/05	Effluent (Mun-WW)	105.5%	103.8%	1.6%
CA0078093	DEUEL VOCATNL INST. WWTP	04/20/05	Effluent (Mun-WW)	91.3%	92.5%	1.3%
CA0078093	DEUEL VOCATNL INST. WWTP	01/12/05	Effluent (Mun-WW)	99.5%	101.2%	1.7%
CA0078093	DEUEL VOCATNL INST. WWTP	10/26/04	Effluent (Mun-WW)	97.4%	93.8%	3.8%
CA0078590	DISCOVERY BAY WWTP	04/25/05	Effluent (Mun-WW)	87.9%	86.7%	1.4%
CA0078590	DISCOVERY BAY WWTP	08/18/04	Effluent (Mun-WW)	96.1%	92.0%	4.4%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0077691	EASTERLY WWTP	01/11/05	Effluent (Mun-WW)	87.1%	92.9%	6.4%
CA0078671	EL DORADO HILLS WWTP	06/07/05	Effluent (Mun-WW)	90.0%	90.0%	0.0%
CA0078671	EL DORADO HILLS WWTP	05/03/05	Effluent (Mun-WW)	95.3%	100.7%	5.5%
CA0078671	EL DORADO HILLS WWTP	01/04/05	Effluent (Mun-WW)	87.1%	92.3%	5.8%
CA0083682	FRENCH CAMP GOLF & RV PARK WWTP	08/17/04	Effluent (Mun-WW)	96.7%	98.0%	1.3%
CA0081434	GALT WWTP	11/02/04	Effluent (Mun-WW)	99.8%	117.0%	15.9%
CA0079898	GRASS VALLEY WWTP	06/02/05	Effluent (Mun-WW)	107.8%	105.6%	2.1%
CA0079898	GRASS VALLEY WWTP	08/26/04	Effluent (Mun-WW)	118.4%	109.3%	8.0%
CA0078956	HANGTOWN CREEK WWTP	07/27/05	Effluent (Mun-WW)	91.9%	93.8%	2.0%
CA0078956	HANGTOWN CREEK WWTP	08/18/04	Effluent (Mun-WW)	92.6%	107.7%	15.1%
CA0079391	JACKSON WWTP	09/14/04	Effluent (Mun-WW)	111.5%	112.3%	0.7%
CA0077852	LAKE CALIFORNIA WWTP	03/15/05	Effluent (Mun-WW)	102.1%	110.8%	8.2%
CA0081612	LAKE OF THE PINES WWTP	11/04/04	Effluent (Mun-WW)	97.4%	93.8%	3.8%
CA0077828	LAKE WILDWOOD WWTP	08/30/04	Effluent (Mun-WW)	106.0%	106.0%	0.0%
CA0077828	LAKE WILDWOOD WWTP	05/18/05	Effluent (Mun-WW)	100.0%	97.6%	2.4%
CA0084476	LINCOLN WWTP	10/20/05	Effluent (Mun-WW)	106.4%	106.5%	0.1%
CA0084476	LINCOLN WWTP	02/08/05	Effluent (Mun-WW)	103.8%	107.0%	3.0%
CA0079430	MARIPOSA WWTP	09/22/04	Effluent (Mun-WW)	106.0%	108.3%	2.4%
CA0079987	MAXWELL PUD WWTP	08/26/04	Effluent (Mun-WW)	79.8%	69.2%	14.2%
CA0079901	NEVADA CITY WWTP	08/30/04	Effluent (Mun-WW)	91.5%	104.0%	12.8%
CA0077836	OLIVEHURST WWTP	12/13/04	Effluent (Mun-WW)	80.7%	92.2%	13.3%
CA0077836	OLIVEHURST WWTP	08/23/04	Effluent (Mun-WW)	103.8%	89.3%	15.0%
CA0079235	OROVILLE WWTP	09/13/04	Effluent (Mun-WW)	97.70%	102.60%	4.9%
CA0079235	OROVILLE WWTP	10/18/04	Effluent (Mun-WW)	91.90%	99.70%	8.1%
CA0079316	PLACER CO SMD NO 1	09/01/04	Effluent (Mun-WW)	108.0%	103.7%	4.1%
CA0079316	PLACER CO SMD NO 1	10/06/04	Effluent (Mun-WW)	103.3%	96.5%	6.8%
CA0079367	PLACER CO SMD NO 3	08/25/04	Effluent (Mun-WW)	90.5%	87.8%	3.0%
CA0079367	PLACER CO SMD NO 3	09/01/04	Effluent (Mun-WW)	101.9%	108.9%	6.6%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0078950	PLANANDA CSD WWTP	12/13/04	Effluent (Mun-WW)	99.0%	107.0%	7.8%
CA0078891	RED BLUFF WWTP	02/09/05	Effluent (Mun-WW)	97.6%	97.9%	0.3%
CA0078891	RED BLUFF WWTP	09/16/04	Effluent (Mun-WW)	116.2%	113.1%	2.7%
CA0079588	RIO VISTA WWTP	04/25/05	Effluent (Mun-WW)	87.9%	86.7%	1.4%
CA0079588	RIO VISTA WWTP	08/18/04	Effluent (Mun-WW)	136.6%	109.1%	22.4%
CA0079464	SAN ANDREAS WWTP	12/29/04	Effluent (Mun-WW)	103.5%	101.9%	1.6%
CA0082848	SAN JOAQUIN CO DPW - FLAG CITY WWTP	04/21/05	Effluent (Mun-WW)	87.9%	86.7%	1.4%
CA0079511	SHASTA LAKE WWTP	11/12/04	Effluent (Mun-WW)	119.1%	111.3%	6.8%
CA0004758	SMUD RANCHO SECO NUCLEAR GEN STA 1	08/04/04	Effluent (Mun-WW)	93.6%	89.9%	4.0%
CA0082589	STILLWATER WWTP	06/09/05	Effluent (Mun-WW)	95.5%	95.5%	0.0%
CA0082589	STILLWATER WWTP	09/08/04	Effluent (Mun-WW)	129.8%	117.7%	9.8%
CA0079138	STOCKTON WWTP	11/10/04	Effluent (Mun-WW)	120.50%	120.10%	0.3%
CA0079138	STOCKTON WWTP	08/18/04	Effluent (Mun-WW)	99.70%	95.10%	4.7%
CA0079154	TRACY WWTP	10/06/04	Effluent (Mun-WW)	108.30%	106.90%	1.3%
CA0079154	TRACY WWTP	08/19/04	Effluent (Mun-WW)	48.30%	49.60%	2.7%
CA0079154	TRACY WWTP	06/22/05	Effluent (Mun-WW)	109.90%	115.40%	4.9%
CA0079154	TRACY WWTP	07/13/05	Effluent (Mun-WW)	90.70%	75.20%	18.7%
CA0078948	TURLOCK WWTP	08/23/04	Effluent (Mun-WW)	74.5%	75.5%	1.3%
CA0078794	WALNUT GROVE WWTP	04/06/05	Effluent (Mun-WW)	102.5%	110.0%	7.1%
CA0077933	WILLIAMS WWTP	08/25/04	Effluent (Mun-WW)	82.0%	122.0%	39.2%
CA0077950	WOODLAND WWTP	03/07/05	Effluent (Mun-WW)	104.1%	98.7%	5.3%
CA0077950	WOODLAND WWTP	08/11/04	Effluent (Mun-WW)	86.8%	100.5%	14.6%
CA0079260	YUBA CITY WWTP	08/24/04	Effluent (Mun-WW)	101.8%	111.7%	7.5%
CA0079260	YUBA CITY WWTP	11/22/04	Effluent (Mun-WW)	98.70%	97.40%	1.3%
CA0079260	YUBA CITY WWTP	05/26/05	Effluent (Mun-WW)	106.50%	93.90%	12.6%
CA0083968	CALAMCO - STOCKTON TERMINAL	08/26/04	Influent	102.6%	104.0%	1.4%
CA0081752	CALAVERAS TROUT FARM, INC TROUT REARING FAC.	09/30/04	Influent	113.6%	106.3%	6.6%
CA0004561	DFG DARRAH SPRINGS HATCHERY	09/15/04	Influent	100.5%	102.9%	2.4%

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NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0004561	DFG DARRAH SPRINGS HATCHERY	09/14/04	Influent	111.9%	114.9%	2.6%
CA0004812	DFG SAN JOAQUIN FISH HATCHERY	09/28/04	Influent	108.8%	111.9%	2.8%
CA0082309	GWF POWER SYSTEMS, SITE IV	05/05/05	Influent	99.6%	93.4%	6.4%
CA0004316	PROCTER & GAMBLE CO WWTP	11/01/04	Influent	108.6%	106.6%	1.9%
CA0004316	PROCTER & GAMBLE CO WWTP	02/16/05	Influent	94.2%	99.3%	5.3%
CA0079197	ATWATER WWTP	09/28/04	Influent (Mun-WW)	37.90%	53.10%	33.4%
CA0079081	CHICO REGIONAL WWTP	09/07/04	Influent (Mun-WW)	113.80%	106.10%	7.0%
CA0078999	COLUSA WWTP	08/26/04	Influent (Mun-WW)	39.8%	33.6%	5.3%
CA0078662	DEER CREEK WWTP	08/02/05	Influent (Mun-WW)	125.0%	118.6%	5.3%
CA0079898	GRASS VALLEY WWTP	05/05/05	Influent (Mun-WW)	108.8%	115.0%	5.5%
CA0079898	GRASS VALLEY WWTP	12/02/04	Influent (Mun-WW)	129.5%	101.3%	24.4%
CA0079898	GRASS VALLEY WWTP	08/26/04	Influent (Mun-WW)	63.5%	44.9%	34.3%
CA0079430	MARIPOSA WWTP	09/22/04	Influent (Mun-WW)	104.2%	104.8%	0.0%
CA0079987	MAXWELL PUD WWTP	08/26/04	Influent (Mun-WW)	87.0%	98.5%	12.4%
CA0079901	NEVADA CITY WWTP	08/30/04	Influent (Mun-WW)	44.6%	31.7%	33.8%
CA0079901	NEVADA CITY WWTP	06/02/05	Influent (Mun-WW)	113.2%	79.6%	34.9%
CA0079588	RIO VISTA WWTP	08/18/04	Influent (Mun-WW)	94.5%	90.7%	4.1%
CA0077933	WILLIAMS WWTP	08/25/04	Influent (Mun-WW)	33.4%	23.2%	36.0%
CA0077933	WILLIAMS WWTP	03/01/05	Influent (Mun-WW)	132.9%	84.2%	44.9%
CA0077950	WOODLAND WWTP	02/09/05	Influent (Mun-WW)	98.2%	95.7%	2.6%
CA0077950	WOODLAND WWTP	09/20/04	Influent (Mun-WW)	83.4%	85.7%	2.7%
CA0077950	WOODLAND WWTP	10/14/04	Influent (Mun-WW)	92.0%	99.8%	8.1%
CA0079197	ATWATER WWTP	09/28/04	Receiving Water	109.70%	107.10%	2.4%
CA0083721	BELL CARTER INDUSTRIAL WWTP	12/15/04	Receiving Water	116.4%	116.3%	0.1%
CA0083721	BELL CARTER INDUSTRIAL WWTP	03/02/05	Receiving Water	129.1%	133.3%	3.2%
CA0079081	CHICO REGIONAL WWTP	09/07/04	Receiving Water	95.60%	102.50%	7.0%
CA0079081	CHICO REGIONAL WWTP	01/18/05	Receiving Water	89.70%	98.20%	9.0%
CA0077691	EASTERLY WWTP	05/10/05	Receiving Water	109.0%	107.0%	1.9%

Table C.1: Summary of Matrix Spike and Matrix Spike Duplicate Recoveries and Relative Percent Differences

NPDES NUMBER	FACILITY	DATE	MATRIX [a]	MS % RECOVERY	MSD % RECOVERY	RPD
CA0077691	EASTERLY WWTP	12/09/04	Receiving Water	105.0%	109.0%	3.7%
CA0077691	EASTERLY WWTP	01/11/05	Receiving Water	94.9%	88.5%	7.0%
CA0077691	EASTERLY WWTP	12/07/04	Receiving Water	97.2%	108.5%	11.0%
CA0004146	HERSHEY CHOCOLATE USA, OAKDALE	10/12/04	Receiving Water	105.5%	111.9%	5.9%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	12/08/04	Receiving Water	114.0%	116.3%	2.0%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	10/19/04	Receiving Water	105.5%	111.9%	5.9%
CA0081191	LEHIGH SOUTHWEST CEMENT CO	10/19/04	Receiving Water	117.5%	103.8%	12.4%
CA0079430	MARIPOSA WWTP	09/22/04	Receiving Water	110.3%	114.3%	3.4%
CA0079901	NEVADA CITY WWTP	08/30/04	Receiving Water	85.5%	83.5%	2.4%
CA0004821	PACTIV MOLDED PULP MILL	05/04/05	Receiving Water	118.0%	116.8%	1.0%
CA0004821	PACTIV MOLDED PULP MILL	09/16/04	Receiving Water	110.6%	116.8%	5.5%
CA0079316	PLACER CO SMD NO 1	08/05/04	Receiving Water	97.8%	106.1%	8.1%
CA0083569	PROCTOR & GAMBLE COGEN. PLANT	08/11/04	Receiving Water	98.8%	95.1%	3.8%
CA0081400	SIERRA PACIFIC, SHASTA LAKE DV	03/23/05	Receiving Water	100.0%	99.6%	0.4%
CA0081400	SIERRA PACIFIC, SHASTA LAKE DV	03/23/05	Receiving Water	88.9%	103.8%	15.5%
CA0081400	SIERRA PACIFIC, SHASTA LAKE DV	12/30/04	Receiving Water	110.6%	94.1%	16.1%
CA0084140	SWA AT MOUNTAIN GATE	10/19/04	Receiving Water	116.9%	115.6%	1.1%
CA0079154	TRACY WWTP	04/11/05	Receiving Water	104.20%	100.70%	3.4%
CA0079154	TRACY WWTP	08/25/05	Receiving Water	97.10%	93.50%	3.8%
CA0078948	TURLOCK WWTP	08/23/04	Receiving Water	13.3%	12.3%	7.8%
CA0078948	TURLOCK WWTP	08/23/04	Receiving Water	103.0%	83.5%	20.9%
CA0084182	UC DAVIS HYDRAULICS LABORATORY	09/22/04	Receiving Water	116.5%	127.4%	8.9%
CA0083348	UCDAVIS AQUATIC CENTER/ANIMAL SCIENCE	09/22/04	Receiving Water	116.5%	127.4%	8.9%
CA0077933	WILLIAMS WWTP	08/25/04	Receiving Water	90.5%	86.5%	4.5%
CA0077950	WOODLAND WWTP	11/09/04	Receiving Water	93.3%	93.6%	0.3%
CA0079260	YUBA CITY WWTP	10/12/04	Receiving Water	86%	99.40%	14.5%

[a] Effluent and influent data for municipal WWTPs is annotated with "(Mun-WW)".
[b] The Manteca Aggregate Sand Plant is now known as Oakwood Lake Subdivision Mining Reclamation.

APPENDIX D
COMMENTS AND RESPONSES SUBMITTED DURING THE ADMINISTRATIVE DRAFT REVIEW AND PUBLIC DRAFT REVIEW

Following are comments submitted during the Administrative Draft Report and Public Draft Report reviews and staff responses. Comments are in **bold** and staff responses are in plain text.

1. Mike Paulucci (Laboratory Manager), City of Yuba City Utilities Department, Yuba City WWTP (CA0079260) – E-mail dated December 15, 2008

2. William T. Aravanis PE REA (Senior Engineer) and Paul C. Deutsch (Principal Scientist), General Electric Company, Former Kendall Site, Merced, California (CA0081833) – Letter dated December 22, 2008

3. Art O' Brien PE (Wastewater Utility Manager), City of Roseville, Roseville Pleasant Grove and Dry Creek WWTPs (CA0084573 and CA0079502) – Letter dated January 14, 2009

4. Linda Dorn (Business Citizen's Assistant), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) – Letter dated January 15, 2009

5. Lysa Voight PE (Senior Civil Engineer), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) – Letter dated March 18, 2009

6. Airy Krich-Brinton, Larry Walker Associates – Email dated June 11, 2009

7. Lysa Voight PE (Senior Civil Engineer), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) – Letter dated 15 June 2009

1. Mike Paulucci (Laboratory Manager), City of Yuba City Utilities Department, Yuba City WWTP (CA0079260) – Letter dated December 15, 2008

Table 11 on page 52 is missing the Field Duplicate data from our August 2004 sample event. I have attached a copy of the laboratory report. The table should include for the City's August 24, 2004 sample event a duplicate 1 value of 0.036 ng/L and duplicate 2 value of 0.038 ng/L (RPD 5.4%). Yuba City did not conduct field duplicates for September 2004 as properly noted in Table 11.

Table 11 on page 52 also lists both values for the July 5, 2005 sample event as 0.025 ng/L; however, the values should indicate that both sample were not detected at a reporting limit (RL) of 0.025 ng/L or"<0.025 ng/L".

Table 15 on page 62 lists Yuba City's discharge flow as 5.50 MGD. The flow for the sample dates is 5.22 MGD.

Table 19 on page 70 lists Yuba City's discharge flow as 5.50 MGD. The flow for the sample dates is 5.22 MGD.

Table C.1 on page 183 indicates Yuba City collected an influent sample on July 5, 2005. The City did not collect any influent methylmercury samples for this study as influent samples were voluntary as listed in the 13267 Order. The data listed in Table C.1 is from a sample location not related to the methylmercury study and should be removed.

R-1: Staff incorporated all of the corrections into the report.

2. William T. Aravanis PE REA (Senior Engineer) and Paul C. Deutsch (Principal Scientist), General Electric Company, Former Kendall Site, Merced, California (CA0081833) – Letter dated December 22, 2008

Table A.1 includes data for the National Pollutant Discharge Elimination System (NPDES) number CA0083739. That NPDES number was discontinued when NPDES number CA0081833 was issued in July 2004 with provisions to include discharges originally permitted under NPDES number CA0083739. The first round of methylmercury samples were collected in October 2004. Consequently, samples included in the December 2008 letter were not collected subject to NPDES number CA0083739 and reference to this NPDES number should be removed from Table A.1.

R-2: Staff removed the record of the NPDES # CA0083739 from Table A.1, since at the time the 13267 letter was sent, discharges originally covered under permit CA0083739 were included under the permit CA0081833.

Tables B.1 through B.4 contain footnotes (footnotes m, f, g, and c of tables B.1, B.2, B.3, and B.4, respectively)describing reasons that results of samples collected from the site on October 8, 2004, were not included in the tables. These footnotes indicate the samples were contaminated at the laboratory and that hold times were exceeded. However, the footnotes do not clearly indicate that the location where the hold time was exceeded was at the laboratory. For example, footnote m of table B.1 says "However, results for samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times exceeding EPA recommendations." GE requests that the RWQCB revise

the footnote to read "However, results for samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations for reanalyzing the samples." This change in wording would remove any ambiguity concerning where the samples were located when hold times were exceeded.

R-3: After looking at the Semiannual Monitoring Report sent on 21 February 2005, it does not appear that Brooks Rand was able to reanalyze the contaminated samples after the GE request because the remaining sample was contaminated as well. Therefore, staff revised the footnotes in Tables B.1 through B.4 to state: "However, results for samples collected on 8 October 2004 were not incorporated in the calculations due to sample contamination with mercury in the laboratory and preservation hold times at the laboratory exceeding EPA recommendations."

3. Art O' Brien PE (Wastewater Utility Manager), City of Roseville, Roseville Pleasant Grove and Dry Creek WWTPs (CA0084573 and CA0079502) – Letter dated January 14, 2009

Thank you for the opportunity to comment on the subject report. The comments are outlined below:

1. Page 26, 2nd full paragraph: "The denitrification process involves anaerobic bacteria converting nitrate to nitrogen gas with the help of methanol (Metcalf and Eddy, Inc., 1972)." This is likely an incorrect reference quote. First, at our WWTPs, the anoxic bacteria convert the nitrate to nitrogen gas. Second, not all WWTPs use methanol as the carbon source for the denitrification process. We do not add methanol as a carbon source. Third, a carbon source is only needed when the denitrification process follows the nitrification process. This sentence should be changed to: "The denitrification process involves anoxic bacteria converting nitrate to nitrogen gas with the help of a carbon source such as methanol (Metcalf and Eddy, Inc., 1972)."

R-4: Staff agrees with the suggested sentence change and modified the sentence in the report accordingly.

2. Table 19 (page 69): PGWWTP should have box 15 and 19 marked off
DCWWTP should have box 15 marked off

R-5: Staff made the suggested changes in Table 19. The Roseville Pleasant Grove WWTP was already placed in the "N/D + Filtration + Chlor./ Dechlor." treatment category, so the effluent methylmercury analysis for the various categories did not need to be redone.

3. Some of the data and statistical analyses do not support the conclusions:

- **Section 4.2.5, pg 30, 2nd full paragraph: the authors conclude there is a "significant positive relationship (R^2=0.1347, Figure 28a and R^2=0.0715, Figure 28b)" between influent methylmercury and effluent methylmercury. The authors go on to state: "These significant relationships indicate that reductions in methylmercury in the effluent were in part due to lower influent concentrations." This conclusion is not supported by the statistical analysis. The extremely low R^2 value would draw the exact opposite conclusion. R^2 is the square of the correlation coefficient or coefficient of determination. This statistical method is a good way of evaluating the strength of the relationship**

between 2 variables and is measure between 0 and 1. When R^2=1, there is a very strong relationship, conversely when R^2=0, a weak relationship exists. Therefore, it appears that these data demonstrates a very weak relationship at best.

R-6: Staff agrees that there is a weak relationship between influent methylmercury and effluent methylmercury indicated by the low R^2 values (square of the correlation coefficient). R^2 is the proportion of the variance of "variable y" that can be explained by the "variable x". Staff discussed this in the last sentence of the 2nd full paragraph on page 30: "…7-13% of the variability in effluent methylmercury concentrations was explained by influent concentrations, indicating that effluent concentrations were affected by other factors as well." Even though both of the relationships shown in Figures 28a and 28b have low R^2 values, they are statistically significant with p-values (two-sided levels of significance) less than 0.0001 using the one-sample t-test for the correlation coefficient (R). Typically, p-values less than 0.05 are considered statistically significant. The reason that the relationships have low R^2 values and are still significant is in part due to the large number of paired data points in each relationship. Figure 28a, which is the scatter plot of all paired data from all WWTPs excluding SRCSD Sacramento River WWTP, has 131 paired data points. Figure 28b, which includes the SRCSD Sacramento River WWTP paired data, has 238.

- **Section 4.2.6, pages 31 and 32: the authors draw the same "significant positive relationship" conclusion as was done in section 4.2.5. These data, again, resulted in extremely low R^2 values indicating that there is very low correlation between effluent methylmercury and effluent total mercury.**

R-7: Staff agrees that the relationships referred to in this comment are weakly correlated. However, all of these relationships have p-values less than 0.01 using the one-sample t-test for the correlation coefficient (R), which indicates statistical significance. See comment R-6 for further explanation.

- **Section 4.2.7, 3rd paragraph, page 32 and Section 4.2.8, 3rd paragraph, page 33: the authors conclude that there is no relationship between effluent methylmercury and influent total mercury. However, no statistical analysis (i.e. R^2 values) is presented that support these conclusions.**

R-8: Staff added the R^2 values and p-values to the text in the report referring to these relationships. All of the effluent methylmercury vs. influent inorganic Mercury and effluent vs. influent inorganic Mercury relationships had p-values greater than 0.05, indicating no statistical significance.

4. General observations:

- **The authors appear to work very hard at trying to draw statistically "significant" conclusions from this data using statistical modeling. This leaves the impression they are trying to make the data support a preconceived conclusion. Based on the data and the statistical analysis performed, the only conclusions that can be drawn are:**

    1. **Low levels of methylmercury exist in some WWTP's influent and effluent; however, a relationship can not be drawn.**

    2. **Low levels of total methylmercury exist in some WWTP's influent and effluent. Removal efficiencies can be determined.**

3. **The type of WWTP treatment process may influence the removal efficiency.**

4. **Seasonality may or may not play a role in methylmercury concentrations.**

R-9: One of the questions the Central Valley Water Board (Board) staff posed and analyzed in this report was: "Does a relationship exist between WWTP treatment processes and effluent methylmercury concentrations? Do WWTPs with a particular treatment process have higher effluent concentrations than WWTPs with other treatment processes?" In order to answer these questions, staff developed 10 mutually exclusive treatment categories based on secondary, tertiary and disinfectant treatment types. Pond and nitrification/denitrification treatments were considered separately from other types of secondary treatment types because they are significantly different from other treatments and could have an effect on effluent methylmercury concentrations. The categories were internally reviewed and verified by multiple Board engineers in the NPDES permitting unit who are very knowledgeable about WWTP treatment processes. Each WWTP that submitted effluent methylmercury data was assigned to one of these 10 categories and the data for all of the WWTPs in each category were grouped together for the analysis. Differences between the treatment categories were analyzed using a nonparametric multiple comparison procedure and the results were presented in the report. Staff allowed for the robust statistical test used to conclude the differences between the treatment categories and did not bias the test and results in any way. A similar procedure was used to compare effluent:influent methylmercury ratios, effluent inorganic Mercury:methylmercury ratios and the 3 secondary subcategories within the "Secondary + C/D" and "Filtration + C/D" categories.

- **The last paragraph of the report is of great concern (pg 38, 39): "additional monitoring studies and pilot projects". To require municipalities, under the auspices of AB13267, to provide personnel and funding to support this massive data acquisition could be problematic. Due to the limited resources and reduced budgets we are operating under, it would present real challenges to support this project both financially and from a personnel standpoint. Sampling for these constituents and performing the associated analyses is very expensive.**

R-10: The full paragraph (pg 38, 39) is: "Several Central Valley WWTP staff and consultants have noted that it would be very helpful to establish a working group that coordinates efforts between CVCWA, San Francisco Bay area facilities, and other regional efforts to develop more detailed analyses of the existing information, further evaluate treatment processes, and design additional monitoring studies and pilot projects. Board staff is supportive of this concept and will work with dischargers and working groups to design and review studies." Board staff appreciates the financial and personnel challenges of conducting additional studies and pilot projects. It is possible that this report's results may be used to support additional studies during the implementation phase of the Delta mercury control program and other upstream mercury control programs. As noted in the February 2008 draft Basin Plan amendment staff report[1] and in later responses to public comments,[2] Board staff recommends that, during the implementation phase of the Delta mercury control program, entities responsible for point and nonpoint sources conduct collaborative and coordinated control studies. During the time of this report, Board staff has been working with stakeholders to develop an efficient and cost effective mercury control program.

[1] Available at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/staff_report_feb08/index.shtml

[2] Available at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/stakeholder_meetings/25nov08_hearing_rtc.pdf

- **Our overarching concern is that further study and/or further regulation of WWTPs regarding methylmercury will not reduce the concentrations of mercury in fish tissue. It is important to provide a clear conclusion on this point in this report. As research has shown, and the authors actually cite in the second sentence of the Executive Summary, methylmercury only accounts for 1% of all mercury discharged to the Delta. Therefore removing 100% of the 1% isn't even statistically significant and wouldn't begin to address the problem. Also it should be noted, that all the WWTPs that discharge to the Delta account for less than 2% of the total mercury in the Delta. Again if 100% of the 2% were removed, no significant impact in reducing the mercury in the Delta would be realized.**

R-11: Of the approximately 400 kg inorganic Mercury that enters the Delta each year, about 2.2 kg is methylmercury. Although methylmercury is less than 1% of all mercury discharged to the Delta, methylmercury is the form that accumulates in the food web. If there were no methylmercury in Delta waters (i.e., if the 1% of all mercury discharged to the Delta that is in the form of methylmercury were demethylated), there would be no fish impairment.

The best available science indicates that reducing methylmercury in ambient water is the most direct way to reduce methylmercury in biota. Methylmercury is produced by many modern-day activities that humans may be able to modify so that less methylmercury is discharged. The Delta control program could focus on reducing methylmercury sources by reducing the inorganic mercury that supplies the methylation sites (i.e., reduce the inorganic mercury levels in Delta sediments by reducing discharges from mine sites and other legacy and modern sources) and by managing the methylation sources themselves to reduce methylmercury discharges. As part of their recommendations for a Delta mercury control program, Board staff recommended that WWTPs, MS4s, wetlands, irrigated agriculture, and new water management activities evaluate and develop management practices to reduce their methylmercury loads, such that each takes responsibility for its contribution to the impairment. As noted earlier, staff does not recommend that every individual NPDES, MS4, and agricultural and wetland landowner individually conduct a study, but instead recommends coordinated studies.

The stakeholder process for the Delta mercury control program will be developing an adaptive management approach to address the methylmercury impairment. Without the completion of point and nonpoint methylmercury control studies, it is not yet possible to define which sources are "important" or "insignificant" or which are feasible or make sense to control. When discussing the importance of different sources, many stakeholders have focused on the amount of loading by source category and by individual discharge. However, there are additional factors that should be considered. Given the number of individual discharges there are in each source category in the Delta, almost all of the individual discharges are small. Although the tributary inputs are substantial, available information indicates that they also contain a similar distribution of individual discharges. As determined as early as 1997 in the Sacramento River Mercury Control Planning Project report prepared for SRCSD by Larry Walker Associates, "… mercury sources in the study area appear to be diffusely distributed without any significant "hotspots" …" (LWA, 1997, page 31). Examples of small discharges include most wastewater treatment plants (which comprise about 4% of methylmercury inputs to the Delta), individual farm fields, and wetlands where water flow is managed in discrete units. It is the sum of all of the individual discharges (point and non-point) in the Delta and its tributary watersheds that impairs the Delta. The "importance" or "insignificance" of different methylmercury and inorganic Mercury sources could be defined by: (a) their load, (b) their distance from an impaired area, (c) how big of a reduction is needed to achieve safe fish mercury levels in a given impaired area, (d) whether they can be controlled, (e) whether they can be controlled without impacting habitat or operational function, (f) the cost to control them, and (g) the resources available to the

responsible parties to implement controls. It is conceivable that the control program for the Delta will need to focus on just a few large projects in some watersheds, but many small projects in other watersheds, to reduce methylmercury levels throughout the Delta.

Please refer to the February 2008 draft Basin Plan amendment and Delta TMDL staff reports[3] and the follow-up document, "Staff's Initial Responses to Board and Stakeholder Questions and Comments at the April 2008 Hearing"[4], for additional discussion on this topic.

4. Linda Dorn (Business Citizen's Assistant), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) – Letter dated January 15, 2009

SRCSD submitted two letters (attached), which included three lab reports, to the RWQCB within the required monitoring period. The three sampling dates are: 12/29/2004, 1/20/2005, and 4/6/2005. The data presented in the report only includes two sampling results rather than the three submitted. The sample result for 12/29/04 is missing. Including this result will decrease the average effluent methylmercury concentration from 2.16 ng/L to 1.69 ng/L. The average methylmercury concentration in discharge is presented in Tables 18 and 19 of the administrative draft of the staff report.

R-12: The sample collected on 29 December 2004 was excluded from calculations made in the report because the hold time between collection and preservation exceeded 60 hours. This is consistent with all other samples that exceeded 60 hours hold times. The effluent sample collected on 29 December 2004 arrived at Frontier Geosciences on 3 January 2005 and was preserved with acid upon receipt. This is approximately 120 hours between collection and preservation. USEPA Method 1630 (methylmercury analysis in water) requires samples to be preserved with acid within 48 hours to a pH of less than two. Acid preservation stops the bacterial activity in the water that produces methylmercury from inorganic mercury. Samples without preservation may not be representative of the conditions at the time of sampling if bacterial activity continues after sampling. Therefore, staff excluded data for all samples whose hold times exceeded 60 hours.

5. Lysa Voight PE (Senior Civil Engineer), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) - Letter dated March 18, 2009

Page 116, Figure 25 and Page 122 Figure 29B: SRCSD requests that a note be added to the figures indicating that three points of data were provided, but only two were used in this report for the SRCSD Walnut Grove WWTP. This might also be explained in section 3.6 anomalous values. A suggested wording for the footnote is: "Three data points were provided, but only two data points were used. The third data point was not considered in this report due to receipt of the

[3] Available at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/staff_report_feb08/index.shtml

[4] Available at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/stakeholder_meetings/25nov08_hearing_rtc.pdf

sample beyond the 48 hour holding period at an elevated temperature as noted on the lab's transmittal memo."

R-13: Staff added a new table (Table 11) to the report to provide the methylmercury data that were excluded from the report's calculations due to quality control concerns (e.g., hold time exceedances greater than 60 hours and laboratory contamination). This table includes the effluent sample collected at SRCSD Walnut Grove WWTP on 29 December 2004. Section 3.2 (page 13) in the revised report refers to Table 11. Samples that do not meet quality control requirements may not be representative of the conditions at the time of sampling. Therefore, including excluded data in calculations could be misleading.

P.22: The statement "Municipal WWTPs may contribute significant methylmercury loads to receiving water" perpetuates the misperception that WWTPs are major sources of the total methylmercury to the river. This report and its analysis are focused on NPDES permit holders which are a small portion of the total and methylmercury loading. All loads to receiving water are not compared in this report so care should be used when referencing whether or not WWTP loading is significant. A more appropriate statement that SRCSD suggests is: "Municipal WWTPs appear to contribute a greater methylmercury load to receiving water when compared to the other permitted sources investigated in this report but are a small fraction of the total and methylmercury load in the Sacramento River and the Delta."

R-14: Staff edited the beginning of Section 4.2.

P.29-30: The paired influent-effluent samples should be qualified more by mention of the following note that SRCSD recommends adding to the second paragraph of page 30: "The paired samples do not necessarily represent the same parcels of water due to in-plant residence time."

R-15: Staff added the suggested text to the report.

P.38: An additional question that might be addressed by future analysis is suggested as follows: "Do other factors impact reported concentrations, such as sampling protocols including location, time of day, holding time, composite vs. grab samples?"

R-16: Staff added the suggested text to the report.

Executive Summary: SRCSD suggests that the following comment be added to the executive summary so that readers understand the relationship between discharge and receiving waters: "The concentration of mercury and methylmercury in waters is dynamic. Mercury methylates and demethylates as a function of several factors including the characteristics of the effluent stream and the characteristics of the receiving waters. The mercury/methylmercury inter-relationships are currently being studied by various stakeholders but are not fully understood at the time of the completion of this report."

R-17: Staff edited the Executive Summary.

6. Airy Krich-Brinton, Larry Walker Associates – Email dated June 11, 2009 sent to Michelle Wood (Environmental Scientist, Central Valley Water Board)

I have been using the data file you sent and checking the statistical calculations shown in the methyl mercury report, and I have a question. In Table 24 (and similar tables), the title indicates that a Kruskal-Wallis Multiple Comparison was performed on median values. However, that test only produces a single p-value, and the table is populated with multiple p-values, one for each

treatment category pair. Can you explain further how those p-values were calculated? The footnote states that they are two-sided significance levels multiplied by 36, but it does not tell how the significance levels are determined (what test was used). Can you help me find out which test was used to calculate the p-values in tables like Table 24?

R-18: Table 24 and similar tables report the p-values for the Kruskal-Wallis Multiple Comparison test run in the Statistica software. Basically, you run a Kruskal Wallis test and if you find that there are significant differences between medians then you have to run a multiple comparison test to identify which medians are responsible for the statistical difference. The documentation from Statistica (see attached) is the best way to determine the type of multiple comparison test used. Most likely it is a Dunn's comparison procedure. With Statistica you can set the test for a default p value. We used a traditional value of $p < 0.05$ as the cut off. However, the program will give you actual p-values, which is what we reported. Also, Table 24 and similar tables report two p-values for each pair comparison, which are actually identical when looking closely. We set the table up this way to make it easier to identify the p-values for a particular pair of treatment categories. [Response provided in a 12 June 2009 email.]

7. Lysa Voight PE (Senior Civil Engineer), Sacramento Regional County Sanitation District, Sacramento River and Walnut Grove WWTPs (CA0077682 and CA0078794) – Letter dated June 15, 2009

Thank you for the opportunity to review the final version of the subject document and for taking into account our comments from the previous draft version of the document. The following comments are being provided by SRCSD to help put the report's findings in a context that is useful for policy and regulatory efforts such as the Delta Mercury TMDL.

In the Executive Summary and in the Introduction, the low aggregate contribution of methylmercury to the Delta by NPDES permitted facilities should be clearly stated. The report refers to the relative contributions from different NPDES permitted sources, but does not provide important information regarding the numerical or quantitative significance of the sum of the point sources in the Delta relative to the entire methylmercury impairment.

R-19: The Administrative and Public Review drafts of this report focused on a review of effluent methylmercury concentrations and did not attempt to calculate effluent methylmercury loads for the more than 100 facilities in the Central Valley. However, staff agrees that having load estimates will be useful for the Delta and upstream TMDL development efforts. To address SRCSD's comment, staff added a new chapter to the report (Chapter 5) that includes a method for calculating methylmercury loads discharged by NPDES facilities within the Delta and its upstream watersheds, and compares the sum of those loads to overall methylmercury loading to the Delta by watershed.

Page 22, Section 4.2: The report cites older data for the SRWTP and states that methylmercury loads as a percentage of receiving water loads "was as high as 30 to 43% during the warm seasons of 2001 and 2002". Page 91 of the report shows a graphical representation of the percentage of methylmercury in SRWTP discharge compared to the Sacramento River. The two points selected for discussion are not typical values for the stated time period. Many of the points reported for years 2000-2006 indicate the SRWTP contribution to methylmercury is under 10%.

R-20: The entire sentence in the report is, "For example, a six-year comparison of the SRCSD Sacramento River WWTP effluent methylmercury loads as a percentage of its receiving

water loads was as high as 30 to 43% during the warm seasons of 2001 and 2002 and less than 1% during the wet seasons of 2005 and 2006 (Figure 4; Bosworth, 2008), ranging from 4.2% to 17% on an annual basis." The purpose of the text is to highlight the range of conditions as well as typical conditions. Also, although the three high points mentioned in the text (30%, 31%, and 43%) are not typical values, they are not anomalously high, given that there were 14 other points that fell between 20% and 30%. No changes were made to the text.

In the absence of an actual conclusive analysis, a general statement regarding the ability to reduce methylmercury levels in water through point source controls is questionable.

R-21: Staff assumes that SRCSD is referring to the sentence that follows the above mentioned percent range, at the end of the last paragraph on Page 22 of the draft report: "For some receiving waters, reducing municipal WWTP methylmercury discharges, along with other point and nonpoint sources, may be an important component in reducing methylmercury levels in water." Staff was careful to include both point and nonpoint sources in this general sentence. Until the proposed Phase 1 control studies are conducted, we cannot know for certain which point and nonpoint sources can be feasibly and reasonably reduced. However, it seems reasonable to note that reducing municipal WWTP methylmercury discharges may be an important component, especially for individual water bodies that are dominated by effluent from municipal WWTPs or for which municipal WWTP discharges comprise a substantial source. For example, the Sacramento River is the largest river in California and drains a 27,000 square-mile area – almost one fifth of the State of California and about one half of the Central Valley – that contains numerous reservoirs and a myriad of point and nonpoint sources downstream of the reservoirs. As noted as early as 1997 in the Sacramento River Mercury Control Planning Project report prepared for SRCSD by Larry Walker Associates, "… mercury sources in the study area appear to be diffusely distributed without any significant "hotspots" …" (LWA, 1997, page 31). As a result, any individual discharge from a point or nonpoint source that provides a notable percentage (e.g., more than 1%) of methylmercury loading to the Sacramento River warrants evaluation.

It should be noted in the report that methylmercury is not strictly bioavailable mercury nor is it conservative.

R-22: Staff edited the Introduction to reflect that methylmercury is the most bioaccumulated form of mercury, rather than most bioavailable. In addition, staff added text to further describe degradation processes, as well as how in some waterways processes of methylmercury production and transport downstream in the water column are dominant and in others, processes that remove methylmercury from the water column such as photodegradation and sedimentation are dominant, and included the results of SRCSD's 2008 Localized Mercury Bioaccumulation Study.

The Water Environment Research Foundation (WERF) recently completed a study of mercury bioavailability discharged from conventional municipal wastewater treatment plants. The WERF research is part of the difficult process of understanding the relationship between total mercury methylmercury and bioavailable mercury, all of which should be considered when evaluating the TMDL.

R-23: Staff agrees and, in response to this comment, staff added the following text to Chapter 6: "… at the time this report was receiving final review, reports for Phases 1 and 2 of the WERF-funded project, "Estimation of Mercury Bioaccumulation Potential from Wastewater

Treatment Plants in Receiving Waters", were released (Dean and Mason, 2009a and 2009b). This project assessed changes in mercury bioavailability in wastewater effluents and receiving waters and developed a guidance document for wastewater treatment professionals who want to assess the bioavailability of mercury in their wastewater, compare it to other point and nonpoint sources, and assess changes in bioavailability in their effluent when it is mixed in a receiving water body. The Phase 1 and 2 reports should be considered by future wastewater analyses and control studies, as well as when the Delta mercury TMDL control program goes through future reviews."

SRCSD previously commented with an objection to the use of the term "significant positive relationship" between paired influent and effluent data with low R^2 values (low model reliability). The Regional Board responded by stating that the low p-values associated with the results allow this term. While it is correct to say that a low p-value indicates statistical significance, the low R-values indicate that the fit of the model cannot be trusted more than "R-value" percent of the time. Thus, the model is not a good predictor on an individual basis.

R-24: Staff assumes that SRCSD is referring to the comment made by Art O' Brien (Wastewater Utility Manager, City of Roseville), and staff's response regarding how paired influent/effluent data with low R^2 values can have low p-values, indicating statistical significance (staff response R-6, page 192 in this appendix). As noted in staff's response, staff agrees that there is a weak relationship between influent methylmercury and effluent methylmercury indicated by the low R^2 values, and further that influent methylmercury concentration alone is not a good predictor of effluent methylmercury on an individual basis. This is why staff had included the following text in earlier drafts, "…7-13% of the variability in effluent methylmercury concentrations was explained by influent concentrations, indicating that effluent concentrations were affected by other factors as well." Staff added the word "substantially" ("were substantially affected") in attempt to more clearly indicate that staff is not stating that influent methylmercury alone is a good predictor, and carefully included similar text wherever low R^2 values were associated with paired data that also had low p values.

Our New Evolution in Wastewater Treatment

Regional San is undertaking a monumental effort—called the EchoWater Project—to take our region's wastewater treatment to a whole new level.

In 2010, Regional San was issued stringent new treatment requirements from the State of California that require us to make the most significant upgrade to our wastewater treatment plant since its original construction. This new system, which must be in place by 2021-2023, will produce cleaner water for discharge to the Sacramento River, as well as for potential reuse as recycled water (e.g., for landscape and agricultural irrigation).

We're calling this major upgrade the "EchoWater Project" to reflect how it will take our wastewater and return it to a clean, natural state—much like an "echo" returning to its original source.

The EchoWater Project is among the largest public works projects in Sacramento's history. When completed, it will keep Regional San in compliance with its regulatory permits and improve water quality by resulting in a nearly 95 percent reduction in ammonia discharged to the Sacramento-San Joaquin River Delta. Ultimately, EchoWater will be capable of meeting our region's needs and protecting our region's waterways for generations to come.

Construction Underway

The project is now in the construction phase—get current construction updates here.

Low-Interest Financing Approved

In early April, the project was approved to receive nearly $1.6 billion in low-interest financing from the State of California's Clean Water State Revolving Fund. The favorable loan terms will save ratepayers more than a half billion dollars in interest costs. Read more here.

This low-interest financing for the EchoWater Project has been provided in part by the Clean Water State Revolving Fund through an agreement with the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

EchoWater Fact Sheet

☐ View the Fact Sheet

Regulatory Permit Conditions

For all wastewater treatment plants, the level of treatment required before the water can be released back into the environment is dictated by a National Pollutant Discharge Elimination System (NPDES) permit. For Regional San, this wastewater discharge permit is issued by the Central Valley Regional Water Quality Control Board (Regional Water Board), the state agency that regulates wastewater dischargers in our region.

New Treatment Processes

Regional San's 2010 discharge permit contains strict mandates that require us to construct costly new "tertiary" treatment processes for ammonia and nitrate removal, filtration and enhanced disinfection:

Ammonia and nitrate removal: Using a process called "biological nutrient removal" (BNR), this will eliminate nearly all ammonia and most nitrate from the effluent (treated water), addressing concerns about possible impacts these constituents may have on the ecosystem, both here and downstream.

Impacts to Customer Rates

The requirements of our new discharge permit will cost our region's ratepayers about $1.5-2.1 billion to build. On top of that, about $50 million per year in ongoing maintenance and operations costs are anticipated.

Gradual annual rate increases to fund these improvements have already begun and will continue to be necessary until the project is completed in 2021-2023. For more information on the anticipated rate impacts of the EchoWater Project, please visit Monthly Rates.

On March 7, 2001, the State Water Resources Control Board (State Water Board) adopted a precedential decision on two refinery permits. The decision, in Order WQ 2001-06, addresses "interim permits." Interim permits are permits that regulate pollutant discharges to waters identified on the Clean Water Act section 303(d) impaired waters list prior to TMDL (total maximum daily load) development.

The two permits under review contained 10-year compliance schedules for impairing pollutants (except for dioxin and furan compounds). The schedules were based on the schedules for TMDL development. The permit findings stated that final water quality-based effluent limitations for these pollutants would be based on waste load allocations in the TMDLs. The permits also included alternative final limits findings, stating that if TMDLs were not available, final limits for bioaccumulative pollutants would be "no net loading" and for non-bioaccumulative pollutants would be the applicable criterion or water quality objective applied end-of-pipe. The permits also included interim, performance-based effluent limitations regulating both the mass and concentration of impairing pollutants.

On interim permitting, the State Water Board held:

- A Regional Water Quality Control Board (Regional Water Board) cannot rely solely on a Section 303(d) listing as the basis for concluding that a receiving water lacks assimilative capacity for an impairing pollutant. Rather, the Regional Water Board must base assimilative capacity determinations on the relevant water quality-related data. This includes the data supporting the 303(d) listing.

- Under the circumstances, the alternative final limits findings were unnecessary and inappropriate. The decision held that a finding stating that final effluent limitations for impairing pollutants will be based on the wasteload allocations in the TMDLs satisfied the Clean Water Act requirement for water quality-based effluent limitations. The alternative final limits findings were inappropriate because the discharges were considered insignificant to the impairment, the alternative final limits may be technically infeasible, TMDLs appeared to be the most appropriate method to address the problems, and development of TMDLs appeared to be on schedule. In addition, the decision held that the State Water Board's Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (2000) does not require alternative final limits findings for TMDL-based compliance schedules for priority pollutants.

- Interim, performance-based mass limits, in the context of a compliance schedule, are legal.

- Interim, performance-based mass limits for impairing pollutants that are discharged by industrial facilities at concentrations above the applicable criteria/objectives are a reasonable step to preserve the status quo pending TMDL development. The decision does not address interim mass limits for publicly owned treatment works (POTW) permits.
- Regional Water Boards should calculate interim, performance-based mass limits, by developing frequency distributions from available, representative data. The Regional Water Boards can select the percentiles or number of standard deviations, based on balancing the risk of a violation with the need to protect receiving water quality.

The decision also addressed other topics. These included the need for effluent limitations for pollutants not detected in the effluent, pollution prevention plans, antibacksliding, and a compliance schedule for dioxin and furan compounds. The decision held that it was inappropriate to include effluent limitations in permits for pollutants that were not detected in the effluent because all detection limits were above the applicable criteria or objectives, absent any additional information that the pollutants were expected to be present.

Regarding the Migden bill (Water Code § 13263.3), the decision held that permits could require that dischargers prepare pollution prevention plans but cannot require that they "implement" the plans. Additionally, it is inappropriate for permits to require these plans for the pollutants discussed in the preceding paragraph (i.e. pollutants not detected and not expected to be in the effluent).

On antibacksliding, the decision held that the proscription does not apply to interim limits in a compliance schedule.

The decision also held that the regional water quality control plan (basin plan) provision authorizing compliance schedules for new criteria or objectives could be interpreted to allow compliance schedules for new interpretations of existing objectives. One permit contained a 12-year compliance schedule for dioxin and furan compounds. The basin plan allowed compliance schedules of up to 10 years. Therefore, the compliance schedule length had to be revised.

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Critical Review

TOXICITY REFERENCE VALUES FOR METHYLMERCURY EFFECTS ON AVIAN REPRODUCTION: CRITICAL REVIEW AND ANALYSIS

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Abstract: Effects of mercury (Hg) on birds have been studied extensively and with increasing frequency in recent years. The authors conducted a comprehensive review of methylmercury (MeHg) effects on bird reproduction, evaluating laboratory and field studies in which observed effects could be attributed primarily to Hg. The review focuses on exposures via diet and maternal transfer in which observed effects (or lack thereof) were reported relative to Hg concentrations in diet, eggs, or adult blood. Applicable data were identified for 23 species. From this data set, the authors identified ranges of toxicity reference values suitable for risk-assessment applications. Typical ranges of Hg effect thresholds are approximately 0.2 mg/kg to >1.4 mg/kg in diet, 0.05 mg/kg/d to 0.5 mg/kg/d on a dose basis, 0.6 mg/kg to 2.7 mg/kg in eggs, and 2.1 mg/kg to >6.7 mg/kg in parental blood (all concentrations on a wet wt basis). For Hg in avian blood, the review represents the first broad compilation of relevant toxicity data. For dietary exposures, the current data support TRVs that are greater than older, commonly used TRVs. The older diet-based TRVs incorporate conservative assumptions and uncertainty factors that are no longer justified, although they generally were appropriate when originally derived, because of past data limitations. The egg-based TRVs identified from the review are more similar to other previously derived TRVs but have been updated to incorporate new information from recent studies. While important research needs remain, a key recommendation is that species not yet tested for MeHg toxicity should be evaluated using toxicity data from tested species with similar body weights. *Environ Toxicol Chem* 2017;36:294–319. © 2016 SETAC

Keywords: Methylmercury Avian toxicity Ecological risk assessment Reproductive toxicity Wildlife toxicology

INTRODUCTION

Effects of mercury (Hg) on the survival and reproduction of birds have been studied extensively over the last 50 yr [1–3]. Birds can be among the most highly exposed organisms in Hg-contaminated areas as a result of biomagnification of methylmercury (MeHg) through the food web, particularly in aquatic systems. Early research on the effects of Hg on birds was initiated by evidence of bird fatalities related to the use of Hg (often MeHg dicyandiamide) as an agricultural seed dressing [4,5]. With the decline in agricultural Hg uses, ecological risk assessments for Hg now more typically focus on diffuse regional contamination related to atmospheric transport and deposition of Hg and on industrial or mining sites where Hg remains in soil or sediment from historical activities. In its contaminated sediment remediation guidance, the US Environmental Protection Agency (USEPA) [6] estimated that Hg wholly or partially drove decisions at more than 15% of sediment sites remediated under the US Superfund program. Artisanal gold mining is also of concern as an ongoing source of Hg contamination in Africa and South America [7,8].

The predominant practice for predicting risks of adverse effects of Hg on birds involves measuring or estimating Hg exposure in a population of interest and then comparing that exposure to 1 or more toxicity reference values (TRVs). Depending on the application, a TRV may be an exposure level previously shown or estimated to be without deleterious effects, or it may represent a low level of adverse effects. In most cases, TRVs are derived from the peer-reviewed scientific literature, although site-specific avian studies may be conducted to derive TRVs for sites where data indicate that Hg bioaccumulation may be limited by site-specific conditions or where the accuracy of predicted risks has large financial consequences. As an example of the consequences of TRV selection, the Oregon Department of Environmental Quality [9] advises that where Hg concentrations exceed background levels in sediment and specified "acceptable tissue levels" in fish, sediment remedial action should be evaluated. However, sediment remediation, particularly dredging, can itself result in adverse environmental effects as a result of aquatic and riparian habitat disturbance, increased contaminant bioavailability and exposure from sediment resuspension and transport, and carbon emissions from heavy equipment and dredged material transportation. If a TRV is inaccurate, perhaps because it is based on data from an outdated or low-quality study, then significant risks may be overlooked or risks may be significantly overestimated leading to unnecessary environmental costs, which can be substantial.

Extensive data have become available over the past decade to inform the development of Hg TRVs for avian risk assessment. In addition to new studies on aquatic-feeding species [10–14], songbirds have increasingly become a subject of investigation [15]. Another recent development is increasing reliance on blood Hg analyses as a primary tool for monitoring avian Hg exposures [13,14]. Many of the recent studies reflect improvements in study design, analytical methods, effects endpoints, and statistical interpretation compared with older studies that

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historically have been relied on for TRV derivation. In this context, a critical review is warranted to support updated TRVs.

The present article reviews avian ecotoxicology data for Hg, focusing on reproduction as a sensitive endpoint that is directly related to the maintenance of wild bird populations. We comprehensively reviewed the relevant literature and developed criteria for study inclusion in the TRV data set. Because extrapolation of toxicity data to new contexts is inherent in the ecological risk-assessment process, we also reviewed issues relevant to understanding similarities and differences among studies and among species. Based on these findings, we identified ranges of effect thresholds for Hg-related reproductive impairment in birds. These threshold ranges are reviewed in comparison with previously developed TRVs as well as with estimates of naturally occurring, preindustrial background Hg concentrations in avian prey.

LITERATURE REVIEW METHODS

Avian toxicity studies and related literature were identified using Google Scholar and other online searches, reference lists of relevant articles, and direct inquiry to researchers. The literature review methodology was consistent with the principles of systematic review [16], including application of criteria for study inclusion and exclusion; evaluation of the strengths, uncertainties, and potential biases of each study; identification of confidence ratings for each study result; meta-analysis of data where applicable; and transparent documentation of findings. Criteria for inclusion of avian toxicity studies were based on the type of effect measured, specificity in attributing the observed effect to Hg exposure rather than to other stressors, chemical form of Hg, exposure pathways, exposure measures, and data quality. Paired exposure and effects data were compiled for the studies that met the designated criteria.

Study inclusion criteria

Effect endpoints. All studies included in the data compilation measured effects of Hg on reproduction, reflecting a focus on potential population-level effects. Broadly speaking, population success depends on the successful reproduction and survival of individuals, and reproductive effects are more sensitive than mortality in Hg-exposed birds [17,18]. Growth is also sometimes considered for TRV development, but growth effects in Hg-exposed birds are not particularly sensitive [19–21]; and from a population perspective, growth is primarily of interest as a surrogate for reproductive fitness. An alternative option would be to include data for survival, growth, and reproduction in the TRV derivation process [22]; but this approach can add uncertainty if safety factors are applied to results for less sensitive endpoints. For Hg, the available data for avian toxicity are sufficiently robust to support TRVs based specifically on reproductive effects. Although effects on reproductive success can be mediated by various mechanisms (e.g., behavioral or physiological effects), our focus is on the net effect of such processes on reproductive outcomes.

Where available, we considered production of independent offspring (e.g., number surviving through fledging) to be the preferred measure of reproductive success. This endpoint integrates effects on various components of the reproductive process (i.e., fertility, clutch size, hatching success, and fledging success) and is most directly relevant to protection of bird populations. If no measure of the production of independent offspring was reported, we considered various measures of offspring survival, hatching success, fledging success, or nest success. A successful nest is typically defined as a nesting attempt that produces at least 1 fledgling, although in some cases nest success is reported based only on successful hatching of at least 1 egg [23]. Studies that considered multiple avian reproductive endpoints suggested that fecundity expressed as clutch size is relatively insensitive to Hg exposure [4,24,25]; for this reason, studies that evaluated egg production but no other reproductive endpoints were excluded.

Causality. We compiled data from studies where observed effects (if any) could be attributed solely or primarily to Hg exposure, including both controlled experiments and field studies. Although there are unavoidable uncertainties associated with both laboratory and field studies, each provides unique and useful information. Laboratory studies provide controlled conditions to isolate MeHg as the cause of any observed effects. However, laboratories cannot fully replicate natural conditions, and laboratory artifacts can interfere with the interpretation of results. Field studies directly examine effects in the wildlife population of interest, but observed effects may be fully or partially caused by other stressors, such as co-occurring chemicals, low prey availability, poor habitat, depredation, or competition. These factors complicate the attribution of observed adverse effects to Hg and, conversely, can contribute to high variability, which can hinder detection of adverse effects. To assess whether Hg is causing adverse effects in the field, investigators should conduct an equally thorough and transparent analysis of all reasonable candidate causes [26], considering factors such as strength and consistency of association and biological plausibility [27]. Few field studies include any investigation of causality. However, field studies designed to detect effects related to Hg-contaminated sites generally involve observations across a site-related gradient of Hg exposure in which habitat and prey types are intended to be similar in Hg-contaminated and reference locations. Causality is more uncertain in cases where gradients in Hg exposure among birds are not a function of a localized contaminant source but rather a function of factors that influence Hg methylation and/or bioaccumulation (e.g., lake pH, primary productivity, availability of different prey types). For this reason, most of the studies that present a reasonably compelling case for effects caused by Hg were designed to investigate Hg-contaminated sites.

Field studies were excluded from the review if dichlorodiphenyldichloroethylene (DDE) or other chemicals probably caused or contributed substantially to observed effects [28–41], except in 1 case where the authors were able to establish a Hg egg concentration below which adverse effects were not expected despite the observation of DDE-related effects [42]. Certain other studies also were excluded even though Hg was associated with reproductive differences and other chemicals were not identified as likely toxicants. In a study of Bonelli's eagles (*Aquila fasciata*), Ortiz-Santaliestra et al. [43] found greater Hg exposures associated with nests supporting single chicks compared with nests with multiple chicks. This difference was attributed to the confounding effect of coincidentally lower Hg concentrations in the eagles' preferred prey; where the preferred prey species was less abundant, fewer chicks could be supported [43]. We also excluded a study of Hg effects on Acadian flycatchers (*Empidonax virescens*) in central Ohio [44] because the authors did not sufficiently evaluate whether habitat conditions contributed to effects on fledgling production that were marginally correlated with Hg exposure, despite demonstrated adverse effects of urbanization on this species' reproductive success in the same study area [45]. Finally, we excluded studies of black-legged kittiwakes

(*Rissa tridactyla*) in Svalbard, Norway [46,47]. Average prebreeding blood Hg levels were greater in birds that did not breed compared with those that bred; but the differences in average Hg levels between birds with different reproductive outcomes were very small (approximately 0.05 mg/kg wet wt), and there was a high degree of overlap in Hg levels between the 2 exposure groups. Therefore, it appears that Hg is at most a cofactor influencing reproductive outcomes in this kittiwake population. Such a result is consistent with effects related to diet and nutritional factors such as those observed by Ortiz-Santaliestra et al. [43].

Chemical form. In field studies, the form of Hg in avian diets is assumed to vary depending on the type of prey consumed. Mercury in fish is usually 95% to 100% MeHg [48,49], whereas the proportion of total Hg present as MeHg is lower and more variable in invertebrates [1,50,51]. We included controlled experiments in which Hg was administered as MeHg because this form of Hg is environmentally relevant and much more toxic and bioaccumulative than inorganic Hg. Specific MeHg forms included MeHg dicyandiamide, MeHg chloride, and MeHg cysteine. We excluded studies of inorganic Hg toxicity as well as studies using other organomercury forms (e.g., ethylmercury p-toluene sulfonanilide [52]). Total Hg exposures were identified for all field studies, as MeHg often was not measured; however, MeHg exposures are also noted in the data compilation, if measured. Mercury in bird eggs and blood is assumed to be almost exclusively MeHg [53,54].

Exposure pathways. The present review includes studies in which Hg exposures occurred via diet and/or via maternal transfer. Studies using egg injection to expose bird embryos to Hg were excluded because injected MeHg induces adverse effects at lower concentrations than maternally transferred Hg [55,56]. Egg injection is not an environmentally relevant exposure pathway in wild bird populations. Studies that applied Hg externally to eggs also were excluded because the absorbed dose cannot be determined and because it is unknown whether this exposure method would produce dose–response relationships comparable to those observed for Hg exposure via maternal transfer.

Exposure measures. We considered studies in which Hg exposure concentrations were reported for diet, eggs, or parental blood. Food consumption is the major pathway by which birds are exposed to Hg, and dietary Hg is often the primary measure of exposure characterized at Hg-contaminated sites. For laboratory studies, we used measured Hg concentrations if available; otherwise, nominal concentrations were used, and this study limitation is noted. For field studies, uncertainty in characterizing Hg exposure based on dietary Hg lies primarily in prey tissue sampling, which may imperfectly represent true avian dietary preferences. Egg Hg has the advantage of directly representing the exposure of embryos, a particularly sensitive life stage in birds. Parental blood Hg directly represents short-term Hg exposure of parents, with measurable changes occurring within weeks in response to changes in exposure [57]. Parental blood Hg concentrations during breeding provide a nondestructive measure of exposure that may be correlated with egg Hg exposures [14]. Parental blood Hg can also be related to behavioral effects on incubation or provisioning that may affect reproductive outcomes [58,59].

Although trends in avian Hg exposures are sometimes evaluated based on concentrations in feathers, this measure of exposure is generally a poor basis for TRVs. Deposition of Hg in feathers is a protective mechanism that sequesters Hg in nonliving tissue. Birds depurate Hg in their feathers only during feather growth; thus, Hg concentrations in the feathers of migratory birds that molt outside the breeding season reflect exposures in wintering grounds, rather than the more toxicologically important exposure incurred during the breeding season [60]. We also considered nestling blood Hg concentrations to be a poor basis for TRV development. Nestling and parental blood Hg concentrations are not comparable because of rapid nestling growth and MeHg depuration in growing feathers [61]. Too few studies are available to develop TRVs specifically for Hg in nestling blood; and, in any case, nestling blood Hg changes relatively rapidly during development [62], which would be expected to limit comparability among studies.

Data quality. All studies were reviewed for appropriate study design, documentation, and data quality. Although secondary references were reviewed, data were compiled only from primary references. Abstracts were not considered. The present review was consistent with the USEPA's [63] assessment factors for evaluating the quality of scientific information, which include soundness (i.e., the extent to which the study design and methods are appropriate to the researchers' intended application), applicability and utility (i.e., the extent to which the study is appropriate to our intended application), clarity and completeness, appropriate consideration of uncertainty and variability (e.g., through statistical analysis), and evaluation and review by others. Consistent with USEPA guidance for evaluation of ecological toxicity data [64], control performance and documentation of test conditions were reviewed for laboratory studies. Additionally, field studies that lacked a comparable reference site or a wide exposure gradient were excluded because in such cases the study design did not provide a basis to determine whether reproductive outcomes differed from what would be expected in the absence of elevated Hg exposure (i.e., [37,65–73], also osprey [*Pandion haliaetus*] data from Anderson et al. [74] and double-crested cormorant [*Phalacrocorax auritus*] data from Henny et al. [75]).

Study interpretation

Paired exposure and effects data were compiled based on reported Hg concentrations in dietary items, eggs, or blood. We report all Hg concentrations on a wet weight basis. In some cases, it was necessary to estimate wet weight concentrations from dry weight data. If the wet or dry weight basis of Hg concentrations was not reported, we assumed a wet weight basis because that is the most common basis used in the scientific literature for reporting concentrations in biological tissue. All such estimates and assumptions are reported in Tables 1 and 2. Concentrations of MeHg were given stoichiometrically on the basis of Hg content.

Dietary exposures were compiled based on reported Hg concentrations in the diet (as milligrams of Hg per kilogram of food) and on a dose basis (as milligrams of Hg ingested per kilogram of body weight per day). Doses are often calculated in wildlife risk assessments to facilitate integration of exposures experienced through multiple exposure pathways (e.g., food ingestion and sediment ingestion) [76]. Doses were estimated as the product of dietary Hg concentrations and body weight–normalized food ingestion rates. In a few cases, study-specific food ingestion rates were available from Hg toxicity studies [25,77,78], but for most studies it was necessary to estimate a food ingestion rate for the species tested. Species-specific food ingestion rates were identified if available. Otherwise, food ingestion rates were estimated from body weights using regressions developed by Nagy [79] or Kushlan [80]. Adult female body weights were study-specific if available and

Table 1. Methylmercury effects on avian reproduction in controlled experiments

Species	Chemical form	Exposure duration	Diet Hg (mg/kg wet wt)	Hg dietary dose (mg/kg-d)	Egg Hg (mg/kg wet wt)	Parental blood Hg (mg/kg wet wt)	Reproductive endpoint	Effect[a]	Reference	Comments
American kestrel (*Falco sparverius*)	Methylmercury chloride	ca. 60 d	0.16	0.05	1.3	2.5	Expected number of fledglings	EC20	[24]	Blood concentration estimated from diet–blood regression [163]. Exposure to Hg through incubation only. Moderate confidence.
Zebra finch (*Taeniopygia guttata*)	Methylmercury cysteine	2 generations	0.75	0.24	2.7	10	Average no. of offspring	EC20	[85]	Fledging success was more sensitive than clutch size, hatching success, time to renest, and adult survival. Egg Hg from Ou et al. [164]. Companion study reported high intraspecies variability in Hg sensitivity [102]. High confidence.
Ring-necked pheasant (*Phasianus colchicus*)	Methylmercury dicyandiamide	12 wk	0.92	0.06	—	—	Surviving chicks/hen	EC20	[25]	No significant effects on chick mortality. Eggs incubated artificially; does not account for any effects related to incubation behavior. Diet Hg unmeasured. Wet or dry weight basis not reported, but uncertainty is minimal because of low moisture content of grain. Moderate confidence.
Ring-necked pheasant (*P. colchicus*)	Methylmercury dicyandiamide	6–9 d	—	—	0.8/1.35	—	Hatching success	NOAEL/ LOAEL	[4]	Constant dietary dose; egg concentrations increased and hatching decreased over time. Does not account for any posthatching effects. Moderate confidence.
Japanese quail (*Coturnix japonica*)	Methylmercury chloride	2 generations	3.3	0.4	3.9	—	Surviving chicks/egg laid	EC20	[86]	Egg production, fertility, and hatchability were less sensitive than chick mortality. Egg Hg from Eskeland et al. [87]. Egg Hg for experiment 2 estimated from reported concentrations in yolk and albumen. Eggs incubated artificially; does not account for any effects related to incubation behavior. Diet Hg not measured. Wet or dry weight basis not reported for diet or eggs; wet weight assumed. Moderate confidence.
Japanese quail (*C. japonica*)	Methylmercury chloride	16 wk	10	1.2	—	15	Surviving chicks/egg laid	EC80	[96]	Chicks not fed Hg diet; mortality was the result of maternal transfer only. Diet Hg unmeasured. Wet or dry weight basis not reported, but uncertainty is minimal because of low moisture content of grain. Parental blood Hg reported for males only. Moderate confidence.
Black duck (*Anas rubripes*)	Methylmercury dicyandiamide	2 breeding seasons	2.6	0.41	3.86	—	Surviving ducklings/pair	EC80–EC90	[165]	Diet Hg converted to wet weight assuming 10% moisture in feed. Moderate confidence.
Mallard (*Anas platyrhynchos*)	Methylmercury dicyandiamide	2 breeding seasons	2.5	0.4	5.0	5.2	Surviving ducklings/egg	EC20	[77,88–90]	Chick mortality associated with neurological signs of Hg toxicity [104]. No significant effect on fertility or hatching success. Eggs incubated artificially; does not account for any effects related to incubation behavior. Blood Hg estimated from egg–blood regression [166]. Moderate confidence.
Mallard (*A. platyrhynchos*)	Methylmercury chloride	71 d	9.3	1.5	16	17	Surviving ducklings/egg	EC20	[10,92]	Eggs incubated artificially; does not account for any effects related to incubation behavior. Blood Hg estimated from egg–blood regression [166]. High confidence.
Chicken (*Gallus gallus domesticus*)	Methylmercury dicyandiamide	54 d	4.6	0.27	9.5	—	Hatching success	EC70	[78]	Diet Hg (nominal) calculated from Hg in grain and proportion of diet as grain. Wet or dry weight basis not reported for diet, but uncertainty is minimal because of low moisture content of grain. Egg Hg calculated from average Hg mass per egg and egg mass. Moderate confidence.

[a]Doses and EC20s are derived in the present study. Other effects are as reported by authors.
ECx = x% effect concentration; Hg = mercury; NOAEL = no-observed-adverse-effect level; LOAEL = lowest-observed-adverse-effect level.

Table 2. Mercury effects on avian reproduction in field studies[a]

Species	Site and Hg source	Diet Hg (mg/kg wet wt)	Hg dietary dose (mg/kg-d)	Egg Hg (mg/kg wet wt)	Parental blood Hg (mg/kg wet wt)	Reproductive endpoint	Effect	Reference	Comments[b]
American dipper (*Cinclus mexicanus*)	Upper Willamette River watershed, Oregon, USA; mining source	0.04	0.02	0.04	—	Young/territory	NOAEL	[167]	Diet Hg converted from dry weight using study-specific moisture content. In invertebrate prey Hg was 57% MeHg. Small sample size. Unbounded NOAEL below range of effects for all species; limits utility for TRV derivation.
Western/Clark's grebe (*Aechmophorus occidentalis*/*A. clarkii*)	Clear Lake, California, USA; mining source	0.09	0.03	—	—	Young/nest	NOAEL	[74]	Diet Hg from Suchanek et al. [168]. Unbounded NOAEL below range of effects for all species; limits utility for TRV derivation.
Carolina wren (*Thryothorus ludovicianus*)	South River and North Fork Holston River, Virginia, USA; industrial sources	0.21	0.14	0.3	2.13	Nest success (production of ≥1 fledgling)	LOAEL	[110,128]	No significant difference in productivity among successful nests. Diet Hg from Northam et al. [169], converted from dry weight assuming 65% water content in aerial life stages of insects [76]. MeHg was 41% of total Hg in diet (weighted average) [170]. Egg concentration is the grand mean of average clutch Hg [128]. Blood Hg is the mean for 2010 females. Nest success was affected by both increased predation and nest abandonment. Small sample size. Moderate confidence.
Common loon (*Gavia immer*)	120 lakes in Wisconsin, USA, and New Brunswick and Nova Scotia, Canada; enhanced Hg methylation in low-pH lakes	0.21	0.05	2.6	4.3	Maximum productivity of 5-wk-old to 6-wk-old chicks/pair	Threshold	[13]	Quantile regression measured effects relative to maximum productivity; 50% decrease from maximum approximates a threshold for consistent effects. Egg concentration estimated from blood–egg regression [171]. Loons are potentially affected by a combination of Hg exposure and prey availability, both a function of lake pH [118]. Moderate confidence.
Tree swallow (*Tachycineta bicolor*)	6 sites, Maine and Massachusetts, USA; industrial and non–point sources	0.29	0.4	0.6	3	Hatching and fledging success	NOAEL	[12]	No effects on productivity observed across exposure gradient. Blood concentration estimated from blood–egg regression [172]. High confidence.
Tree swallow (*T. bicolor*)	South River, Virginia, USA; industrial source	0.34	0.5	0.63	3.0	Fledglings/nest	LOAEL ≈ EC20	[11,123]	Approximately 20% reduction in number of fledglings in 2 of 3 yr; parental blood Hg estimated as average of 3 yr; effects associated with adverse weather conditions. Attribution of effect to Hg supported by feather analyses of dead versus surviving nestlings [173]. Diet Hg converted from dry wt assuming 65% water content in aerial life stages of insects [76]. Egg concentration estimated from blood–egg regression [172]. Adult survival not affected [17]. High confidence.
Black-crowned night-heron (*Nycticorax nycticorax*)	Carson River, Nevada, USA; mining source	0.45	0.08	1.8	—	Young/nest	NOAEL	[75,174]	Hypothesized effect threshold of 0.8 mg/kg (egg) was not predictive of effects with egg Hg up to 1.8 mg/kg. Offspring production was lower in study area than reference area, but this was not attributed to Hg because of lack of exposure–response relationship for Hg in eggs. Diet Hg is average of stomach contents; effect of digestion on Hg concentration is uncertain. In stomach contents Hg was 98% MeHg. Moderate confidence.
Snowy egret (*Egretta thula*) (drought years only)	Carson River, Nevada, USA; mining source	0.46	0.09	0.8	—	Young/nest	Diet, dose: LOAEL; egg: threshold	[75,174]	Study tested utility of hypothesized effect threshold in eggs (0.8 mg/kg); sample size deemed too small to derive a study-specific effect threshold. Results consistent with hypothesized threshold primarily during drought years. Dietary exposure is based on 1997 stomach contents; in 1997, offspring production was lower in study area than reference area (reference data not reported for other years). Effect of digestion on Hg concentration is uncertain. In stomach contents Hg was 90% MeHg. Moderate confidence.

(*continued*)

Table 2. (*Continued*)

Species	Site and Hg source	Diet Hg (mg/kg wet wt)	Hg dietary dose (mg/kg-d)	Egg Hg (mg/kg wet wt)	Parental blood Hg (mg/kg wet wt)	Reproductive endpoint	Effect	Reference	Comments[b]
Osprey (*Pandion haliaetus*)	Northern Quebec, Canada; enhanced Hg methylation in reservoirs	1.4	0.29	0.22	—	Fledgelings/nest	NOAEL	[175,176]	Dietary concentration of 1.4 mg/kg represents grand mean of estimated exposures; maximum station-specific average prey Hg was 2.4 mg/kg, also with no observed adverse effect. Egg Hg is mean reported for all reservoir stations. In eggs and nestling stomach contents Hg was 90% to 95% MeHg. Prelaying dietary Hg exposure uncertain.[c] Moderate confidence.
Black skimmer (*Rynchops niger*)	Lavaca Bay, Texas, USA; industrial source	—	—	0.46	—	Young/nest	NOAEL	[177]	Offspring production was lower than in reference area, reflecting differential nest success. However, Hg concentrations were the same between nests where no eggs hatched and those where some or all eggs hatched, indicating no effect from Hg. High confidence.
Bald eagle (*Haliaeetus leucocephalus*)	Aleutian archipelago, Alaska, USA; military and non–point sources	—	—	0.5	—	Young/territory	NOAEL	[161]	Eight sites, no effect on productivity across exposure gradient. Egg Hg converted from dry wt assuming 80% moisture content. High confidence.
Bald eagle (*H. leucocephalus*)	Pinchi Lake, British Columbia, Canada; mining source	—	—	—	6.7	Chicks/territory	NOAEL	[61]	Small sample size. Moderate confidence.
American avocet (*Recurvirostra americana*)	San Francisco Bay, California, USA; mining source, enhanced methylation in saline areas	—	—	0.54	1.47	Hatching success and chick mortality	NOAEL	[14,162]	No difference in egg Hg between unhatched eggs and random eggs from successful nests. Sample size 382 eggs. Egg Hg estimated using feather–egg regression for chick down feathers [178]. Parental blood Hg from Ackerman et al. [179]. High confidence.
Merlin (*Falco columbarius*)	Mainland Britain, agricultural source; Orkney and Shetland Islands; source assumed food web–related	—	—	2/0.6	—	Nest success (production of ≥1 fledgling), brood size	NOAEL (islands)/ Threshold (mainland)	[109]	Mainland effect threshold based on breakpoint in dose–response data set. Nest success was 43% lower for nests with egg Hg above identified threshold; brood size also decreased above Hg threshold. Merlins on islands were unaffected. Basis for geographic difference in responses is uncertain; see text. Egg concentrations converted from dry wt using study-specific moisture content. Limited documentation of methods, $n = 55$ clutches. Moderate confidence.
Black-necked stilts (*Himantopus mexicanus*)	San Francisco Bay, California, USA; mining source, enhanced methylation in saline areas	—	—	0.74/1.2	1.5/2.6	Mortality of newly hatched chicks	NOAEL /LOAEL	[14,162]	Egg Hg estimated using feather–egg regression for chick down feathers [178]. Blood concentrations estimated from egg–blood regression [14].[d] Mean egg Hg was 0.74 mg/kg for newly hatched live chicks ($n = 79$) and 1.2 mg/kg for newly hatched dead chicks ($n = 14$). No effect on chick survival after immediate posthatching period. Hatching success also not affected. High confidence.
White-tailed sea eagle (*Haliaeetus albicilla*)	Baltic coast and Lapland, Sweden; regional non–point sources	—	—	1	—	Nest success (production of ≥1 hatchling)	NOAEL	[42]	Any effect of Hg at concentrations >1 mg/kg confounded by DDE. Does not account for any posthatching effects, $n = 57$ clutches. Moderate confidence.
Common tern (*Sterna hirundo*)	Wabigoon–English River system, northwestern Ontario, Canada; industrial source	—	—	1 / 3.65	—	Abundance of fledged young versus unhatched eggs	NOAEL/ severe effect level	[180]	Semiquantitative description; abundant fledged young at NOAEL ($n = 40$ nests), near complete reproductive failure at LOAEL ($n = 37$ nests). Moderate confidence.

(*continued*)

Table 2. (*Continued*)

Species	Site and Hg source	Diet Hg (mg/kg wet wt)	Hg dietary dose (mg/kg-d)	Egg Hg (mg/kg wet wt)	Parental blood Hg (mg/kg wet wt)	Reproductive endpoint	Effect	Reference	Comments[b]
Forster's tern (*Sterna forsteri*)	San Francisco Bay, California, USA; mining source, enhanced methylation in saline areas	—	—	1.4/1.8	3.1/4.2	Hatching success	NOAEL /LOAEL	[14]	Mean egg Hg was 1.4 mg/kg in random eggs from successful nests and 1.8 mg/kg in unhatched eggs (egg Hg adjusted to fresh wet wt basis). Does not account for effects on chick survival (if any). No effects observed on postfledging survival [18]. Blood concentrations estimated from egg–blood regression [14], $n = 298$ eggs. High confidence.
Forster's tern (*S. forsteri*)	Lavaca Bay, Texas, USA; industrial source	—	—	0.4	0.7	Young/nest	NOAEL	[177]	Offspring production was 70% higher than at reference location. High confidence.

[a]Tabulated concentrations represent total Hg exposures. The percentage of Hg as methylmercury (MeHg) is noted in the comments where available.
[b]Doses are calculated in the present study; all other results are as reported by authors. Dose–response information and sample sizes are given in Supplemental Data, Table S7, except as noted herein.
[c]Authors attribute low egg Hg to limited prelaying foraging in reservoirs as a result of partial ice cover. However, similarly low diet-to-egg Hg bioaccumulation in osprey has also been observed elsewhere [40].
[d]Application of sequential regression equations is justified because of the very high r^2 (96%) of the down feather–egg regression.
DDE = dichlorodiphenyldichloroethylene; EC20 = 20% effect concentration; LOAEL = lowest-observed-adverse-effect level; NOAEL: no-observed-adverse-effect level; TRV = toxicity reference value.

otherwise generally identified as averages based on data from the Cornell Lab of Ornithology [81]. The body weights and food ingestion rates used in analyses and their basis are detailed in Supplemental Data, Table S1.

We characterized exposure–response relationships using 2 complementary approaches: dose–response model analysis and bounding or estimation of effect thresholds. We conducted dose–response regression analyses for studies that reported sufficient data representing a range of effect levels. Although we preferred at least 5 dose groups, including a control, we also deemed a pheasant data set with 4 dose groups [25] suitable for regression analysis, based on the range of effect levels and availability of replicate results. Of the available data, only laboratory studies reported the requisite number of exposure groups with paired effects data. Reproductive results were not normalized to control performance, because this adjustment has been shown to produce biased results [82]. This restriction precluded combined regression analysis of results for the same species from multiple studies, in cases where control results differed markedly among studies. It was possible to combine results from multigeneration studies, however, because these studies exhibited similar control performance across generations. Regression analyses were performed with R software using a Poisson model for count variables (i.e., number of offspring) and logistic models for proportion variables (i.e., surviving chicks per egg laid) [83,84]. A 4-parameter logistic model was used to accommodate data sets that indicated an upper asymptote associated with no-effect exposures. For mallards, the 4-parameter model yielded a poor fit, and a simpler 2-parameter model was used. Regression equations (given in Supplemental Data, Tables S2–S6) were used to calculate 20% and 50% effect concentrations (EC20s and EC50s).

We compared dose–response relationships among studies and species by compiling and graphing results for all studies that provided paired exposure and response data for treatment groups (i.e., laboratory dose groups or field study areas). To allow comparisons across species, data were normalized to control or reference performance; this adjustment is appropriate for visualization purposes, as no multispecies regression analysis was performed. The dose–response compilation included studies with fewer than 4 treatments, as well as those studies for which we performed species-specific regression analyses.

Effect thresholds were characterized as EC20s if available. Otherwise, the bounds around presumed toxicity thresholds were identified as no-observed–adverse-effect levels (NOAELs) or lowest-observed–adverse-effect levels (LOAELs). Results that support only a NOAEL or a LOAEL are considered "unbounded." In a few cases, researchers identified specific thresholds below which adverse effects were not observed and above which adverse effects were frequent, and these results were simply identified as "thresholds." The designation of NOAELs, LOAELs, and thresholds generally defers to the original authors' interpretation; the rationale for specific exceptions is discussed in the section *Literature Review Results*. The compilation of effect thresholds includes several field studies that could not be incorporated in the dose–response evaluation because of limited documentation or because results were organized by reproductive outcome (e.g., Hg concentrations in unhatched eggs versus randomly sampled eggs) rather than by treatment (e.g., proportion of individuals affected in different areas).

We assigned each result a confidence level to reflect the fact that the criteria for data quality and demonstration of causality

are applied to a continuum of study characteristics. Characteristics required for a high confidence rating are evaluation of effects from nest establishment through fledging, adequate sample size, potential confounding factors assessed (field studies), Hg exposures measured using modern analytical methods, no other obvious sources of potential inaccuracy or bias noted, and study methods and results well documented. If at least 1 of these criteria was not met but the data were deemed usable for quantitative analysis, the result was assigned a moderate level of confidence. Uncertainties associated with results assigned a moderate level of confidence are further considered as part of the identification and discussion of TRV ranges. Studies interpretable with low confidence were excluded from quantitative analysis based on the data quality criterion but are discussed qualitatively in the Supplemental Data.

LITERATURE REVIEW RESULTS

The studies compiled and evaluated for the present review are described separately for controlled experiments and field studies. For controlled experiments (Table 1), a key focus is the applicability of each study's results to avian exposures in the natural environment. For field studies (Table 2), a key focus is whether any observed adverse effects can be confidently attributed to Hg exposures. Dose–response data for both laboratory and field studies are compiled in Supplemental Data, Table S7.

Controlled experiments

Table 1 summarizes toxicity test results for 7 bird species exposed to MeHg in controlled experiments. Species represented by more than 1 study include ring-necked pheasant (*Phasianus colchicus*), Japanese quail (*Coturnix japonica*), and mallard (*Anas platyrhynchos*). Three or more exposure groups were tested for 5 of the species, including American kestrels (*Falco sparverius*) [24], zebra finches (*Taeniopygia guttata*) [85], ring-necked pheasants [25], Japanese quail [86,87], and mallards [10,77,88–92]. Dose–response relationships are shown on a dietary Hg basis in Figures 1 and 2. Dose–response relationships based on egg and/or blood Hg concentrations, where available, are similar to the diet-based relationships and are provided as Supplemental Data, Figures S1 through S4; underlying data are documented in Supplemental Data, Tables S2 through S6. For the remaining 2 species—black ducks (*Anas rubripes*) and chickens (*Gallus gallus domesticus*)—toxicity thresholds are poorly defined because testing was limited to greater exposures that induced severe effects. The latter studies are informative with respect to dose–response relationships and the relative sensitivity of the test species, although they are not directly usable to estimate toxicity thresholds.

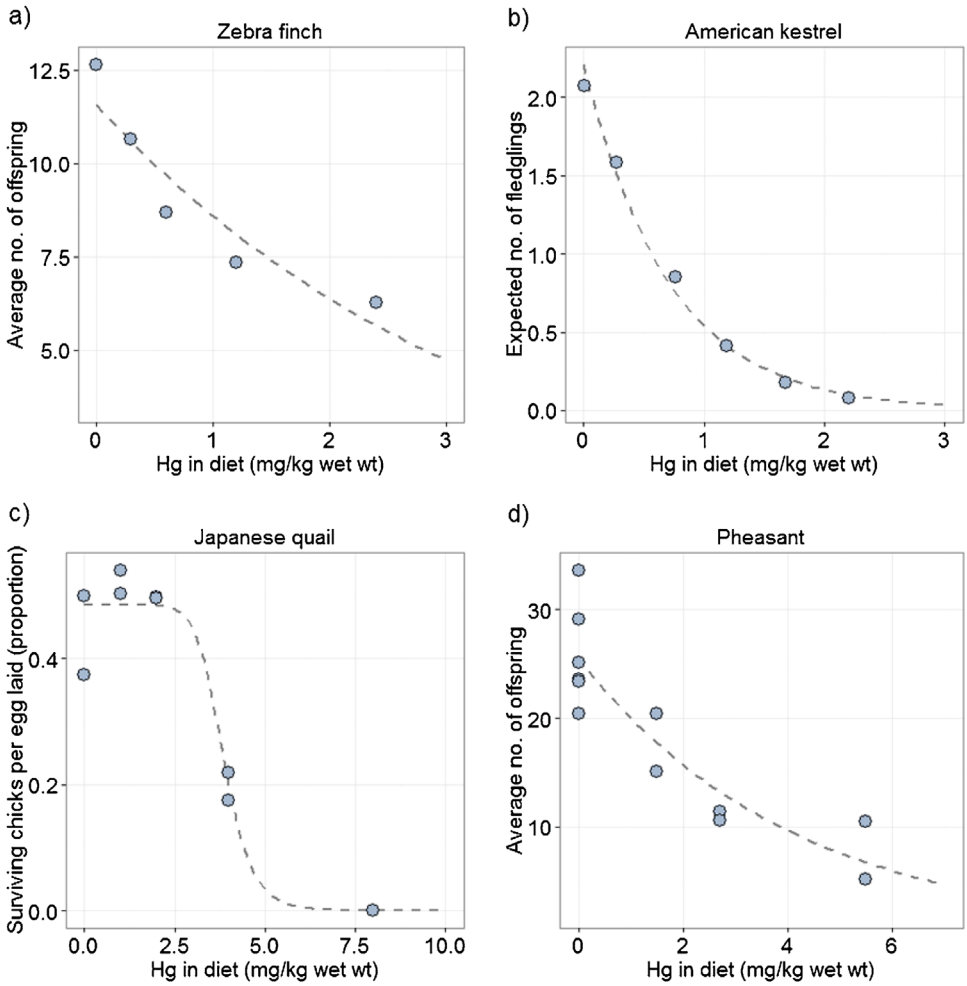

Figure 1. Dose–response relationships for 4 species exposed to methylmercury. Dashed lines represent fitted regressions. (**a**) Zebra finch data [85] represent model averages from generalized linear mixed models, including first- and second-generation pairs. (**b**) For American kestrels, expected number of fledglings accounts for removal of eggs for analysis [24]. (**c**) Japanese quail reproductive success was calculated as % fertility × % hatch × % chick survival (data from Eskeland and Nafstad [86]). (**d**) Pheasant productivity calculated as chicks hatched per hen × % chick survival (data from Fimreite [25]).

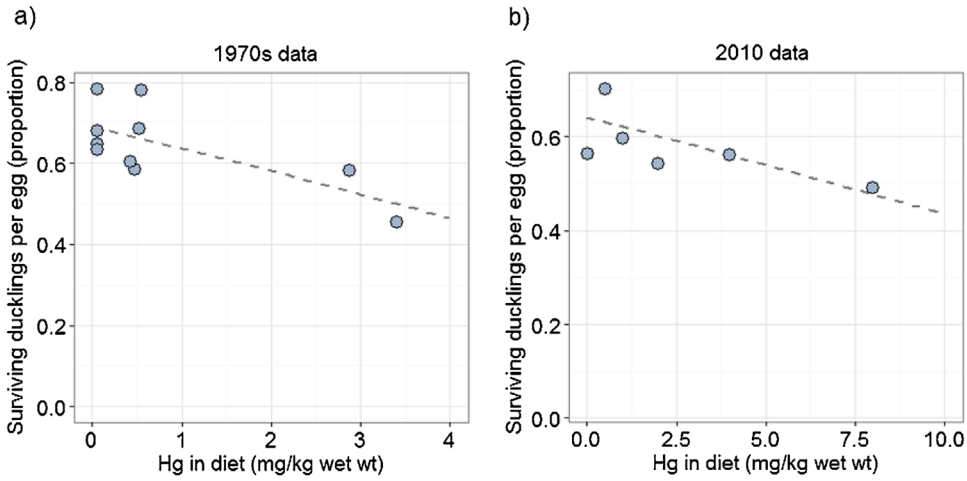

Figure 2. Dose–response relationships for mallards exposed to methylmercury dicyandiamide (1970s) or methylmercury chloride (2010). Dashed lines represent fitted regressions. Response variable calculated as % egg fertility × % hatchability × % duckling survival. Data from Heinz [77,88–90] and Heinz et al. [10,92].

The zebra finch study by Varian-Ramos et al. [85] is viewed with high confidence, as are the results of the mallard study by Heinz et al. [10] once laboratory artifacts related to egg production are factored out (see the section *Mallard studies*). The remaining studies are assigned a moderate confidence rating, in most cases because of study age and historical analytical limitations (or reliance on nominal Hg concentrations). The kestrel study of Albers et al. [24] is assigned a moderate confidence rating because chicks were exposed only via maternal transfer and not via diet. However, even the laboratory studies given a high confidence rating are not without uncertainty. Bioaccessibility of MeHg in laboratory-spiked feed is likely to be greater than that of MeHg that has been biologically incorporated in prey [93]. Also, the ratio of Hg to selenium (Se) in diet is very important because Se protects against Hg toxicity [94], but Hg-to-Se ratios were not reported in spiked feed and may or may not have been realistic (see the section *Extrapolation issues* for further discussion). We also note that the frequently employed practice of artificially incubating eggs eliminates the potential to observe adverse effects on productivity related to parental incubation behavior (nest attentiveness). Adverse effects on hatching success as a result of impaired incubation behavior have been demonstrated for polychlorinated biphenyls [95] and have also been hypothesized as a mechanism by which Hg may cause embryo malposition and subsequent hatching failure in Forster's terns (*Sterna forsteri*) [58]. Lastly, food ingestion rates for laboratory feed may differ from ingestion rates under natural conditions as a result of differing caloric and nutrient contents of dietary items and differing energetic requirements of captive versus free-ranging birds.

Additional discussion is warranted for certain other aspects of the controlled experimental studies, namely, comparison of effects across generations for zebra finches and Japanese quail, comparisons across multiple studies using mallards, and a study using white ibis that is suggestive of possible effects but is not sufficiently conclusive to support TRV derivation. Each of these matters is discussed in the following sections.

Effects on multiple generations. Varian-Ramos et al. [85] observed greater sensitivity in zebra finches that were exposed to Hg throughout their lifetime (i.e., second generation of exposure) compared with finches exposed only as adults (i.e., first generation). The authors posited that combining the results for both generations (Figure 1) is representative of wild populations, which include both immigrants and individuals exposed from conception. Eskeland and Nafstad's [86] study using Japanese quail is noteworthy because it demonstrated selection for Hg tolerance through exposures over 6 generations. The Hg dosage was not consistent across generations, limiting the utility of later generations for TRV development purpose. Doses that were lethal to quail chicks from unexposed parents induced only partial mortality in the chicks descended from quail that had been exposed to moderately toxic Hg doses over several generations. These results illustrate the potential for development of Hg tolerance in bird populations within contaminated areas. For purposes of dose–response analysis, we used data from the first 2 generations. Second-generation chicks consisted of the pooled offspring from the NOAEL and LOAEL dose groups of the first-generation test, which differs from the more typical approach in multiple-generation studies of administering a consistent dosage across generations. However, reproductive responses were generally similar between the first and second generations, and we judged that the uncertainty of including the second-generation results was less than the uncertainty of conducting the regression analysis with 50% fewer data points. An additional Japanese quail study [96] provides results that are generally consistent with those of Eskeland and Nafstad [86], but it could not be included in the regression analysis because the control results were not sufficiently comparable.

Mallard studies. Mallards are the most extensively investigated bird species in experimental studies of MeHg effects on reproduction. Heinz [77,88–90] evaluated effects of a diet containing 0.5 mg/kg Hg as MeHg dicyandiamide on mallard reproduction over 3 generations. A 3 mg/kg exposure was also tested over 2 yr using first-generation birds only [88,89]. The lower dosage has often been identified as a LOAEL [97–100] because production of 1-wk-old ducklings was reduced by 29% ($p < 0.05$) in the second generation only [77]. In the third generation, egg production was 18% lower than the control ($p < 0.05$), but overall duckling production did not differ significantly from control [77]. More recent studies conducted by Heinz et al. [10,92] cast doubt on the identification of 0.5 mg/kg in diet as a reproducible LOAEL for this species.

Heinz et al. [10,92] identified increased productivity (hormesis) in mallards fed a diet containing 0.5 mg/kg Hg in the form of MeHg chloride and observed limited adverse effects even at much greater doses. Hormesis at low Hg exposures was confirmed in a subsequent egg injection study [101].

A limitation common to all the mallard productivity studies cited above is that the authors removed all eggs from the nest for artificial incubation, which stimulated excessive egg production relative to wild populations. Wild ducks typically lay eggs daily until the clutch is complete, whereupon they begin incubating all eggs at the same time. If eggs are removed, the duck will continue to lay; indeed, the total egg production observed by Heinz [77,90] was greatly in excess of the natural production rate [10,92]. Thus, although effects related to egg production rates in the mallard studies could be considered relevant in a livestock production context, with respect to wild birds they are a laboratory artifact.

To further evaluate the implications of artificial incubation on interpretation of the mallard studies, we recalculated the mallard productivity results excluding the egg production endpoint. Specifically, duckling production per egg was identified as the product of egg fertility, hatchability of fertile eggs, and survival of hatchlings. Details are provided in Supplemental Data, Table S6. For exposures up to 1 mg/kg in diet, duckling production per egg was within the range observed for control mallards across studies, even excluding an anomalously low control result from Heinz and Hoffman [91]. At greater exposures, the mallards exposed to MeHg dicyandiamide in the 1970s were more sensitive than those exposed in later studies to MeHg chloride, although without a controlled comparison it is uncertain whether the difference in chemical form was responsible for the difference in toxicological responses. Intraspecies variation is another plausible explanation because the studies used mallards from different sources that may have represented different strains [10,102]. Additionally, analytical methods for quantifying Hg improved considerably after the 1970s [103], such that there is unavoidable uncertainty in Hg concentrations reported from early studies. Animal husbandry practices also may have improved since the 1970s.

We conducted separate analyses of the 2 sets of mallard studies from the 1970s and from 2010. In the 1970s study, the dietary Hg concentration of 2.9 mg/kg caused a statistically significant but small (10%) reduction in duckling survival, an effect accompanied by neurological signs of Hg poisoning and brain lesions [77,89,104]. Greater mortality was associated with exposure to 3.4 mg/kg in diet [88], although Heinz [88] noted uncertainty because of pseudoreplication during that study phase. Based on surviving duckling production per egg, we identified a dietary EC20 of 2.5 mg/kg from that study. In the later MeHg chloride exposures, duckling production per egg was greater than or approximately equal to the control for exposures up to 4 mg/kg in diet, with hormesis observed at a dietary concentration of 0.5 mg/kg [10,92]. We addressed the hormetic results in our regression analysis using methods consistent with those of Folland et al. [105]. Specifically, control results were excluded from the fitted regression but used to define the response level of the EC20 (i.e., 20% lower than the control). This approach yielded an EC20 of 9.3 mg/kg. Results from Heinz and Hoffman [91], an earlier study also using MeHg chloride, could not be included in the regression analysis because of substantially lower control performance. The latter study indicated a severe reduction in reproductive success of mallards exposed to a dietary MeHg concentration of 9.2 mg/kg [91], essentially equal to the EC20 from the later experiment [10,92]. Although the control results from Heinz and Hoffman [91] suggest suboptimal test conditions compared with the other mallard studies, the control-normalized data are included in Supplemental Data, Table S7, for completeness.

Consistent with the marked insensitivity of mallards observed by Heinz et al. [10,92], mallards were among the least sensitive species in a 26-species egg injection study with MeHg [55]. Although egg injection with MeHg produces lower embryotoxicity thresholds than more natural routes of exposure (i.e., diet and maternal transfer) and thus is a weak basis for TRV development, the method may elucidate the relative sensitivity of different species [55]. Also consistent with these findings is a field-based study of duck reproduction at several US National Wildlife Refuges, including a Hg-contaminated area (Lahontan Valley of the Carson River basin, NV, USA) [106]. The authors postulated an egg-based effect threshold for Hg of 0.8 mg/kg wet weight, based on the egg Hg concentration in mallards exposed to 0.5 mg/kg Hg in diet, which the authors identified from Heinz [77] as an unbounded LOAEL. However, Henny et al. [106] observed no difference in hatching success between eggs of multiple duck species containing 3 mg/kg to 9.5 mg/kg dry weight (approximately 0.8–2.4 mg/kg wet wt) compared with eggs with lower Hg concentrations, although the number of samples in the greater concentration range was small [106]. As an additional line of evidence, Heinz and Hoffman [107] evaluated effects of Hg based on concentrations in individual mallard eggs. The lowest egg Hg concentration associated with neurological signs of Hg toxicity in any individual duckling was 2.3 mg/kg, while other ducklings were unharmed despite egg Hg concentrations up to 30 mg/kg. Heinz and Hoffman [107] also evaluated deformities and failure to hatch; but because these conditions also appeared in some control eggs, their cause in individual eggs from Hg-treated mallards could not be definitively determined. In summary, the available data indicate that mallards are relatively insensitive to Hg, with dietary toxicity thresholds of approximately 3 mg/kg to 9 mg/kg.

White ibis study. In addition to the studies summarized in Table 1, a white ibis toxicity study conducted by Frederick and Jayasena [108] would meet the criteria for study inclusion based on study design and documentation; but conclusive interpretation of the study results for TRV development purposes is not possible because of the lack of a clear dose–response relationship and the occurrence of testing artifacts. The study evaluated effects of 3 MeHg chloride treatments on ibis courtship and mating behavior, number of nestlings, and number of fledglings. From the perspective of potential effects on ibis populations, the most relevant of these endpoints is the number of fledglings per female. Although the number of fledglings per female in the low-dose and high-dose groups was nominally lower than the control over 3 breeding yr, the difference was not statistically significant, and the number of offspring fledged per female in the medium-dose group was greater than that of the control. Frederick and Jayasena [108] observed dose-related behavioral effects, most notably male–male pairing. However, male–male pairing also was observed in the control group, even though this behavior has not been reported in wild white ibis at low Hg exposures. Thus, the study reveals an interaction between Hg exposure and captivity, but it is unclear whether the resulting effects on behavior are actually expressed in wild Hg-exposed ibis populations and, if so, whether they occur at a level that would affect overall reproductive success. Frederick and Jayasena [108] also reported that nestling production per female was not

significantly different from that of the control, whereas nestling production per heterosexual male showed a significant difference. The different findings for maternal versus paternal reproductive success are not intuitive but may reflect the occurrence of multiple mating attempts, whereby multiple females eventually mated with the more successful males. In that case, reproductive success would be similar among individual females, but some individual males would register as failing to reproduce. Ultimately it is maternal reproductive success that determines overall productivity and is most critical to population-level effects.

Although Zhang et al. [22] identified the low-dose group in the white ibis study as a reproductive LOAEL, that interpretation is not well supported given that the medium-dose group produced more fledglings per female than the control. On the other hand, we stopped short of identifying the medium-dose or high-dose groups from that study as NOAELs because of the inconsistent results for other reproductive endpoints. Additional investigation is needed to determine the level of Hg exposure that would adversely affect white ibis reproductive success under natural conditions.

Field studies

Table 2 summarizes the results of field studies evaluating Hg effects on reproduction in 16 bird species. Most of the field studies evaluated avian responses to Hg point sources from past industrial, mining, or military operations. Study species included songbirds, raptors, seabirds, shorebirds, wading birds, and other water birds. Species represented by more than 1 field study include tree swallows (*Tachycineta bicolor*), bald eagles (*Haliaeetus leucocephalus*), and Forster's terns. Also, merlin (*Falco columbarius*) results are presented separately for 2 populations that apparently responded very differently to Hg [109], with merlins in mainland Britain exhibiting much greater Hg sensitivity than merlins on the Orkney Islands and Shetland Islands. Merlin brood size on the mainland was not significantly correlated with either DDE or dieldrin metabolite exposures. The authors hypothesized a difference in Hg form, with Hg exposure on the mainland originating primarily from agricultural uses (e.g., MeHg dicyandiamide) and island exposures originating from aquatic food webs. Another possible explanation for the different responses of these merlin populations could have been a difference in Se status (see the section *Extrapolation issues* for further discussion). A third possibility is that the mainland merlins were actually responding not to Hg but rather to differences in available types of prey that happened to contain different Hg levels, as documented recently for Bonelli's eagles [43]. Although we are unable to distinguish these potential causes based on the available data, we provisionally included results for both the mainland and island merlins, recognizing that Hg causality is a significant uncertainty in the mainland data set. In the following sections, we discuss the extensive data available for common loons (*Gavia immer*) and tree swallows, followed by the Carolina wren (*Thryothorus ludovicianus*) study by Jackson et al. [110] (which we interpret differently from the study authors), as well as other field studies that provide supporting information but not stand-alone NOAELs or LOAELs.

Common loon studies. Depew et al. [111] recently reviewed the effects of dietary MeHg on the common loon. The authors proposed an MeHg concentration in prey fish of 0.18 mg/kg as a threshold for significant reproductive impairment in loons, while 0.4 mg/kg was identified as the concentration in fish associated with reproductive failure in wild adult loons. The first of these screening values was derived as the geometric mean of 4 toxicity thresholds [13,112–114]. The inclusion of 1 of these studies [114] relied on extrapolation of egg injection data to a hypothetical dietary concentration and thus did not meet the criteria for inclusion in the present review. Because of the use of quantile regression to address known confounding factors, we consider the analysis by Burgess and Meyer [13] to be the strongest of the available common loon studies, and we have opted to use it to represent common loon sensitivity to MeHg in Table 2. Regardless, both this approach and the Depew et al. [111] synthesis indicate a threshold concentration of approximately 0.2 mg/kg in loon prey.

Although Hg effects on loons have been extensively studied, the exposure–response relationship for this species has not been definitively characterized. Controlled reproductive studies have not been conducted because adult loons fare poorly in captivity. The majority of field studies have focused on loon productivity across regional gradients of Hg exposure, where the observed exposure gradients reflect differential bioaccumulation of atmospherically deposited Hg because of differences in lake pH and other geochemical and landscape factors. However, lake pH and Hg concentrations in fish are also correlated with lake productivity and thus prey availability [115], which in turn influence chick production and survival. Thus, low chick production could be the result of either Hg exposure or low prey availability, and conclusive demonstration of causality is a common challenge to these field studies. Merrill et al. [116] observed loon foraging behavior and the type and size of captured prey across a Hg exposure gradient and concluded that prey availability, rather than Hg exposure, was the factor most likely affecting loon productivity in northern Wisconsin lakes. Indeed, Stafford and Haines [117] and Driscoll et al. [115] identified low lake productivity as a cause of elevated Hg bioaccumulation in fish as a result of low biodilution (i.e., lower growth dilution and/or distribution of the pool of bioavailable MeHg across a smaller total biomass). Kenow et al. [118] identified parental fitness as an additional factor contributing to differences in loon productivity among lakes, with the largest males occupying more desirable (i.e., productive) territories, which also have lower prey Hg levels attributable at least in part to biodilution. Thus, observed correlations do not provide strong evidence of causality and may be specious. The LOAEL identified by Evers et al. [112] for loons in Maine and New Hampshire (0.16 mg/kg in prey) does not account for the characteristic intercorrelation of Hg exposures and prey availability (both a function of lake pH). A recent study of loon reproduction in the Adirondack Mountains (NY, USA) [119] shares the same limitation.

In an evaluation of loon productivity (viable offspring per pair) in Wisconsin and the Canadian Maritimes, Burgess and Meyer [13] addressed confounding factors using quantile regression. This method aims to assess Hg as a limiting factor by quantifying the relationship between maximum productivity and Hg exposure; instances of lower productivity associated with lower Hg exposure are assumed to be caused by other factors. Using quantile regression, Burgess and Meyer [13] calculated an EC50 of 0.21 mg/kg Hg in prey. Although quantile regression is an appropriate tool as applied by Burgess and Meyer [13], even this approach could be confounded if covariance among stressors (e.g., prey productivity and fish Hg concentrations) is sufficiently strong. Also, the term "EC50" as applied to quantile regression results must be interpreted carefully because it represents a 50% decrease compared with the most productive of all loons, not compared with the average

productivity of loons with low Hg exposure. There is a great deal of overlap in productivity distributions between loons exposed to low versus moderate Hg levels in prey, with obvious effects only at exposures exceeding the EC50. This variability is less pronounced when the analysis is carried out using loon blood Hg as the measure of exposure, likely because fish samples are an inexact representation of the species and sizes of prey actually consumed by loons, whereas blood analyses represent loon exposures more directly. Because of the high variability in the exposure–response relationship based on prey Hg concentrations and given Burgess and Meyer's definition of the EC50, Depew et al.'s [111] inclusion of the EC50 from that study for prey-based TRV derivation purposes (rather than the EC20, for example) was appropriate. In Table 2, we identify Burgess and Meyer's [13] EC50 as a "threshold," to avoid confusion with the more typical usage of the term "EC50," namely, an exposure level associated with a 50% reduction in reproductive success compared with average control or reference conditions.

In contrast to the regional studies described, Barr [113] evaluated loon productivity in the vicinity of a point source of Hg (a pulp and paper mill with a chlor-alkali plant) in the Wabigoon–English River system (Ontario), where lake pH was not a confounding factor. However, sudden and frequent dam-related water fluctuations rendered much of the study area essentially unusable for loon nesting regardless of Hg exposure [113], and loons might also have been exposed to other, unmeasured stressors related to pulp and paper mill operations in the vicinity of the Hg source. An association between Hg exposure and reduced productivity remained when water fluctuation–affected nests were removed from the analysis, although the resulting sample size was small ($n = 5$ loon pairs in the LOAEL exposure group). Depew et al. [111] identified a LOAEL of 0.17 mg/kg Hg in prey from that study, based on reported average concentrations in yellow perch (*Perca flavescens*). However, Barr [113] analyzed Hg concentrations in multiple prey species. Although yellow perch are a frequent prey of common loons, they are by no means the only prey [120]. Considering all sampled prey, Barr [113] identified a LOAEL from that study of 0.3 mg/kg to 0.4 mg/kg in prey. Either interpretation is approximately consistent with the toxicity threshold identified from Burgess and Meyer [13].

Depew et al. [111] also evaluated a study of loon productivity in Quebec [121], which demonstrated no correlation between Hg exposure and loon productivity. Because the average prey fish Hg concentration was reported as 0.15 mg/kg [121], Depew et al. [111] considered the lack of effect in that study to be consistent with the TRV derived from the loon studies discussed. By reporting only a single average fish tissue Hg concentration, however, Champoux et al. [121] obscured an important difference between western and eastern Quebec. In part because of differences in lake pH, average Hg concentrations in loon blood (and thus presumably in prey fish) were nearly 5-fold greater in eastern Quebec than in western Quebec [121]. The lack of any discernible effect of Hg on loon productivity in the Quebec study is thus consistent with the observation that there is a high degree of overlap in loon productivity between low and moderate Hg exposures.

In summary, reduced productivity is associated with common loon exposure to Hg at environmentally relevant prey Hg concentrations, but the available field studies do not provide a fully predictive effect threshold. Controlled experimental approaches would benefit the understanding of exposure–response relationships for this species if effective investigative methods could be developed. The recent suggestion of intraperitoneal injections in wild adult female birds as a means of generating varied egg Hg concentrations within a field site [122] may be a useful application in common loons, though further evaluation would be needed to determine whether that practice would replicate important conditions such as the ameliorative effects of Se that are expected to occur with dietary exposures.

Tree swallow studies. For tree swallows, 2 studies examining the effects of similar Hg exposures yielded somewhat different results. Tree swallows exposed to Hg from the South River (VA, USA) exhibited a 20% reduction in productivity that was observable only during 2 of 3 yr, in part because of the role of adverse weather conditions as a costressor [11,123]. In contrast, nearly identical Hg exposures in a 2-yr study of New England tree swallows yielded no adverse effect on hatching or fledging success [12]. While egg Hg concentrations in both of these studies were approximately 0.6 mg/kg, a further study of tree swallow reproduction adjacent to the Carson River (NV, USA) [124] suggests a slightly greater egg-based Hg threshold. Specifically, Custer et al. [124] reported an average Hg concentration of 1 mg/kg in eggs from clutches with 100% hatchability versus an average concentration of 2 mg/kg for clutches with $<100\%$ hatchability. However, the sample size ($n = 5$ nests for each group) was too small to determine whether these results were significantly different [124], and fledging success was not evaluated; therefore, we did not include the study in Table 2.

Carolina wren study. Jackson et al. [110] evaluated Carolina wren reproduction in the floodplains of 2 Hg-contaminated river systems in Virginia (South River and North Fork Holston River) over a period of 4 yr. Wrens were studied upstream and downstream of the historical Hg sources, by monitoring both nest boxes and natural nests. Exposure to Hg was evaluated primarily based on analyses of adult wren blood, although some egg analyses were also conducted. Considering only successful nests (i.e., nests that produced at least 1 fledgling), Jackson et al. [110] identified no significant difference between the study areas and the upstream reference areas in the number of fledglings produced per nest. However, a significant difference was observed in nest success, in part because of parental abandonment of a larger number of nests in the study areas. Jackson et al. [110] used MCESTIMATE software to derive a dose–response relationship based on the 2010 data, estimating nest success as a function of blood Hg concentrations. The resulting dose–response equation was extrapolated to Hg concentrations in eggs, based on a blood–egg regression equation [110]. Several researchers have adopted the EC10 estimates from this dose–response analysis as a means of interpreting both egg and blood Hg concentrations in a variety of bird species [125–127].

Although it is apparent that nest success in 2010 differed between the reference and downstream areas in the Jackson et al. [110] study, there are important limitations in the dose–response relationship developed from the data set. Specifically, the article does not provide sufficient detail to allow the dose–response modeling exercise to be reproduced, and the limited data presented do not agree with the model as presented. The dose–response model predicts that nest success in the references areas should have been between 75% and 80% based on a blood Hg level of 0.2 mg/kg to 0.5 mg/kg wet weight. However, the actual reference area nest success rate is reported as only 60%. Nest success in the study area appears to be predicted more accurately than in reference areas, at least based on

average blood Hg concentrations. Consequently, the slope of the dose–response curve appears to be exaggerated. It is possible that the failure of the model to accurately reflect the underlying data is the result of high sensitivity of the model to individual results when quantifying the likelihood of low-probability outcomes based on limited data. Only a few results fell within a concentration range of 0.5 mg/kg to 1.0 mg/kg [128]; thus, the shape of the exposure–probability curve is not well defined by data in the vicinity of the EC10. Also, in estimating the percent reduction in nest success associated with various Hg exposures, Jackson et al. [110] defined the baseline blood Hg concentration as 0, rather than consistent with reference conditions. Mean blood Hg concentrations in the reference areas were on the order of 0.2 mg/kg to 0.5 mg/kg. The EC10 of 0.7 mg/kg Hg in wren blood was closer to the concentrations in the reference areas than in the study areas, where mean female blood Hg concentrations ranged from 1.96 mg/kg to 3.38 mg/kg.

Nest success by itself is of limited utility as a test endpoint, because it does not account for the fact that many bird species, including Carolina wrens, normally nest more than once per season [23,129]. In fact, nest success and production of fledglings per season often are not correlated [23]. Jackson et al.'s [110] analysis assumes that the success of each nesting attempt is independent of the outcome of the pair's prior nesting attempt(s), but this assumption is not necessarily valid because more experienced breeders may be more likely to lay multiple successful clutches and less experienced breeders may be more likely to establish a first nest in an area susceptible to depredation. Jackson et al. [110] did not report the overall production of fledglings per mated pair, although Jackson and Evers [128] recorded fledgling production by territory during the final year of the same study. Although the latter results suggest production of approximately 1 fledgling fewer per territory (data not shown), the sample size was low ($n = 11$ study area territories); and unlike Jackson et al.'s [110] analysis of nest success, our calculation of fledglings per territory for the present review did not account for observation biases (e.g., the relationship between nest discovery time and probability of observing nest failure).

In addition, Jackson et al. [110] did not evaluate the potential for causative factors other than Hg potentially contributing to the lower nest success rate observed in the study area. Jackson et al. [110] did not consider habitat characteristics, even though nests were monitored in both forested and developed areas. Habitat quality has the potential to affect reproductive success, given that differences in habitat quality may influence susceptibility to disturbance and availability of food. Also, causes of nest failure were recorded only during the last year of the study, and egg predation rates were found to be greater in the study areas than in the reference areas [128]. The dose–response relationship for nest success published by Jackson et al. [110] did not distinguish effects attributable to depredation from those attributable to nest abandonment. The limited available data indicate greater nest abandonment rates and greater egg depredation in the study areas, but the sample sizes for abandoned nests were relatively small (study area $n = 6$ abandoned nests in 4 territories, reference area $n = 2$ abandoned nests in 2 territories). It is not known whether habitat factors or encounters with predators could have contributed to differences in nest abandonment rates. Further, E. Henry (Anchor QEA, Saratoga Springs, New York, personal communication) obtained and reanalyzed the original data and found that nest success rates did not differ between the study and reference areas in 2007 through 2009 and that nest type (natural versus artificial) was a potential confounding factor in 2010.

In summary, although a difference in Carolina wren nest success rates between reference and study areas was sometimes observed, the quantitative dose–response function presented by Jackson et al. [110] does not accurately represent the relationship between Hg exposures and effects at their study sites. Further, the relative contributions of Hg versus other stressors and confounding factors in affecting nest success rates are uncertain, with differential depredation pressure identified as a cofactor. For these reasons, the dose–response function estimated by Jackson et al. [110] is not recommended as a basis for avian Hg TRVs. However, the unbounded LOAEL from that study is provisionally included in the present data compilation (Table 2), recognizing that small sample size and potential costressors are significant limitations.

Other supporting studies. A study of eastern bluebird (*Sialia sialis*) reproduction near the South River (VA, USA) [59] indicated no relationship between maternal blood Hg levels and any measure of reproductive success. A significant correlation was observed between paternal blood Hg and nestling survival. This effect was attributed not to paternal transfer of Hg (indeed, bluebirds are promiscuous) but rather to effects on the ability of males to provide sufficient food for nestlings. Although the results appear consistent with an effect threshold of approximately 1.5 mg/kg in male blood, the authors did not identify any specific effect threshold; and such caution is appropriate because of the small number of male bluebirds with Hg concentrations above this level. Given that the authors did not identify a threshold from their study, we too are cautious about relying on their study as a basis for TRVs.

For marsh wrens (*Cistothorus palustris*) and white-faced ibises (*Plegadis chihi*) breeding at Great Salt Lake (UT, USA), Ackerman et al. [130] found statistically significant differences in Hg concentrations between opportunistically collected eggs from abandoned nests and randomly collected eggs from successful nests (termed "surrogate eggs"). However, the difference in Hg concentration in the 2 groups was small (<0.15 mg/kg), and the eggs consistently contained more Se than Hg on a molar basis, which may ameliorate potential Hg-related effects [56]. Also, the sample size for marsh wrens was small ($n = 6$ for abandoned and failed-to-hatch eggs combined). For both species, an evaluation of nest abandonment rates based on surrogate egg concentrations indicated no significant relationship between egg Hg concentration and nest success. One possible explanation for the apparent discrepancy is that Hg-related nest abandonment occurred primarily during the first week of incubation, before the collection of surrogate eggs, which occurred between incubation day 6 and day 12. However, additional investigation would be required to verify such a specific behavioral effect. Alternatively, factors other than Hg (e.g., differences between sites with respect to habitat, food, shelter, and/or predators) may have influenced nest abandonment behavior in a manner that covaried with egg Hg concentrations. Such differences were taken into account statistically in the surrogate egg evaluation but not in the opportunistic abandoned egg evaluation. For instance, food web differences can be hypothesized as a possible explanation for the observed results [43]. Thus, while the study results are useful for highlighting areas of potential future research, they are not sufficiently conclusive to support identification of NOAELs or LOAELs for TRV derivation purposes. The Great Salt Lake study also reported no evidence of adverse effects of Hg on American avocets (*Recurvirostra americana*), black-necked

stilts (*Himantopus mexicanus*), or Forster's terns, all of which were subject to lower Hg exposures than those identified for the same species in San Francisco Bay [14] (see Table 2).

Three other studies are worth noting despite their exclusion from the present quantitative analysis because of a lack of data from temporally paired reference areas. Great blue herons (*Ardea herodias*) inhabiting Clear Lake (CA, USA) were exposed to 0.56 mg/kg Hg in prey fish and reproduced normally, based on their production of young per successful nest in comparison to regional monitoring data from prior years [70]. Endangered California clapper rails (*Rallus longirostris obsoletus*) exhibited low reproductive success in San Francisco Bay as a result of predation and egg inviability. An assessment of multiple inorganic and organic contaminants identified Hg as the most widespread contaminant potentially contributing to depressed hatching success, with average fresh wet weight egg Hg concentrations in failed-to-hatch eggs ranging from 0.27 mg/kg to 0.79 mg/kg [66]. Herring gulls (*Larus argentatus*) nesting at Clay Lake (Ontario, Canada) exhibited near-complete hatching success, despite egg Hg concentrations up to 15.8 mg/kg. Fledging success was also considered normal compared with past herring gull studies at other sites [71]. Although the interpretation of these studies is too uncertain to use quantitatively for TRV development, the great blue heron results appear consistent with those observed for black-crowned night-herons, whereas the California clapper rail results may be more consistent with those observed for snowy egrets [75]. The reported herring gull exposures are notably high, but these analytical results are particularly uncertain because only first-laid eggs were sampled, analytical methods at the time of the study were less developed than current methods, and the authors did not report whether results were presented on a dry weight or wet weight basis.

Extrapolation issues

In addition to compiling data on Hg toxicity thresholds from avian reproductive studies, we reviewed information relevant to applying those data in ecological risk assessments. In particular, we reviewed available studies related to interspecies differences in sensitivity, considerations related to body weight and dose calculations, bioaccessibility, Hg–Se interactions, and MeHg form.

Interspecies extrapolation is integral to ecological risk assessment because for any given toxicant, species sensitivity has been characterized for only a subset of wildlife species that warrant protection. We discuss 2 factors of particular interest for TRV development: feeding guild and body weight. Feeding guild is important to Hg TRV derivation for birds because there is some evidence that MeHg tolerance may have evolved to a greater extent in piscivores than some other feeding guilds as a result of natural biomagnification of background Hg. Body weight is important because toxicokinetic and toxicodynamic parameters tend to vary as a function of body size.

Mercury tolerance and feeding guild. As reviewed by Robinson et al. [131] and Eagles-Smith et al. [132], birds can detoxify MeHg through demethylation in the liver, with the resulting inorganic Hg being either eliminated or stored as a nontoxic Hg–Se complex. Both MeHg and inorganic Hg can be secreted in bile for elimination in feces. Birds can also depurate MeHg through deposition in feathers, although this mechanism is effective only during periods of feather growth. All of these mechanisms reduce MeHg concentrations in blood and maternal transfer of MeHg to eggs, which in turn may reduce adverse effects on reproduction. Feeding guilds that naturally experience greater MeHg exposure (e.g., piscivores) might thus have evolved more efficient MeHg detoxification [131].

Hepatic demethylation is a dose-dependent process, with increased demethylation efficiency observed above an exposure threshold; both demethylation rates and thresholds vary among species [132]. Hepatic demethylation is thought to be an active process requiring energy input, and the existence of a threshold that triggers this detoxification mechanism is consistent with that requirement [131]. As such, demethylation should be subject to natural selection, with greater demethylation potentially favored in species with higher MeHg exposure, such as predators of large fish. Indeed, ospreys exhibit efficient MeHg demethylation and low diet-to-egg MeHg bioaccumulation [40]. The connection between maternal diet-to-egg transfer and feeding guild has not been confirmed, however, because detoxification processes have been studied primarily in piscivores to date. However, the studies by Robinson et al. [131] and Eagles-Smith et al. [132] suggest that similarity in feeding guild could be an important consideration when extrapolating across species.

Body weight and dose extrapolation. Species body weight affects several parameters relevant to MeHg exposure in birds and other animals, including food ingestion rates and key toxicokinetic processes (absorption, distribution, metabolism, and elimination) [133–136]. Additionally, as an adaptation to flight, small birds (<300–400 g) have proportionally smaller intestines and higher rates of paracellular absorption of nutrients compared with larger birds, which could potentially enhance uptake of water-soluble toxicants [137] such as protein-bound MeHg [138]. Although many aspects of chemical metabolism and toxic responses are not dependent on body weight [134], there is some evidence that longer-lived bird species tend to have greater resistance to oxidative stress [139,140]. Because larger birds tend to have longer life spans and oxidative stress is a mechanism of MeHg toxicity [94], this represents another mechanism by which MeHg exposure–effect relationships could potentially be related to avian body weight.

In North America, ecological risk-assessment practice typically translates the dietary exposures of the toxicity test species to doses, based on species-specific body weights and food ingestion rates. This linear extrapolation approach takes into account differences in food ingestion rates between toxicity test species and species to which TRVs are applied. However, it does not account for differences in elimination rates, which are also related in part to body size, with smaller animals having faster metabolic rates and contaminant elimination rates [133]. In veterinary medicine, it is recognized that linear extrapolation of drug doses among species tends to overdose large animals and underdose small ones [141]; this is analogous to underestimating the effects of a toxicant in large animals and overestimating the effects in small animals. The European Union's environmental standard for Hg in prey tissue was developed directly from dietary concentrations in toxicity studies [100] and does not account for differences in either ingestion rates or elimination rates. Sample et al. [142] found that dose estimation provided no improvement over dietary concentrations in reducing variation in copper toxicity values among species, for either birds or mammals. Although taxonomic similarities in sensitivity are expected, they were evident only when toxicity values were expressed on a dietary concentration basis and not on a dose basis [142]. These findings suggest that dose extrapolation between species of very different body weights (e.g., from loons to songbirds) introduces considerable uncertainty. Also, size-related factors

such as paracellular absorption and oxidative stress resistance suggest that body weight could affect exposure–response relationships when considered on the basis of dietary or tissue MeHg concentrations, in addition to doses.

Bioaccessibility. Several studies have used in vitro methods to assess MeHg bioaccessibility in freshwater fish and seafood potentially consumed by humans. Although results vary widely, bioaccessibility in raw tissue is frequently less than 60% [93,143–145]. He and Wang [93] found that variation in Hg bioaccessibility among species was related to differences in the subcellular distribution of Hg, with Hg bound to heat-stable proteins such as metallothioneins being less bioaccessible than Hg contained in cellular debris. This observation suggests that biologically incorporated MeHg may be less bioaccessible than MeHg in spiked feed prepared for laboratory toxicity tests. Consistent with these findings, Berntssen et al. [146] found that rats fed contaminated fish exhibited greater fecal excretion and less Hg accumulation than rats fed uncontaminated fish spiked with MeHg chloride to the same concentration. Bioaccessibility of MeHg has not been evaluated using methods designed specifically to address avian digestive uptake, but it is reasonable to expect that results of mammalian bioaccessibility investigations are at least qualitatively applicable to birds. Indeed, Kaufman et al. [147] found in vitro estimates of lead bioaccessibility to be very similar between procedures mimicking avian digestive processes and those mimicking mammalian digestive processes. Bioaccessibility differences could contribute to overprediction of risks when extrapolating from laboratory studies to field conditions.

Mercury–selenium interactions. Another complicating factor in interpreting avian Hg exposures is that Hg toxicity depends in part on Se status because Hg and Se can protect against each other's toxicity (i.e., antagonistic interaction) [148,149]. Selenium is a biologically essential element for nervous system function, although it can be toxic to avian reproduction at high concentrations. For a variety of species, the onset of Hg toxicity roughly corresponds to when the molar concentration of Hg exceeds that of Se in tissue or diet [148,150]. The presence of Se can also reduce Hg bioaccumulation [148,149]. Recent evidence suggests that Hg toxicity is the result of Se deficiency because of the sequestration of Se by Hg [94], and thus the presence of an excess of Se guards against Se deficiency caused by this sequestration. As reviewed by Klimstra et al. [56], several studies in birds confirm the generally antagonistic interaction between Se and Hg toxicity. In mallard eggs injected with embryotoxic and teratogenic doses of both Se and Hg, however, the Hg–Se interaction was antagonistic for embryo mortality but approximately additive for deformities [56]. Additional research is needed to further clarify Hg–Se interactions in birds when Se levels approach a toxicity threshold. Despite this uncertainty, Hg–Se ratios are generally interpretable, and their measurement is recommended for future Hg exposure and effect studies.

Methylmercury form. Potential differences in toxicity among different MeHg forms are a source of uncertainty in applying nearly all of the available controlled experimental studies testing MeHg toxicity to birds. Almost no data exist to assess the effects of MeHg form on toxicity. As previously discussed (see *Mallard studies*), Hg toxicity data for mallards suggest that dietary exposure to MeHg dicyandiamide might cause effects at lower doses than MeHg chloride [10,77,92]; without a controlled comparison, however, other explanations can be advanced, such as decreased sensitivity as a result of improvements in animal husbandry since the 1970s. Although MeHg chloride has been considered applicable to present-day food web Hg exposures, Harris et al. [151] determined that Hg in fish exists as MeHg cysteine. And, MeHg chloride is not an ion pair that can be used to introduce "free" MeHg to toxicity test species; rather, the chloride is covalently bound [151]. On the other hand, it appears that MeHg chloride is metabolized to MeHg cysteine in chickens [152]. Varian-Ramos et al. [85] evaluated the toxicity of MeHg cysteine to zebra finches, but zebra finch reproductive responses to other MeHg forms have not been characterized. In an acute fish toxicity test MeHg chloride was more toxic than MeHg cysteine [151], but we identified no chronic comparison of effects of MeHg forms for any species. A controlled comparison of the metabolism and toxicity to wildlife of the cysteine, chloride, and dicyandiamide forms of MeHg would aid interpretation of the available data for TRV derivation purposes.

APPLICATION TO ECOLOGICAL RISK ASSESSMENT

Ecological risk assessments are typically implemented using a tiered approach, beginning with a conservative screening phase to determine whether additional assessment is warranted, followed by a more definitive phase if needed. Corresponding to this tiered approach, TRVs can be developed as screening values or as predictive risk thresholds. The latter are most appropriate for purposes of weighing cost–benefit and risk–benefit trade-offs, as in the case of environmental remediation decisions. In the present review, we describe typical reproductive effect threshold ranges as well as outlying thresholds and severe effect observations. We focus on predictive risk thresholds, although the data compiled herein could also be used to formulate screening values (e.g., using species sensitivity distribution methods or the low end of effect threshold ranges). For specific ecological risk-assessment applications, TRVs should be tailored as closely as possible to the species and the type and degree of effect most relevant to site conditions and management goals.

To help visualize patterns in the available data, we developed 2 sets of graphs based on dose–response data (Figure 3) and effect thresholds (Figure 4) for each exposure metric (i.e., dietary concentration, dietary dose, egg concentration, and blood concentration). Visual inspection of Figure 3 and the range of EC20 values indicates that dose–response relationships tend to show lower interspecies variability when expressed on the basis of tissue Hg concentrations compared with diet-based or dose-based exposures. For Figure 4, we arrayed the toxicity thresholds and bounding estimates from low to high, in a manner analogous to a species sensitivity distribution (recognizing, however, that the effect types and magnitudes are not consistent in this data set). Thresholds and EC20s are shown as circles, while NOAELs and LOAELs are represented by arrows that point toward the presumed toxicity threshold. (That is, the toxicity threshold is presumed to be an unknown Hg concentration or dose that is greater than the NOAEL and/or lower than the LOAEL for each species.) Exposures that caused reproductive impairment of more than 50% compared with controls are indicated with an X; however, such results are omitted for clarity if an EC20 or LOAEL representing less than 50% effect is also available from the same study (as in the case of several controlled experiments). Based on the factors identified as potentially contributing to interspecies differences in Hg sensitivity, we prepared these figures using colors and shading to distinguish species categories based on body weight

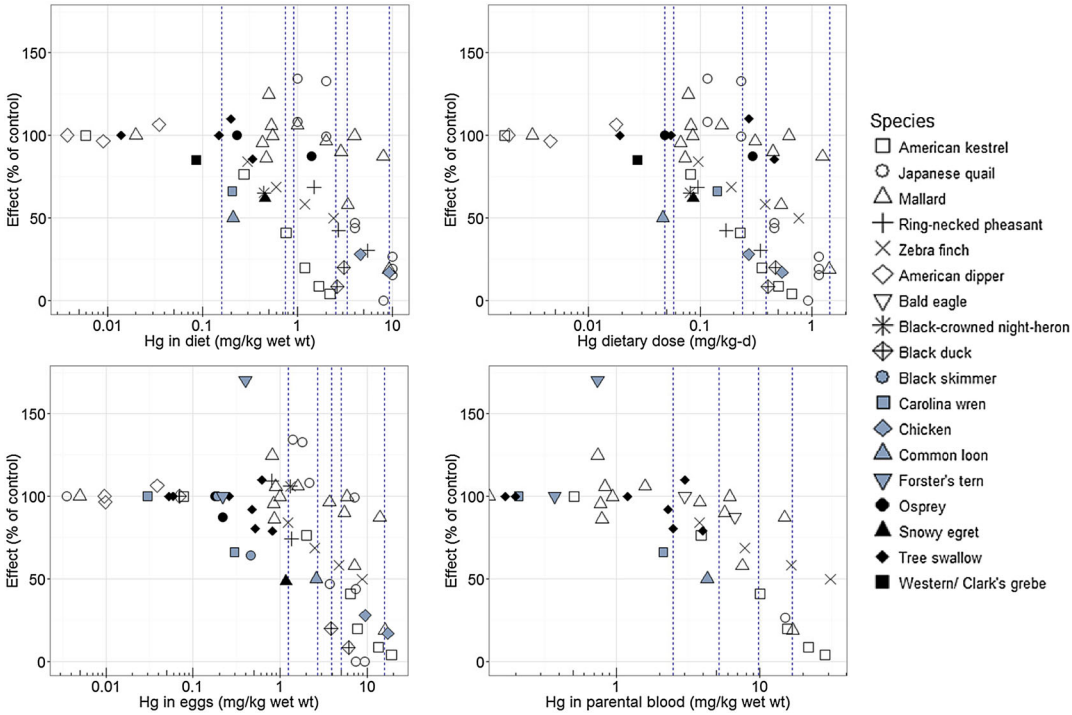

Figure 3. Dose–response data for 18 bird species exposed to methylmercury. Results are measures of reproductive success normalized to control (laboratory) or reference area (field) results for comparability. Vertical lines represent 20% effect concentration values from Table 1.

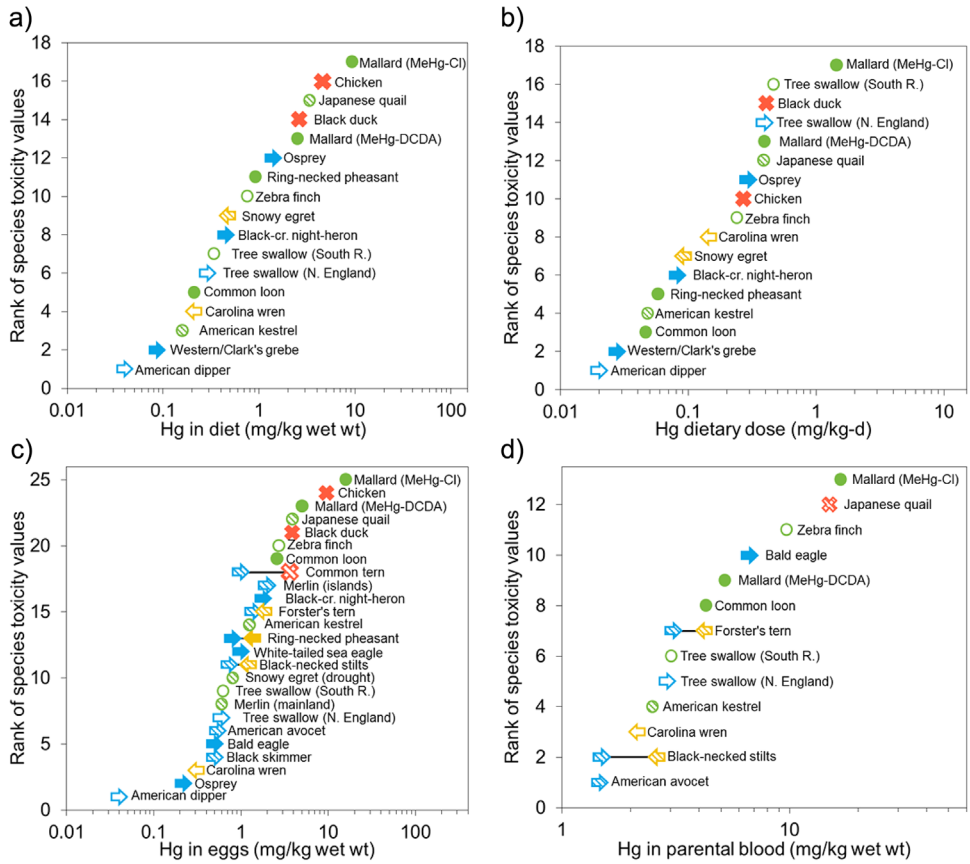

Figure 4. Responses of 23 bird species to methylmercury exposure in laboratory and field studies, based on (**a**) Hg in diet, (**b**) Hg dose, (**c**) Hg in eggs, and (**d**) Hg in parental blood. Blue right-facing arrow indicates no-observed-adverse-effect level; yellow left-facing arrow indicates lowest-observed-adverse-effect level; green circle indicates effect threshold; red X indicates severe effect. Bird size classes are shown as open symbols (small birds, 12–54 g), hatched symbols (medium birds, 120–423 g), and filled symbols (large birds, 794–5500 g).

(Figure 4) and feeding guild (Supplemental Data, Figure S5). Bird size categories were defined as small (12–54 g), medium (120–423 g), and large (794–5500 g), based on natural breaks in the data set as well as the approximate body weight threshold for increased paracellular absorption [137]. Feeding guilds were defined as piscivores, insectivores, omnivores, terrestrial carnivores, and herbivores.

Figure 4 shows that large birds tend to be less sensitive than small or medium-sized birds on the basis of dietary and blood Hg concentrations, with a few exceptions (i.e., common loon and Japanese quail). This difference is somewhat less apparent on an egg Hg basis. Avian body size and taxonomy are not necessarily independent, and thus, it is worth examining whether trends in Hg sensitivity appear more closely related to body size or phylogeny. Although in the present data set the "small" body size category represents only passerine species, the "medium" size category includes 4 different taxonomic orders, and the "large" size category includes 6 orders. It seems unlikely that purely taxonomic differences in sensitivity would coincidentally align with differences in body size, given the large number of orders represented. Conversely, 2 orders are represented by both medium and large species, and these orders present a mixed picture of the relative importance of body size versus taxonomy in affecting MeHg sensitivity. In the Pelecaniformes, the medium-sized species represented in the current data set (snowy egret) exhibits greater sensitivity compared with the large species (black-crowned night-heron). However, in the Galliformes, the medium-sized Japanese quail exhibits sensitivity similar to that observed for larger ring-necked pheasants. It seems likely that both taxonomy and body size may influence sensitivity to MeHg; but overall, the available data support further consideration of body weight in TRV development.

Theoretically, the calculation of dietary doses is supposed to bridge the gap among different size classes of birds by accounting for interspecies differences in food ingestion (and Hg intake) per unit of body weight. Indeed, on a dose basis, the bird size classes are more evenly interspersed with respect to sensitivity. However, if dose calculations accurately reflected differences in Hg intake and elimination, then the sensitivity rankings by dose would resemble those based on tissue Hg because tissue concentrations are a function of Hg intake and elimination rates. In fact, sensitivity rankings based on dose do not resemble those based on egg or blood Hg. For example, tree swallows appear to be moderately sensitive based on their response to Hg on the basis of dietary, egg, and blood Hg concentrations; yet, on a dose basis, they appear highly insensitive. These results suggest that dose-based TRVs for Hg should not be extrapolated among different size classes of birds.

Table 3 summarizes the ranges of effect thresholds and LOAELs by bird size class, as estimated from the available data. Typical ranges and outlying thresholds are identified. Observations of severe effects are also identified and defined for comparison purposes as >50% reproductive impairment relative to controls or reference organisms. The limitations of dose as an exposure metric again are apparent, as dose is the exposure metric for which the observations of severe effects most frequently overlap with the typical range of effect thresholds. Among the effect thresholds identified as extreme values, sensitive outliers include the common loon on a dietary basis and the Carolina wren on an egg basis. The thresholds for both of these species are uncertain because of confounding factors related to prey availability (loons) and predation pressure (wrens). The adverse effect observed in Carolina wrens was related to adult behavior (nest abandonment) rather than embryotoxicity [110]; in fact, on an adult blood basis, the Carolina wren effect threshold does not appear to be an extreme value. Carolina wrens had relatively low egg Hg concentrations relative to blood Hg levels compared with most other species for which both tissue types were evaluated (see Table 2).

At the insensitive end of the spectrum, outlying effect thresholds include the mallard for all exposure metrics, as well as the Japanese quail on a dietary concentration basis and the zebra finch on a blood basis. As previously discussed (see the section *Mallard studies*), multiple lines of evidence indicate that mallards are among the least sensitive species to Hg. Also, the dietary concentrations for both mallards and quail apply to a dry feed mixture, in which both Hg and nutrients may be more concentrated than in a natural diet. Thus, there are substantial uncertainties associated with most of the results identified in Table 3 as extreme values, and these values are not recommended as the basis for predictive risk thresholds to be extrapolated to other species.

Mechanistic studies reviewed by Robinson et al. [131] and Eagles-Smith et al. [132] suggest that feeding guild might affect species sensitivity to Hg. However, sensitivity trends related to feeding guild are not readily apparent on the basis of dietary concentrations, doses, or egg concentrations (Supplemental Data, Figure S5). On the basis of blood concentrations,

Table 3. Summary of estimated reproductive effect thresholds and LOAELs for birds of different size, with severe effect observations shown for comparison

		Hg EC20s, effect thresholds, and LOAELs (mg/kg wet wt)		
Exposure metric	Bird size[a] (*n*)	Typical range	Extreme values	Severe effect observations (mg/kg wet wt)[b]
Diet	Small–medium (6)	0.16–0.75	3.3 (Japanese quail)	0.8–8
	Large (8)	>0.45–>1.4	0.2 (common loon), 2.5–9.3 (mallard)	2.6–9.2
Dose	Small–medium (6)	0.05–0.5	None	0.2–0.9
	Large (8)	0.05–>0.3	0.4–1.2 (mallard)	0.2–0.5
Egg	Small–medium (11)	0.6–2.7	0.3 (Carolina wren), 3.9 (Japanese quail)	1.2–19[c]
	Large (9)	>1–2.6	5.0–16 (mallard)	3.9–17
Blood	Small–medium (7)	2.1–4.2	9.7 (zebra finch)	10–31
	Large (3)	4.3–>6.7	15 (mallard)	17

[a]Bird size ranges are based on average adult female body weight as small = 12–54 g, medium = 120–423 g, and large = 794–5500 g.
[b]Severe effects are defined for comparison purposes as >50% effect compared to control or reference organisms.
[c]Low end of severe effect range is estimated for snowy egret, lower Carson River system, 1997 [75]; data from 2006 in the same system showed no such effect despite higher egg Hg concentrations [174]. Excluding snowy egrets, the severe effect range for egg Hg in small–medium birds is 3.7–19 mg/kg.
EC20 = 20% effect concentration; LOAEL = lowest-observed-adverse-effect level.

piscivores are less sensitive than insectivores; but the number of species in the blood-based analysis is more limited than for other exposure metrics. If similar trends exist on a dietary or egg basis, they may be obscured by differences related to body weight as well as differences in study design and inclusion of unbounded NOAELs and LOAELs in the toxicity data set. Additional research is needed to understand the extent to which feeding guild can be used as a predictor of species sensitivity to Hg.

COMPARISON WITH EXISTING TRVS

Previously published TRVs for protection of birds from the adverse effects of Hg are summarized in Table 4. Most of the previously published TRVs are based on dietary exposures (concentration and/or dose) and derive from seminal TRV development efforts in the 1990s [97,98]. Those original TRVs adopted a conservative interpretation of the mallard studies that were available at the time, and they employed additional uncertainty factors to address data gaps. Two recent publications [3,22] proposed TRVs on the basis of diet and/or tissue based on more current reviews of the avian toxicity literature. Figure 5 compares these previously published TRVs for Hg based on diet, dose, egg, and blood exposures with the reproductive toxicity data set compiled for the present review.

Diet-based and dose-based TRVs

Most of the existing diet-based and dose-based TRVs are lower than the lowest effect thresholds or LOAELs shown in Figure 5, some by more than an order of magnitude. To understand these differences, we review the derivation of the previously published TRVs. Additionally, as a measure of the TRVs' reasonableness, we compare the diet-based TRVs to estimates of preindustrial background Hg concentrations in prey fish. This comparison is appropriate because bird populations have persisted for millennia despite naturally occurring Hg exposures; thus, at least at the population level, Hg exposures at or below levels prevalent over an evolutionary timescale should not be expected to cause adverse effects.

Derivation of existing TRVs. With the exception of the TRVs reported by Zhang et al. [22], all of the diet-based and dose-based TRVs are based on mallard studies by Heinz [77,88–90]. Even though more recent data show that mallards are relatively insensitive to Hg, the mallard-based TRVs derived from Heinz [77,88–90] are lower than necessary for several reasons. First, they are based on identification of the lowest-dose group from the 1970s mallard studies as a LOAEL. This interpretation is not supported by subsequent investigations, and it places undue weight on egg production in studies that used artificial incubation, which induced ducks to lay many more eggs than they would in a natural environment (see the section *Mallard studies*). Second, many of the TRVs incorporate LOAEL to NOAEL and interspecies uncertainty factors to address data gaps, which are no longer applicable given the large amount of avian toxicity data generated since those TRVs were derived. Third, several of the diet-based TRVs entail dose extrapolation from the mallard (a large bird) to much smaller bird species and subsequent back-calculation of diet concentrations for the smaller species. As previously discussed (see the section *Body weight and dose extrapolation*), such dose-based

Table 4. Previously published toxicity reference values (TRVs) for Hg effects on birds

Source (abbreviation)	TRV			Basis per TRV developers[a]
	Hg dose (mg/kg/d)	Hg in diet (mg/kg wet wt)	Hg in avian tissue (mg/kg wet wt)	
Sample et al. [98] (ORNL)	0.0064	0.005	NA	Mallard reproduction LOAEL [77], 10× LOAEL-to-NOAEL uncertainty factor; dose extrapolated to diet of American robin
Zhang et al. [22] (CRAES-SSD)	0.00309	0.00956	NA	SSD, combines multiple end points (biochemical, behavioral, reproductive, mortality); HC5 dose extrapolated to diet of night heron, little egret, and Eurasian spoonbill
Zhang et al. [22] (CRAES-CSA)	0.005	0.01547	0.365 (blood)	White ibis reproduction LOAEL [108], 2× LOAEL-to-NOAEL uncertainty factor; dose extrapolated to 3 species' diet (as above)
USEPA [97,181] (US GLI)	0.013	0.02	NA	Mallard reproduction LOAEL [77], 3× interspecies uncertainty factor, 2× LOAEL-to-NOAEL uncertainty factor; dose extrapolated to diet of belted kingfisher, herring gull, and bald eagle
European Commission [100] (EU)	NA	0.022	NA	Mallard reproduction LOAEL [77], 2× LOAEL-to-NOAEL uncertainty factor, 10× general uncertainty factor
Environment Canada [99] (Canada)	0.031	0.033	NA	Mallard reproduction [77], geometric mean of NOAEL and LOAEL, where NOAEL estimated using 5.6× LOAEL-to-NOAEL uncertainty factor; dose extrapolated to diet of Wilson's storm petrel
Oregon DEQ [9] (Oregon-Ind, Oregon-Pop)	0.013 (Ind), 0.026 (Pop)	0.074 (Ind), 0.15 (Pop)	0.5 (egg, Ind), 2.5 (egg, Pop)	Protection of individual birds based on NOAEL (Ind) and avian populations based on LOAEL (Pop). Doses apparently from USEPA [97]; doses extrapolated to diet of great blue heron. Egg TRV for individuals is bald eagle productivity NOAEL [39]; egg TRV for populations calculated with 5× NOAEL-to-LOAEL uncertainty factor
Ontario Ministry of the Environment [182] (Ontario)	0.064	NA	NA	Mallard reproduction LOAEL as identified by Sample et al. [98]
Shore et al. [3] (Shore-SSD)	NA	NA	0.6 (egg)	Species sensitivity distribution, avian reproduction

[a]The lowest-observed–adverse effect levels and no-observed–adverse effect levels identified by past toxicity reference value (TRV) developers are outdated (mallard), not well supported (ibis), or misidentified (eagle); see text.

ORNL = Oak Ridge National Laboratory; CRAES = Chinese Research Academy of Environmental Sciences; SSD = species sensitivity distribution; CSA = critical study approach; USEPA = US Environmental Protection Agency; GLI = Great Lakes Initiative; DEQ = Department of Environmental Quality; HC5 = hazardous concentration for 5% of species; Ind = individual; Pop = population; LOAEL: lowest-observed-adverse-effect level; NOAEL: no-observed-adverse-effect level; NA = not available.

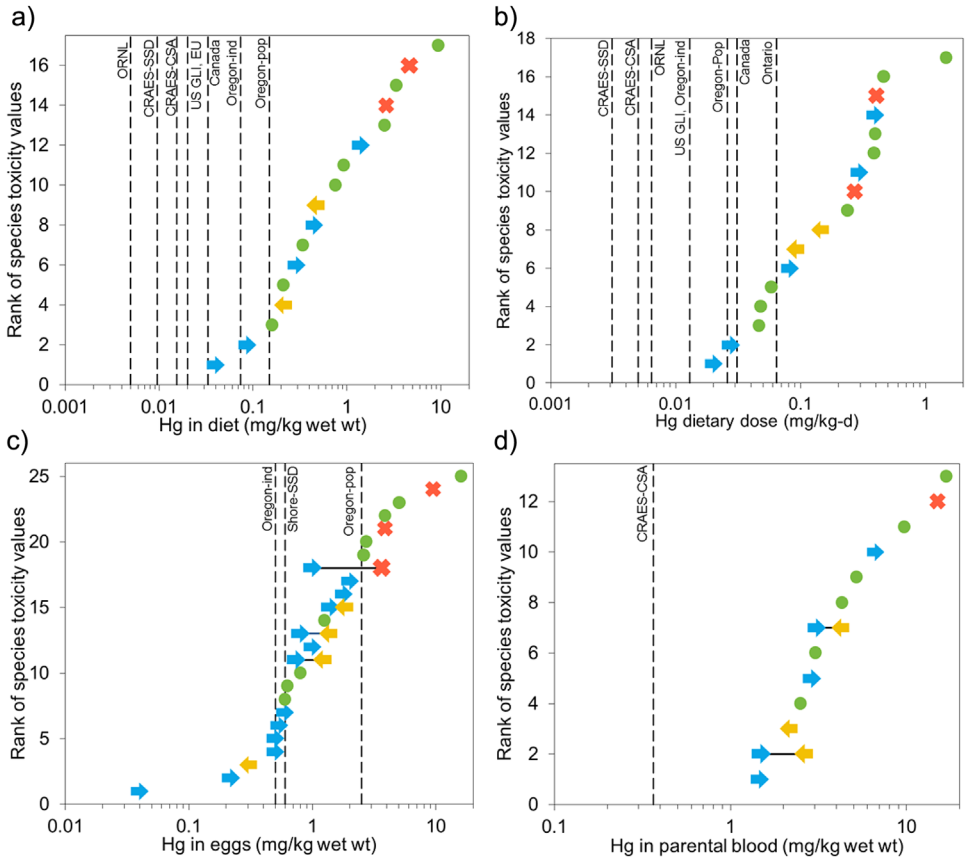

Figure 5. Comparison of previously published toxicity reference values with avian exposure–response data set compiled for the present review, based on (**a**) Hg in diet, (**b**) Hg dose, (**c**) Hg in eggs, and (**d**) Hg in parental blood. Vertical lines indicate toxicity reference values. Blue right-facing arrow indicates no-observed-adverse-effect level; yellow left-facing arrow indicates lowest-observed-adverse-effect level; green circle indicates effect threshold; red X indicates severe effect. TRV sources are shown in Table 4. CRAES = Chinese Research Academy of Environmental Sciences; CSA = critical study approach; EU = European Union; Ind = individual; ORNL = Oak Ridge National Laboratory; Pop = population; SSD = species sensitivity distribution; US GLI = US Great Lakes Initiative.

extrapolations between large and small species tend to distort interspecies sensitivity patterns. Thus, although data limitations meant that the mallard-based TRVs were appropriate at the time they were originally derived, they are now outdated.

Zhang et al. [22] developed avian TRVs for MeHg on behalf of the Chinese Research Academy of Environmental Sciences using 2 approaches: the critical study approach and the species sensitivity distribution approach. The critical study approach is like that used to derive the mallard-based TRVs in that a single toxicity study is identified as being appropriately representative of sensitive species targeted for protection, and the results of that study are adapted using uncertainty factors and interspecies extrapolation methods to develop TRVs. The species sensitivity distribution approach compiles all available and relevant toxicity test results for taxa of interest and then estimates a quantitative species sensitivity distribution function. A target percentile of the distribution function, often the 5th percentile (5% hazard concentration [HC5]), is then selected as the TRV. Both approaches have precedents in existing environmental management arenas. For example, the USEPA uses the critical study approach in the development of toxicity criteria for human health risk assessment and the species sensitivity approach in the derivation of aquatic life criteria for surface water. Although the basic methods are widely accepted, Zhang et al.'s [22] applications of both are problematic.

Using the critical study approach, Zhang et al. [22] identified the white ibis study of Frederick and Jayasena [108] as the most appropriate basis for avian TRVs. As previously discussed (see the section *White ibis study*), that study did not yield a clear dose–response relationship. Although Zhang et al. [22] identified the lowest Hg treatment in that study as a LOAEL, the effect on fledgling production per female was not significant in the lowest treatment group, and it exceeded that of the control in a treatment group receiving greater Hg exposures. Thus, this TRV derivation is inconsistent with the authors' stated methods, which specify that the critical study should demonstrate a clear dose–response relationship for an ecologically relevant endpoint.

For the species sensitivity distribution approach, Zhang et al. [22] compiled NOAELs observed or estimated from controlled experiments for 10 species and used the resultant HC5s to derive dose-based and diet-based TRVs. In principle, the species sensitivity distribution approach provides a useful framework to incorporate a large amount of relevant data. However, the data set compiled by Zhang et al. [22] mixes several different endpoints of varying sensitivity and varying magnitude of effect, ranging from biochemical endpoints to mortality. As a result, the relative sensitivity of the test species to MeHg is not necessarily accurately reflected, and the biological response associated with the HC5 cannot be defined. The inclusion of mortality results is potentially underprotective because reproductive effects tend to be more sensitive than mortality in Hg-exposed birds. Conversely, inclusion of biochemical endpoints adds uncertainty and is potentially overprotective because the magnitude of the response that would correspond to an ecologically relevant effect is unknown.

For this reason, endpoints such as biochemical parameters, immune function, and behavior often are excluded from TRV derivation [153], as they are in the present review. In the case of chicken sensitivity, the magnitude of effect identified by Zhang et al. [22] as a LOAEL (i.e., a 2% decrease in body weight compared with control [154]) is not ecologically relevant. Despite the very small effect reported (i.e., 2%), the chicken LOAEL was divided by a 20-fold uncertainty factor to account for study duration and lack of a NOAEL, causing the chicken to be identified as highly sensitive to MeHg. Such an uncertain datum should have been omitted from the data set. Zhang et al. [22] also included data from a pheasant toxicity test using ethylmercury p-toluene sulfonanilide [52], although the toxicity of this compound relative to MeHg is uncertain. Overall, the most sensitive values in the species sensitivity distribution are questionable for the various reasons presented above, resulting in questionable TRVs.

Comparison with natural background concentrations. Because Hg is naturally occurring (e.g., in volcanic eruptions, natural seeps, geological deposits) and bioaccumulative, there must be a lower limit to the Hg concentrations in prey that could plausibly harm bird populations; that is, TRVs should not be lower than naturally occurring Hg concentrations in the normal prey of the bird species being assessed. However, as reviewed by Fuchsman et al. [155], it is challenging to define naturally occurring Hg concentrations in fish and other avian prey, because Hg released by humans to the environment over centuries has become globally distributed. Fuchsman et al. [155] evaluated 3 lines of evidence relevant to estimating natural background Hg concentrations in prey fish: a modeling exercise by Hope and Louch [156], Hg concentrations in control fish from toxicity experiments [157], and Hg concentrations in fish collected from areas minimally impacted by anthropogenic increases in aerial deposition of Hg and sulfur [158–160]. Sulfur deposition is relevant because it contributes to increases in Hg methylation and subsequent bioaccumulation [115]. These lines of evidence indicated that average naturally occurring Hg concentrations in forage fish are roughly 0.03 mg/kg to 0.1 mg/kg, with greater concentrations (on the order of 0.1–0.3 mg/kg) expected in predatory fish [155]. By this estimate, all of the previously published diet-based avian TRVs for Hg are similar to or lower than naturally occurring Hg concentrations in fish. As such, these TRVs would be expected to overpredict risks to piscivorous birds.

In contrast, the typical diet-based Hg threshold ranges identified in the present review for small to medium-sized birds are slightly greater than estimated naturally occurring Hg concentrations in forage fish, while the typical diet-based threshold ranges for large birds are greater than estimated naturally occurring Hg concentrations in larger fish (Table 3). The data set underlying the typical threshold range for small to medium-sized birds includes few piscivorous species. Thus, it would be more appropriate to compare the diet-based threshold ranges for these bird species to preindustrial background Hg concentrations in invertebrate prey, but no such background estimates are available for comparison. However, most invertebrates and other prey normally contain lower Hg concentrations than are present in fish. In summary, from an evolutionary perspective, the Hg threshold ranges identified in the present review seem more reasonable than previously published diet-based TRVs.

Egg-based TRVs

We identified 3 egg-based TRVs from 2 sources [3,9], all of which fall within the typical threshold range for Hg in eggs. Specifically, Shore et al. [3] identified an HC5 of 0.6 mg/kg. The Oregon Department of Environmental Quality [9] identified egg-based TRVs specifically for protection of ospreys and eagles, with a lower TRV targeting protection of individual birds and a higher TRV targeting protection of populations.

Shore et al. TRV. Shore et al. [3] assembled egg-based NOAELs and LOAELs for Hg effects on reproduction in 19 bird species and applied a species sensitivity distribution approach to the set of LOAELs ($n = 10$). We assembled a substantially different set of egg-based EC20s, NOAELs, and LOAELs for Hg. For example, Shore et al. [3] included a LOAEL of 1 mg/kg in eggs based on older mallard studies, whereas we identified an EC20 from the same studies as 2.5 mg/kg (see the section *Mallard studies*). As another example, Shore et al. [3] included a LOAEL of 1.15 mg/kg for white-tailed sea eagles (*Haliaeetus albicilla*) from Helander et al. [42], but the authors of that study attributed the observed effects to DDE rather than Hg, such that only a NOAEL of 1 mg/kg can be appropriately identified for Hg. Despite differences in the underlying data sets, the Shore et al. [3] TRV is consistent with the exposure–response data compiled in the present review. We identified an effect at an egg concentration lower than 0.6 mg/kg in only 1 of 22 species included in Figure 4, and that LOAEL (for Carolina wrens) is relatively uncertain. The Shore et al. [3] egg TRV is intended to be protective of 95% of species and appears to be consistent with that goal.

Oregon TRVs. Oregon state law requires that TRVs for the protection of bird populations be identified based on LOAEL exposures, whereas TRVs for the protection of individual birds (i.e., for threatened and endangered species) must be identified based on NOAEL exposures. The Oregon Department of Environmental Quality [9] stated that the Hg egg-based TRV for protection of individual birds (0.5 mg/kg) was based on a NOAEL for bald eagle eggs from Wiemeyer et al. [39]. The Oregon Department of Environmental Quality derived the population-level TRV by multiplying the individual-level TRV by a default NOAEL to LOAEL uncertainty factor of 5. In fact, Wiemeyer et al. [39] did not provide a bald eagle NOAEL, although the authors did cite an egg concentration from Wiemeyer et al. [38] for comparison purposes. That comparison value was based on the pheasant toxicity study of Fimreite [25], in which the lowest Hg concentration in pheasant eggs from the LOAEL dose group was 0.5 mg/kg. The identification of this concentration as a NOAEL is thus questionable, and the derivation of a LOAEL from this value using a default uncertainty factor could be underprotective. Nevertheless, the population-based TRV lies within the typical threshold range for Hg in bird eggs. The Oregon Department of Environmental Quality [9] TRV for protection of individual eagles is based on a misinterpretation of historical studies, but it is coincidentally equal to a more recent bald eagle NOAEL [161] and, thus, achieves its target level of protection.

Blood-based TRVs

The present review represents the first broad compilation of avian blood Hg data associated with toxicity studies. As such, only 1 existing blood-based TRV is available for comparison [22], although some researchers have also used the calculated EC10 from Jackson et al. [110] as a basis for comparison (see the section *Carolina wren study*). Zhang et al. [22] identified a blood-based TRV using the critical study approach, based on the white ibis study of Frederick and Jayasena [108]. Analogous to their diet-based TRV, Zhang et al. [22] identified the lowest Hg treatment from that study as a

LOAEL and further modified the corresponding Hg blood concentration with a LOAEL to NOAEL uncertainty factor to identify a TRV (Table 4). As previously discussed (see the section *Diet-based and dose-based TRVs*), this interpretation of the white ibis study is problematic because of the lack of a dose–response relationship or a statistically significant effect on key endpoints. Indeed, the white ibis blood Hg concentration of 0.73 mg/kg would be an outlier compared with the blood Hg results assembled in Figure 4, further supporting our conclusion that this exposure is not a LOAEL. Similarly, the Carolina wren EC10 calculated by Jackson et al. [110] as 0.7 mg/kg is not well supported by the underlying data from that study. The data provisionally support identification of an unbounded LOAEL for Carolina wrens of 2.1 mg/kg Hg in blood, with the recognition that factors other than Hg exposure (e.g., predation pressure, habitat, small sample size) may have affected the results (see the section *Carolina wren study*).

We identified typical ranges of effect thresholds for Hg in avian blood as 2.1 mg/kg to 4.2 mg/kg for small to medium-sized birds and 4.3 mg/kg to >6.7 mg/kg for large birds (Table 3). Studies involving lower Hg exposures found no evidence of adverse effects when parental blood Hg concentrations were 1.5 mg/kg or lower in American avocets and black-necked stilts [14,162]. The bluebird study of McCullagh et al. [59] is also consistent with a lack of adverse effects as a result of adult blood Hg concentrations $\leq$ 1.5 mg/kg, although interpretation of possible effects at greater concentrations in that study was uncertain because of the small number of bluebirds exposed at such levels (see the section *Other supporting studies*). In summary, the data compiled for the present review indicate that Zhang et al.'s [22] blood-based TRV and Jackson et al.'s [110] blood-based EC10 are lower than necessary by factors of approximately 4 and 2, respectively.

CONCLUSIONS

We conducted a comprehensive review of MeHg effects on avian reproduction, using transparent and objective criteria for study inclusion, evaluating uncertainties and biases in each study reviewed and assigning confidence levels to the compiled data. Where multiple studies were available for the same species, we evaluated their consistency and identified possible reasons for inconsistencies where noted. The resulting data set compiles data documenting the occurrence or lack of observed adverse effects attributed to Hg exposure in 23 bird species. We also reviewed information relevant to the extrapolation of these data to other species, including issues related to avian body size and feeding guild as well as Hg bioaccessibility and chemical interactions. Based on the present review, typical ranges of Hg thresholds for adverse effects on avian reproductive success are approximately 0.2 mg/kg to >1.4 mg/kg in diet, 0.05 mg/kg/d to 0.5 mg/kg/d on a dose basis, 0.6 mg/kg to 2.7 mg/kg in eggs, and 2.1 mg/kg to >6.7 mg/kg in parental blood. Within these ranges, the observed thresholds vary for different size classes of birds (Table 3). Severe effects (>50% reduction of reproductive success) are generally limited to exposures greater than the threshold ranges, although this trend is less reliable when exposure is expressed on a dose basis. This analysis is intended to support predictive ecological risk assessments that in turn will support realistic cost–benefit and risk–benefit analyses with respect to environmental decisions such as remediation planning for contaminated sites.

The effect threshold ranges identified in the present review are greater than previously published TRVs on the basis of dietary and blood-based exposures, whereas they are consistent with previously published egg-based TRVs. The discrepancy among diet-based TRVs (including related dose-based TRVs) is primarily the result of past reliance on a conservative interpretation of a mallard toxicity study from the 1970s, which is no longer supportable based on subsequent investigations by the same researchers. Indeed, the continuing widespread reliance on a single, dated mallard study could be viewed as a failure to use available information to advance the science of TRVs and underscores the need for critical review. Certain other TRVs also differ from those proposed in the present review because of specific differences in interpretation of particularly uncertain studies, notably in the identification of a LOAEL for white ibis despite the lack of a dose–response relationship in the subject study. Based on the systematic methodology used and the comparison of TRVs to background Hg concentrations in fish, we contend that the TRVs presented in the present review are more supportable than those previously published by others.

Although MeHg effects on birds have been studied extensively, some important research needs remain. In particular, the interpretation of controlled experimental results would benefit greatly from research to improve the understanding of MeHg bioaccessibility to birds in wild prey versus laboratory-spiked feed. A comparative study of the metabolism and toxicity of MeHg cysteine (the form of MeHg found in fish) versus MeHg chloride and MeHg dicyandiamide is also warranted. Techniques to apply controlled experimental exposures to wild loons are also intriguing because prey availability and Hg exposures are closely intertwined in this key indicator species' habitat, complicating the interpretation of field studies. Further work is needed to improve methods of interspecies extrapolation that limit the distortions introduced by the current practice of applying body weight–normalized doses, which implicitly assumes that body weight–normalized intake governs interspecies differences without regard for differences in elimination rates. Understanding the physiological and genetic bases for differences in sensitivity to MeHg would greatly aid interspecies extrapolation. Research is also needed to clarify interpretation of Hg–Se ratios in birds and their prey, especially when Se concentrations approach a toxicity threshold, although existing data are already sufficient to recommend Se analyses for all Hg exposure and toxicity studies. In the meantime, ecological risk assessors evaluating species not tested for MeHg toxicity should strive to apply toxicity data from species of similar body weight.

Supplemental Data—The Supplemental Data are available on the Wiley Online Library at DOI: 10.1002/etc.3606.

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Data Availability—Data are provided in the online Supplemental Data and in the cited references.

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U.S. Department of the Interior
Fish and Wildlife Service

Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California

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EXECUTIVE SUMMARY

Introduction

In January 2001, the U.S. Environmental Protection Agency (EPA) developed a new recommended water quality criterion for methylmercury, under section 304(a) of the federal Clean Water Act. The criterion, a tissue residue concentration (TRC) of 0.3 milligrams per kilogram wet weight (mg/kg, ww) of methylmercury in edible portions of fish and shellfish, was designed to protect human health against adverse effects of methylmercury toxicity. The EPA intends to propose this human health criterion in California in order to fulfill consultation obligations under the federal Endangered Species Act (ESA) stemming from promulgation of the California Toxics Rule in 2000. As part of that ESA consultation, the EPA agreed that the human health criterion should be sufficient to protect federally listed aquatic and aquatic-dependent wildlife species in California. In proposing this criterion, the EPA must complete a biological evaluation of the effects of the proposed action on federally listed and proposed threatened and endangered species and critical habitat within California.

To facilitate this biological evaluation, the EPA's Region 9 entered into an Intergovernmental Agreement (IAG) with the U.S. Fish and Wildlife Service's (Service) Sacramento Fish and Wildlife Office, Environmental Contaminants Division (ECD). The primary objective of this IAG was to conduct the analyses necessary to determine whether the TRC may affect any federally listed species in California. This document presents the risk assessment methodology, developed collaboratively by scientists from both the Service and EPA, used to perform these analyses. This document also provides the ECD's interpretation of the results and our conclusions regarding the TRC's effect on the species evaluated. **These conclusions do not represent the results of consultation under Section 7 of the ESA, rather they were based solely on our current understanding of methylmercury's behavior in aquatic ecosystems and the toxicological foundation from which the risk assessment methodology was developed.** The results of these analyses may be used by the EPA in making ESA-related effects determinations for the subsequent biological evaluation. Any such determinations are solely the responsibility of the EPA.

Evaluating Wildlife Protection

The 0.3 mg/kg TRC represents a generic dietary concentration intended to be the maximum allowable concentration of methylmercury in freshwater and estuarine fish and shellfish that would protect human consumers, based on an average consumption of 17.5 grams of fish and shellfish per day. It is possible to develop similar dietary concentrations for wildlife species, provided sufficient life history and toxicity data exist. However, the protection of wildlife cannot be evaluated by simply comparing a protective generic dietary concentration determined for any given species with the generic dietary concentration proposed as the human health criterion.

One of the primary principles in constructing a risk assessment to evaluate wildlife protection is the need to consider the food chains of aquatic ecosystems in terms of trophic levels. Food chains, defined in their most simplistic form, start with trophic level 1 (TL1) plants. These plants are consumed by trophic level 2 (TL2) herbivores, which are consumed by trophic level 3 (TL3) predators, which are then consumed by the top predators in trophic level 4 (TL4). Consideration of trophic levels is necessary because methylmercury is a highly bioaccumulative pollutant which concentrates in biological tissues and biomagnifies as it moves up through successively higher trophic levels of a food chain. Organisms higher on the food chain contain greater methylmercury concentrations than those lower on the food chain. If fish and shellfish from TL2 contain tissue methylmercury concentrations of 0.3 mg/kg, then biota from TL3 and TL4 will have higher tissue concentrations. Conversely, if TL4 biota have tissue concentrations of 0.3 mg/kg, biota from TL2 and TL3 will have lower tissue concentrations.

There are numerous challenges in taking a trophic level approach to evaluating the TRC for its protectiveness of multiple listed fish and wildlife species. Most predators that feed from aquatic food webs are opportunistic and will consume prey from more than one trophic level. These dietary habits vary widely among different species and can change seasonally. Thus, methylmercury concentrations in any trophic level that may be protective of one species may place another consumer from the same water body at increased risk. In addition, different species of wildlife vary in their sensitivity to methylmercury toxicity. Since the toxicological literature contains dosing studies from very few species of wildlife, most ecological risk assessment methodologies, including this one, use uncertainty factors to account for unknown variations in sensitivity among species.

Consideration of these food chain dynamics in a risk assessment for wildlife requires trophic level-specific methylmercury concentrations. The manner in which the TRC is to be implemented for protection of human health will determine the limiting concentrations of methylmercury in the various trophic levels. Under a strict interpretation of the criterion (*i.e.*, no fish tissue exceeding the TRC), and given an understanding of biomagnification relationships between trophic levels, it is possible to set the TRC as the limiting concentration for TL4 biota and then estimate the tissue concentrations expected for biota in TLs 2 and 3. However, if a specific human population consumes only TL2 or TL3 fish from a water body, then the TRC could be applied to just those trophic levels. This would result in methylmercury concentrations in TL4 biota that are higher than the TRC and increase the exposure risks for wildlife.

For this evaluation, two approaches were used to determine trophic level-specific methylmercury concentrations that could be expected from the TRC. The Average Concentration TL Approach estimated these concentrations based on the human consumption rate of 17.5 g per day, with a defined trophic level composition (*i.e.*, a certain percentage from each trophic level). The Highest TL Approach set the TRC as the limiting concentration for TL4 biota, and then estimated the subsequent concentrations for TLs 2 and 3. Both approaches required assumptions about the relationships of bioaccumulation and biomagnification between trophic levels.

Average Concentration Trophic Level Approach

This approach estimated the methylmercury concentrations in each trophic level consumed by humans that, when combined, would correspond to the overall dietary concentration of 0.3 mg/kg. The EPA's human health methylmercury criterion document presented a national average intake rate of 17.5 grams of fish per day based on an assumed percentage from each individual trophic level: TL2 - 21.7% (3.8 g), TL3 - 45.7% (8.0 g), TL4 - 32.6% (5.7 g), for a total of 100% (17.5 g).

Based on national bioaccumulation data, it was determined that methylmercury concentrations in TL4 biota are generally 4.0 times those seen in TL3 biota. Concentrations in TL3 biota are generally 5.7 times those seen in TL2 biota. Using these methylmercury biomagnification factors and the assumed trophic level composition of the average human diet, the concentration of methylmercury in TL2, TL3, and TL4 fish and shellfish that will maintain an overall human dietary concentration of 0.3 mg/kg methylmercury can be calculated. The resulting concentrations are: TL2 - **0.029 mg/kg**; TL3 - **0.165 mg/kg**; and TL4 - **0.660 mg/kg**.

Highest Trophic Level Approach

This approach would set the proposed TRC of 0.3 mg/kg as the limiting concentration in TL4 biota. Concentrations expected in TLs 2 and 3 were then estimated by dividing by the appropriate biomagnification factors (*i.e.*, TL3 = TL4 concentration divided by 4, TL2 = TL3 concentration divided by 5.7). The resulting concentrations are: TL4 - **0.3 mg/kg**, TL3 - **0.075 mg/kg**; and TL2 - **0.013 mg/kg**.

This approach is the most conservative (*i.e.*, protective) method of establishing trophic level concentrations with the TRC. This is because it eliminates the possibility of different human populations exceeding the protective reference dose, assuming the national average consumption rate remains constant. Thus, a diet of 100 percent TL4 fish would maintain the overall dietary concentration of 0.3 mg/kg. Any other combination of trophic level foods in the diet (totaling 17.5 g per day) will maintain a dietary concentration at or below the protective level.

The trophic level methylmercury values for the two approaches were then used, along with dietary intake information for each species of concern, to evaluate the protectiveness of the TRC for aquatic and aquatic-dependent wildlife species at greatest risk from exposure to methylmercury.

Selection of Species

Based on the information available in the scientific literature, and given consideration of methylmercury's capacity to bioaccumulate and biomagnify in the aquatic food chain, this evaluation assumed that upper trophic level wildlife species (*i.e.*, predatory birds and mammals)

have the greatest inherent risk from exposure to methylmercury. In California these species are:

Southern Sea Otter (*Enhydra lutris nereis*)
California Least Tern (*Sterna antillarum brownii*)
California Clapper Rail (*Rallus longirostris obsoletus*)
Light-Footed Clapper Rail (*Rallus longirostris levipe*)
Yuma Clapper Rail (*Rallus longirostris yumaensis*)
Western Snowy Plover (*Charadrius alexandrinus nivosus*)
Bald Eagle (*Haliaeetus leucocephalus*)

The scientific literature was also reviewed to see whether the listed fish, reptile, and amphibian species may be protected under either trophic level approach. For fish species, the risk assessment was based solely on adverse effects associated with tissue methylmercury concentrations. The scientific literature contains little information on methylmercury risk to reptiles and amphibians.

Wildlife Values and Predicted Dietary Concentrations

A Wildlife Value (WV) represents the overall dietary concentration of methylmercury necessary to keep the daily ingested amount at or below a level at which no adverse effects are expected. The WV is analogous to the TRC for the human health criterion. For each species of concern, a WV was determined using body weight, total daily food ingestion rate, and a protective reference dose.

A predicted dietary concentration (DC) also represents an overall concentration in the diet, but is determined using the trophic level methylmercury concentrations expected under each TL approach and the trophic level composition of the species' diet. In effect, the percentage of each trophic level consumed is multiplied by the concentration expected for that trophic level. The resulting products are then summed to provide the total concentration of methylmercury in the diet.

The predicted DC for each species of concern was then compared to the WV determined to be protective for that species. If the predicted DC was at or below the WV then it was assumed that the species is not at risk from dietary exposure to methylmercury under that scenario. If the predicted DC is higher than the WV, it was assumed that the species would likely have a dietary exposure that may place it at risk for adverse effects from methylmercury toxicity.

Results of the Evaluation

Average Concentration Trophic Level Approach

Based on the analyses conducted for this evaluation, applying the TRC with the estimated trophic level methylmercury concentrations under the Average Concentration TL Approach may be

sufficiently protective for only two of the seven species considered: southern sea otter and Western snowy plover. **The five other species examined (California least tern; California, light-footed, and Yuma clapper rails; bald eagle) would likely have dietary exposures under this approach that may place them at risk for adverse effects from methylmercury toxicity**.

Highest Trophic Level Approach

This approach, with its lower estimated trophic level methylmercury concentrations, would provide a greater degree of protection than the Average Concentration TL Approach. Applying the TRC under the Highest TL Approach should be sufficiently protective for four of the seven species considered: southern sea otter, California clapper rail, Western snowy plover, and bald eagle. **Two of the species examined (California least tern and Yuma clapper rail) would likely have dietary exposures under this approach that may place them at risk for adverse effects from methylmercury toxicity**. The least tern may be at an elevated risk for methylmercury toxicity because of its small body size and its diet of exclusively TL3 fish. Although methylmercury concentrations for all three trophic levels are expected to be substantially lower under this approach, the estimated TL3 concentration of 0.075 mg/kg would still not be low enough to remove the potential risk of adverse effects from dietary methylmercury exposure for the least tern. The evaluation for the Yuma clapper rail, regardless of the WV used in the analysis, indicates this subspecies would likely have a dietary exposure under this approach that may place it at risk for adverse effects from methylmercury toxicity.

At this time, no conclusion can be drawn regarding the light-footed clapper rail. If this subspecies' sensitivity to methylmercury is the same as the California clapper rail and the analysis of its dietary composition is correct, the light-footed rail would likely have dietary exposures under this approach that may place them at risk. However, if other biological characteristics (*e.g.*, a greater ability to detoxify ingested methylmercury, lower diet-to-egg transfer efficiency) indicate a lower sensitivity to methylmercury, the evaluation results suggest this TL approach should be sufficiently protective for the light-footed rail. Research should be initiated to answer questions surrounding the relative sensitivity of this subspecies and to determine the appropriate trophic level methylmercury concentrations to provide sufficient protection against toxicity.

Fish

None of the data examined provided definitive answers regarding the level of protection for fish afforded by the TRC. **The methylmercury concentrations expected from applying the TRC under both trophic level approaches appear to be well below observed adverse effects concentrations; however, the trophic level concentrations expected under the Average TL Approach are much closer to these adverse effects concentrations.** Increasing emphasis on examining more subtle methylmercury-induced effects may reveal even lower tissue-based threshold effects concentrations for fish.

Reptiles and Amphibians

Too little is presently known about mercury bioaccumulation in reptiles and amphibians to allow for any comparative risk prediction capability based on bioaccumulation in fish. **The available scientific literature strongly suggests that both reptiles and amphibians can bioaccumulate methylmercury, although possibly less so than piscivorous birds and mammals with a greater daily reliance on aquatic prey. Until the appropriate toxicological data are generated, no definitive conclusions can be drawn about the protectiveness of either trophic level approach for the California red-legged frog, San Francisco garter snake, or giant garter snake.**

Discussion

The Service's Environmental Contaminants Division believes the analyses presented in this document represent the most current state of knowledge regarding the risk to California's listed species from dietary methylmercury. Conclusions about the protectiveness of the TRC for each species evaluated by the two trophic level approaches are summarized in Executive Summary (ES) Table 1. Of the two approaches evaluated, the Highest TL Approach affords a greater degree of protection for California's listed bird and mammal species than the Average TL Approach. The best currently available data on mercury toxicity in fish suggest that the TRC under either approach should be sufficiently protective of all listed fish in California; however, the trophic level concentrations expected under the Average TL Approach would be much closer to observed adverse effects concentrations described in the scientific literature. Although a lack of relevant data precludes any conclusions regarding the potential impact of the TRC on the reptile and amphibian species considered, the lower trophic level concentrations expected under the Highest TL Approach would afford a greater measure of protection than those expected under the Average TL Approach. **We believe that the TRC would not adequately protect all listed species in California; however, applying the TRC under the Highest TL Approach would reduce the number of species at risk.**

These conclusions reflect the interpretation of the evaluation results by the Service's Environmental Contaminants Division only, and are not intended to represent the views of those EPA or Service scientists who helped develop the risk assessment methodology. In addition, these conclusions do not constitute the results of consultation under Section 7 of the ESA.

Finally, it must be noted that the risk assessment methodology presented in this document was not applied to any wildlife species other than the federally listed species. Other non-listed wildlife may be potentially at risk under the TRC, due to their dietary dependence on aquatic ecosystems. **Using the same approach followed in this effort, regulatory agencies should be able to determine whether concentrations of methylmercury in fish tissue under the TRC may also pose a risk to non-listed wildlife species.**

ES Table 1. Protectiveness of EPA's Methylmercury Tissue Residue Criterion for Seven Federally Listed California Species.

Is the TRC Protective for...	Southern Sea Otter	Ca. Least Tern	Ca. Clapper Rail	Light-footed Clapper Rail	Yuma Clapper Rail	Western Snowy Plover	Bald Eagle
Under the Average TL Approach?	Yes	**No**	Yes	**No**	**No**	Yes	**No**
-with interspecies uncertainty factor of 3*	na	na	**No**	**No**	**No**	Yes	na
Under the Highest TL Approach?	Yes	**No**	Yes	Yes	**No**	Yes	Yes
-with interspecies uncertainty factor of 3*	na	na	Yes	**No**	**No**	Yes	na

(na - not applicable)

* - discussion of uncertainty is presented in Section III.D. of document

I. INTRODUCTION

I.A. Background

In January 2001, the U.S. Environmental Protection Agency (EPA) developed a new recommended water quality criterion for methylmercury, under section 304(a) of the federal Clean Water Act (CWA; 33 U.S.C. 1251 - 1376, as amended). The criterion, a tissue residue concentration (TRC) of 0.3 milligrams per kilogram wet weight (mg/kg, ww) of methylmercury in edible portions of fish and shellfish, was designed to protect human health against adverse effects of methylmercury toxicity. In order to fulfill consultation obligations under the federal Endangered Species Act (ESA; 16 U.S.C. 1531-1544, as amended) stemming from promulgation of the California Toxics Rule in 2000, the EPA intends to propose this criterion in the State of California. While EPA intends to propose this TRC as a human health criterion, the Agency agreed as part of the California Toxics Rule ESA consultation that the human health criterion should be sufficient to protect federally listed aquatic and aquatic-dependent wildlife species. As part of the proposal process, the EPA must complete a biological evaluation of the effects of the proposed action on federally listed and proposed threatened and endangered species (see Appendix) and critical habitat within California.

To facilitate this biological evaluation, the EPA's Region 9 entered into an Intergovernmental Agreement (IAG) with the U.S. Fish and Wildlife Service's (Service) Sacramento Fish and Wildlife Office, Environmental Contaminants Division (ECD). The primary objective of this IAG was to conduct the analyses necessary to determine whether the TRC may affect any federally listed species in California. This document presents the risk assessment methodology, developed collaboratively by scientists from both the Service and EPA, used to perform these analyses. The results of these analyses may be used by the EPA in making ESA-related effects determinations for the subsequent biological evaluation. Any such determinations are solely the responsibility of the EPA. However, this document also provides the ECD's interpretation of the analytical results and our conclusions regarding the TRC's effect on the species evaluated. These conclusions do not represent the results of consultation under Section 7 of the ESA, rather they were based solely on our current understanding of methylmercury's behavior in aquatic ecosystems and the toxicological foundation from which the risk assessment methodology was developed.

I.B. Evaluating Wildlife Protection

When sufficient methylmercury toxicity data exist to determine a dietary dose at which no adverse effects to an organism are expected, then it becomes a relatively simple process to calculate a protective methylmercury concentration in the overall diet, based on information about that organism's body weight and daily food consumption. The 0.3 mg/kg[1] TRC represents just such a generic dietary concentration for humans. The TRC is intended to be the maximum

[1] All concentrations are reported on a wet weight basis unless otherwise noted.

allowable concentration of methylmercury in freshwater and estuarine fish and shellfish that would protect human consumers, based on an average consumption of 17.5 grams of fish and shellfish per day.

However, the protection of wildlife cannot be evaluated by simply comparing a protective generic dietary concentration determined for any given species with the generic dietary concentration proposed by the human health criterion. One of the primary principles in constructing a risk assessment methodology to evaluate wildlife protection was the need to consider aquatic ecosystems in terms of trophic levels. Trophic levels are general classifications applied to the various biotic components of a food chain, and organisms are placed in these classifications depending on what they consume. Stated in its most simplistic form, trophic level 1 plants are consumed by trophic level 2 herbivores, which are consumed by trophic level 3 predators, which are then consumed by the top predators in trophic level 4. Predator-prey relationships in real-world ecosystems are generally more complex than this simple linear model, with a tendency for higher order predators to include prey from more than one trophic level in their diets. However, the risk assessment methodology employed in this evaluation was based on the assumption that the general concepts underlying the simple linear food chain model remain a valid approach for considering the trophic transfer of methylmercury in aquatic biota. Trophic levels used in this evaluation were based on definitions provided in Volume I of *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals* (U.S. Environmental Protection Agency, 1995a):

Trophic Level 1 - Plants and detritus
Trophic Level 2 - Herbivores and detritivores
Trophic Level 3 - Predators on trophic level 2 organisms
Trophic Level 4 - Predators on trophic level 3 organisms

This consideration of trophic levels was necessary because methylmercury is a highly bioaccumulative pollutant which concentrates in biological tissues and biomagnifies as it moves up through successively higher trophic levels of a food chain. The TRC was not derived by assuming specific methylmercury concentrations in any particular trophic level. Instead, 0.3 mg of methylmercury per kg of fish and shellfish tissue in a daily consumed average of 17.5 g was assumed to be protective for human populations eating from various trophic levels, rather than from any particular trophic level. However, due to the characteristics of methylmercury described above, aquatic food chains do not attain a steady-state condition wherein aquatic biota from all trophic positions exhibit the same tissue concentrations. Instead, organisms higher on the food chain contain greater concentrations than those lower on the food chain. For example, if fish and shellfish from trophic level 2 (*e.g.*, herbivorous fish) contain concentrations of 0.3 mg/kg, then biota from trophic levels 3 and 4 (*e.g.*, predatory fish) will undoubtedly have higher tissue concentrations. Conversely, if aquatic biota from the highest trophic level in the system have tissue methylmercury concentrations of 0.3 mg/kg, examination of lower order biota will show substantially lower tissue concentrations. Consideration of methylmercury's propensity to bioaccumulate and biomagnify as it is passed up the aquatic food chain was critical in this

evaluation as many higher order predators (*e.g.*, piscivorous birds and mammals) eat aquatic biota from a variety of trophic levels.

There are several challenges in evaluating the TRC for its protectiveness of multiple listed fish and wildlife species. The first involves determining the dietary characteristics of the species of concern (*e.g.*, ratio of daily food ingestion rate to body weight; trophic level composition of diet). Most predators that feed from aquatic food webs are opportunistic and will consume prey from more than one trophic level. Furthermore, the distribution of prey types they consume may vary seasonally. While an overall dietary methylmercury concentration can be calculated that will protect any given species, the amount of prey consumed from each trophic level is the driving factor influencing the amount of methylmercury ingested on a daily basis. The methylmercury concentration in the overall diet for any species is dependent on both the trophic level composition of its diet *and* the methylmercury concentrations in each of the trophic levels from which the species feeds. Without an understanding of this dietary composition, it is impossible to determine the limiting concentrations for each trophic level that will result in any calculated overall dietary concentration.

A second challenge is that these dietary characteristics vary widely from species to species. While one species may eat primarily from trophic level 2, another may prey predominantly on higher trophic level organisms. Methylmercury concentrations in any trophic level that may be protective of one species may place another consumer from the same water body at increased risk.

Another challenge is due to the potential for different species of wildlife to vary in their sensitivity to methylmercury toxicity. The toxicological literature contains dosing studies from very few species of wildlife, so most ecological risk assessment methodologies, including this one, use uncertainty factors to account for unknown variations in sensitivity among species. This is discussed in more detail in Section III.D., below.

In addition to the complexities of wildlife diets, another challenge involves how the TRC is to be implemented for protection of human health. Under a strict interpretation of the criterion (*i.e.*, no fish tissue exceeding the TRC), and given an understanding of biomagnification relationships between trophic levels, it may be possible to set the TRC for trophic level 4 biota and then estimate the tissue concentrations expected for biota in trophic levels 2 and 3. If the aforementioned dietary characteristics can be determined, the various trophic level methylmercury concentrations can then be used to evaluate their protectiveness for any given species. However, in implementing the criterion, adjustments may be made to account for site-specific or regional conditions regarding human consumption of fish and shellfish. These adjustments could include apportioning a fish intake rate to the highest trophic level consumed for a specific human population. This suggests that if a specific human population consumes only trophic level 2 or 3 fish from a water body, then the TRC could be applied to those trophic levels. The increased methylmercury concentrations in higher trophic levels resulting from this implementation could then increase the exposure for top wildlife predators.

II. APPROACHES TO EVALUATION

In order to evaluate the protectiveness of any given criterion expressed as a general concentration in the overall diet of a consumer eating from various trophic levels, it is first necessary to establish concentrations specific to each trophic level. As noted above, it is possible to set the human health criterion as the limiting concentration at trophic level 2, 3 or 4, depending on the particular fish consumption habits of the human population to be protected. Alternatively, varying concentrations in each trophic level could be calculated based on different combinations of the human dietary trophic level composition (*e.g.*, 90% trophic level 4 and 10% trophic level 3 vs. 50% trophic level 4, 40% trophic level 3, and 10% trophic level 2). Although a multitude of trophic level approaches are possible, this evaluation is focused on two options, each described below.

II.A. Average Concentration Trophic Level Approach

In the human health criterion development, the TRC was determined using a national average fish consumption rate of 17.5 g/day for the general population. This national average can be broken out by determining the percentage of fish and shellfish consumed from each of the three trophic levels (TL2, TL3, TL4). A trophic level breakout was presented in the human health criterion document, although this was not intended to be used in setting concentration limits for each trophic level. However, using this breakout to estimate individual trophic level concentrations that would maintain the overall dietary concentration of 0.3 mg/kg provides one way to evaluate the protectiveness of the TRC for species of concern. The following methodology describes the steps for conducting this approach.

The first step is to estimate the methylmercury concentrations in each trophic level consumed by humans that, when combined, would correspond to the overall dietary concentration of 0.3 mg/kg. In order to do this, several input parameters must first be identified:

%TL2 - Percent of trophic level 2 biota in diet
%TL3 - Percent of trophic level 3 biota in diet
%TL4 - Percent of trophic level 4 biota in diet
MTL3 - Food chain multiplier from TL2 to TL3 biota
MTL4 - Food chain multiplier from TL3 to TL4 biota

Food chain multipliers are values derived from relationships of bioaccumulation and biomagnification between trophic levels. These can be determined several ways, depending on the information available. For example, bioaccumulation factors (BAFs) are numeric values showing the amount of contaminant uptake into biota, relative to concentrations in the water column. These BAFs can be determined for each trophic level of aquatic biota. The food chain multiplier for any given trophic level is the ratio of the BAF for that trophic level to the BAF for the trophic level directly below.

For example: BAF for water to trophic level 4 = 680,000
BAF for water to trophic level 3 = 160,000

MTL4 = 680,000/160,000 = 4.25

Any methylmercury concentration estimated for trophic level 3 biota can then multiplied by the MTL4 to estimate the expected concentration in trophic level 4 biota.

If sufficient data on existing fish tissue methylmercury concentrations are available, food chain multipliers can also be established using the ratio of these concentrations between trophic levels.

For example: Average tissue concentration in TL4 fish = 0.45 mg/kg
Average tissue concentration in TL3 fish = 0.15 mg/kg

MTL4 = 0.45/0.15 = 3

For this evaluation, food chain multipliers were calculated from draft national BAFs presented in the EPA's methylmercury criterion document. Although these values are draft only, they were empirically derived from national data. If more site-specific BAF data exist for water bodies in California, they may be used in place of the draft values to calculate food chain multipliers.

Draft national BAF for trophic level 4 = 2,700,000
Draft national BAF for trophic level 3 = 680,000
Draft national BAF for trophic level 2 = 120,000

MTL4 = 2,700,000 / 680,000 = 4
MTL3 = 680,000 / 120,000 = 5.7

Having identified the above input parameters, the following additional terms are necessary to then construct the equation for calculating trophic level concentrations necessary to maintain the overall dietary concentration:

FDTL2 - concentration in food (FD) from trophic level 2
FDTL3 - concentration in food from trophic level 3 - (equivalent to FDTL2 × MTL3)
FDTL4 - concentration in food from trophic level 4 - (equivalent to FDTL2 × MTL3 × MTL4)

The overall dietary concentration (DC) of methylmercury can be expressed in the equation:

$$\mathbf{DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL3) + (\%TL4 \times FDTL4)} \quad \mathbf{(1)}$$

The equation can then be further arranged, substituting food chain multiplier equivalents, as:

$$\mathbf{DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL2 \times MTL3) + (\%TL4 \times FDTL2 \times MTL3 \times MTL4)} \quad \mathbf{(2)}$$

This equation can then be solved for the concentration in the lowest trophic level:

FDTL2 = DC / [(%TL2) + (%TL3 × MTL3) + (%TL4 × MTL3 × MTL4)] **(3)**

Once the concentration in trophic level 2 is calculated, the remaining trophic levels can be determined using the food chain multiplier relationships:

FDTL3 = FDTL2 × MTL3 **(4)**

FDTL4 = FDTL3 × MTL4 **(5)**

As discussed above, the human health methylmercury criterion document presents a national average intake rate of 17.5 grams of fish per day for the general population. This national average was based on an average consumption of individual trophic levels as follows: TL2 = 3.8 g, TL3 = 8 g, TL4 = 5.7 g. These values correspond to: TL2 = 21.7%, TL3 = 45.7%, TL4 = 32.6%. Using these values, and substituting the TRC for the DC term in Equation 3, the concentration in trophic level 2 biota necessary to maintain the overall dietary concentration can then be calculated.

FDTL2 = TRC / [(%TL2) + (%TL3 × MTL3) + (%TL4 × MTL3 × MTL4)]

FDTL2 = 0.3 mg/kg / [(0.217) + (0.457 × 5.7) + (0.326 × 5.7 × 4)]

FDTL2 = 0.3 / 10.247

FDTL2 = 0.029 mg/kg

Then, using the previously calculated food chain multipliers from above:

FDTL2 = 0.029 mg/kg
FDTL3 = 0.029 × 5.7 = **0.165 mg/kg**
FDTL4 = 0.165 × 4.0 = **0.660 mg/kg**

Based on the trophic level breakout for the default human fish consumption rate identified in the criterion document, the above concentrations of methylmercury will result in an overall dietary concentration (DC) of 0.3 mg/kg:

DC = (%TL2 × FDTL2) + (%TL3 × FDTL3) + (%TL4 × FDTL4)

0.3 mg/kg = (.217 × 0.029 mg/kg) + (.457 × 0.165 mg/kg) + (.326 × 0.66 mg/kg)

II.B. Highest Trophic Level Approach

In contrast to the Average Concentration Trophic Level Approach, the Highest Trophic Level Approach sets the proposed human health methylmercury criterion of 0.3 mg/kg as the limiting concentration in edible portions of trophic level 4 fish. Concentrations expected in trophic levels 2 and 3 can then be estimated using a variation of the food chain multiplier approach described above. In effect, these multipliers determined by the ratios of trophic level concentration relationships become food chain dividers: 0.3 mg/kg in trophic level 4 is divided by the MTL4 to estimate the concentration in trophic level 3, which is then divided by the MTL3 to estimate the concentration in trophic level 2.

FDTL4 = 0.3 mg/kg
FDTL3 = 0.3 / 4 = **0.075 mg/kg**
FDTL2 = 0.075 / 5.7 = **0.013 mg/kg**

This approach is the most conservative (*i.e.*, protective) method of establishing trophic level concentrations with the TRC, as it eliminates the possibility of different human populations exceeding the protective reference dose, assuming the national average consumption rate remains constant. A diet of 100 percent trophic level 4 fish would maintain the overall dietary concentration of 0.3 mg/kg.

III. PROTECTIVE WILDLIFE VALUES

III.A. Selection of Species

The next step in this evaluation was to determine an overall dietary concentration of methylmercury that will protect each species of concern. Species considered in this evaluation include representatives from several taxonomic classes: birds, mammals, fish, reptiles, and amphibians (see Appendix). Initially, the taxonomic class or classes with the greatest potential risk from methylmercury concentrations in fish tissue were identified. For fish species, risk assessment was based solely on adverse effects associated with tissue methylmercury concentrations (see Section X). For non-fish species, the risk assessment was based on exposure through ingestion of methylmercury-contaminated aquatic prey.

The scientific literature contains little information on methylmercury risk to reptiles and amphibians, with no studies found that relate effects to dietary doses (see Section X). Throughout the past several decades, however, a great deal of toxicity research has been conducted on various birds, mammals, and fish. While toxicity data for fish indicate adverse effects resulting from a wide range of tissue methylmercury concentrations, the majority of this research has been conducted with tissue concentrations substantially higher than the TRC. Research on birds and mammals, particularly piscivorous species, is also extensive. Much of this work has involved oral dose studies.

Based on the information available in the scientific literature, and given consideration of methylmercury's capacity to bioaccumulate and biomagnify in the food chain, this evaluation assumed that upper trophic level wildlife species (*i.e.*, predatory birds and mammals) have the greatest inherent risk from exposure to methylmercury, compared to other biota. Wildlife Values (WV), which are the total dietary methylmercury concentrations that will protect predatory birds and mammals, were determined for these upper trophic level species. The methodology then allows for an assessment of whether these values would be exceeded based on the various trophic level concentrations estimated by the two approaches described above. After an analysis of the protection afforded to listed birds and mammals, the scientific literature was reviewed to see whether the listed fish, reptile, and amphibian species may be protected by either trophic level approach.

Listed species for which WVs were generated:

Southern Sea Otter (*Enhydra lutris nereis*)
California Least Tern (*Sterna antillarum brownii*)
California Clapper Rail (*Rallus longirostris obsoletus*)
Light-Footed Clapper Rail (*Rallus longirostris levipe*)
Yuma Clapper Rail (*Rallus longirostris yumaensis*)
Western Snowy Plover (*Charadrius alexandrinus nivosus*)
Bald Eagle (*Haliaeetus leucocephalus*)

III.B. Equation to Calculate Wildlife Values

A Wildlife Value represents the overall dietary concentration of methylmercury necessary to keep the daily ingested amount at or below a sufficiently protective reference dose. Reference doses (RfD) may be defined as the daily exposure to a toxicant at which no adverse effects are expected. In effect, the WV converts the protective RfD into an overall dietary concentration (in mg/kg in diet). The WV is analogous to the TRC for the human health criterion. The WV is calculated using the following equation:

$$\mathbf{WV} = \frac{\mathbf{RfD} \times \mathbf{BW}}{\sum \mathbf{FIR_i}} \qquad \mathbf{(6)}$$

WV = Wildlife Value (mg/kg in diet)
RfD = Reference Dose
BW = Body Weight (in kg) for species of concern
FIR_i = Total Food Ingestion Rate (kg food/day), from the i^{th} trophic level, for species of concern

Because the most sensitive endpoints for toxicity of methylmercury in birds and mammals relate to reproduction, the focus of this methodology is to establish reference doses based on preventing adverse impacts from maternally ingested methylmercury, that could potentially affect the reproductive viability of the species. In order to establish RfDs, the scientific literature was first

reviewed to find the most appropriate toxicity test doses for avian and mammalian species. An uncertainty analysis (described below, Section III.D.) was then conducted for each test dose to arrive at the appropriate RfD. Body weights used in this approach were those of adult females for the species of concern. Total food ingestion rates for species of concern, and the trophic level breakout of the diet, were obtained from the scientific literature or estimated using allometric equations.

III.C. Determination of Test Doses

Once the taxonomic class or classes assumed to be at greatest risk were identified (*i.e.*, predatory birds and mammals), the next step in the evaluation was to identify appropriate toxicity test doses to use for determining a protective RfD for each group. As the species of concern for this evaluation are federally listed as threatened or endangered, the goal of this step was to find the lowest test doses associated with endpoints that could adversely affect the continued existence of the species or the loss of individuals from the population. Most often these toxicity endpoints were based on subtle effects concentrations (*e.g.*, reproductive success), rather than more severe effects in individuals (*e.g.*, lethality). However, if the lowest test dose was found to cause impacts that could effectively remove an individual from the population, even without any apparent effect on reproductive success, this test dose was used in the analyses.

The approach used in this methodology assesses toxicity through ingestion of methylmercury in contaminated prey, so the scientific literature was searched for all available oral test doses demonstrating observable effects concentrations. The data preferences used in this analysis were the same as outlined in the Great Lakes Initiative (GLI) *Technical Support Document for Wildlife Criteria* (U.S. Environmental Protection Agency, 1995c):

- Appropriate endpoints (reproductive or developmental success, organismal viability or growth, other parameters influencing population dynamics)
- Chemical-specific dose-response curve
- Chronic or sub-chronic study duration
- Wildlife species preferred over traditional laboratory animals
- Field studies preferred over laboratory studies
- Oral route of exposure, although other routes acceptable if possible to convert to oral dose

Many oral dose toxicity studies report test doses as the amount of contaminant in the diet of the tested species (*e.g.*, mg/kg food). Therefore, it is often necessary to convert these reported levels to a daily ingested dose (mg/kg-bw/day), using body weights and food ingestion rates for the species studied (*i.e.*, mg/kg in food × kg food consumed per kg body weight per day = mg/kg body weight per day).

For this evaluation, the scientific literature was reviewed with particular emphasis on searching for rigorous data reported since the development of water quality wildlife criteria for the GLI in

1995. For the GLI effort, two studies that best fit the data preferences were selected to calculate the mercury wildlife criteria for avian and mammalian species. These are described below, along with relevant findings from the current literature search.

Mammalian Test Dose: In developing water quality criteria for mercury in the GLI, the EPA reviewed numerous mammalian chronic and subchronic toxicity studies. Test animals studied were rats and mink. Toxicity to mink was evaluated in two subchronic studies by Wobeser *et al.* (1976a,b), and these studies formed the basis for EPA's calculation of the mammalian wildlife criterion for mercury. Each study had different exposure durations (93 and 145 days) and dosing levels. The 145 day study dosed mink with two methylmercury concentrations (0.22 and 0.33 mg/kg) in food. These concentrations corresponded to dietary doses of 0.033 and 0.05 mg/kg-bw/day, respectively, using a food ingestion rate of 0.15 kg/day and a body weight of 1 kg for captive mink. The EPA determined that no adverse effects were seen at either dose, and concluded the 0.05 mg/kg-bw/day constituted a No Observable Adverse Effects Level (NOAEL) test dose.

From the 93 day study, the EPA determined both NOAEL and LOAEL (Lowest Observable Adverse Effects Level) test doses. A concentration of 1.1 mg/kg in food caused pathological alterations in the mink nervous system (nerve tissue lesions), while concentrations of 1.8 mg/kg and higher in food resulted in clinical signs of mercury intoxication [anorexia (loss of appetite) and ataxia (loss of coordination)] and subsequent mortality. Using the same food ingestion rate and body weight converts the 1.1 and 1.8 mg/kg concentrations to dietary doses of 0.16 and 0.27 mg/kg-bw/day, respectively. The EPA concluded that the effects seen in the 0.16 mg/kg-bw/day dose group were not associated with any obvious clinical evidence of toxicity, and that this dose constituted the NOAEL test dose, despite Wobeser's conclusion that distinct clinical signs of toxicity would have resulted had the exposure period been longer. The 0.27 mg/kg-bw/day dose was designated the LOAEL.

For several years, the U.S. Department of Energy (DOE) (1993-1996) has published *Toxicological Benchmarks for Wildlife*. These documents have also used toxicity studies of rats and mink to determine the mammalian benchmarks for methylmercury compounds. In determining final NOAEL and LOAEL values for piscivorous mammals, Wobeser *et al.*'s (1976b) 93 day study was used. The DOE's evaluation of this study agreed with the EPA's conclusion that the 1.1 mg/kg concentration constituted a NOAEL; however, using a slightly different value for the mink food ingestion rate (0.137 kg/day), a dietary dose of 0.15 mg/kg-bw/day was calculated.

In 1997, the EPA published the *Mercury Study Report to Congress* (MSRC). Volume VI of this report (U.S. Environmental Protection Agency, 1997a) presented reviews of several methylmercury toxicity tests with mammalian wildlife, including both Wobeser *et al.* (1976a,b) studies. For the MSRC, the EPA concluded that the nerve tissue lesions observed in the 1.1 mg/kg concentration group from the 93 day study were relevant effects endpoints, noting the researcher's opinion that the nerve tissue damage would have become manifested as impaired

motor function had the study continued for a longer period. For this reason, the EPA assigned the 1.1 mg/kg concentration as the LOAEL. As this was the lowest dosing group in the study, a NOAEL could no longer be determined. Instead, the EPA selected the 0.33 mg/kg concentration from the 145 day study as the NOAEL. Using the food ingestion rate found in the DOE analysis (0.137 kg/day) and a body weight of 0.8 kg (as opposed to 1.0 kg used in both the GLI and DOE reports), the EPA converted the 0.33 mg/kg dose in food to a dietary NOAEL test dose of 0.055 mg/kg-bw/day for the MSRC.

The MSRC also presented findings from a long-term feeding study with domestic cats (Charbonneau *et al*., 1974). Cats were fed various doses of methylmercury, either as methylmercuric chloride in food or as methylmercury-contaminated fish, for two years. The dietary test doses of 0.046 and 0.020 mg/kg-bw/day were determined to be the LOAEL and NOAEL, respectively, based on neurological impairment effects. These values were only used for comparative purposes, however, as the intent of the MSRC effort was to derive water quality criteria that would be protective of wildlife. The NOAEL test dose from the 145 day mink study was used in the subsequent MSRC calculations to derive criteria values for mammalian wildlife.

As all the effects seen in the semi-domesticated mink and domestic cat studies involved toxicity to individual animals, an effort was made for this evaluation to find data on effects to reproductive performance. Wren *et al*. (1987) reported no effects on reproduction in mink fed a diet supplemented with 1.0 mg/kg methylmercury every other day for 150 days. In a two generation study (G1, G2) of mink fed organic mercury-contaminated diets, Dansereau *et al*. (1999) analyzed effects on reproductive performance. Dosing groups were 0.1, 0.5, and 1.0 mg/kg total mercury. Whelping percentage for the G1 females was statistically higher in the 0.1 mg/kg group than in the 0.5 or 1.0 groups. Whelping percentages for all other G1 and G2 dosing groups were low relative to reported performance of untreated female mink. The researchers suggested that the observed linear decrease of performance with increasing methylmercury exposure may have been the result of adverse effects of methylmercury on the reproductive process; however, they were unable to show a statistically significant difference. Although the study could not conclude the reproductive process itself was adversely affected, female mink from both generations in the 1.0 mg/kg suffered mortality from methylmercury intoxication. A large percentage of first generation females died at 11 months of age, after 90 days of exposure. Death occurred approximately one month after whelping the G2 offspring. Second generation females died at the same age as their mothers, but after approximately 330 days of exposure. However, the G2 females had been mated at the age of 10 months and death occurred one month later in 6 out of 7 individuals, before giving birth. The remaining individual died shortly after giving birth. The researchers concluded that "...survival and consequently the reproduction of the G2 females fed 1.0 ppm Hg diet were therefore affected."

Although the 1999 Dansereau *et al*. study could not confirm impaired reproductive performance, it is useful for validating that a concentration of 1.0 mg/kg methylmercury in food represents an observable adverse effects level, which could inhibit the overall success of a population by removing reproductively viable individuals. The researchers found no mortality or neurological

signs of toxicity in any mink in the 0.1 and 0.5 mg/kg diet groups; however, the animals were not sacrificed and examined for histopathological effects in either of these groups. A review of the available scientific literature since the GLI revealed no new data that better fits the GLI preferences or that reports lower oral dose observed effects concentrations for mammalian wildlife. Therefore, the NOAEL dose of 0.33 mg/kg in food (0.055 mg/kg-bw/day) from the 145 day study by Wobeser *et al*. (1976a) is the appropriate test dose for determining protection of piscivorous mammalian wildlife in this evaluation.

Avian Test Dose: For the GLI effort, the EPA also reviewed numerous subchronic and chronic mercury toxicity studies using avian species. Species examined in this review included domestic chicken, pheasant, Japanese quail, red-tailed hawk, zebra finch, and game farm mallard ducks. The EPA ultimately selected a study examining reproductive and behavioral effects in three generations of mallard ducks (Heinz, 1979) to determine an appropriate test dose for its avian wildlife criteria calculations.

In these studies, three generations of mallard ducks were exposed to a mercury-free control diet or one containing 0.5 mg/kg methylmercury dicyandiamide. Several measurements of reproductive success were evaluated throughout the course of the study. Statistically significant adverse effects were observed in the percentage of eggs laid outside the nest box (increase) and in the number of one-week-old ducklings produced (decrease), relative to controls. In addition, adverse behavioral effects were seen in the ducklings from the treatment group, relative to controls. The behavioral aberrations observed included a smaller percentage of ducklings approaching tape-recorded maternal calls, and an increased sensitivity to frightening stimuli, as measured by the distance traveled in avoidance.

Based on the methylmercury concentration tested (0.5 mg/kg in food) and the reported average food consumption rate for 2nd and 3rd generation mallards in the treatment group (0.156 kg/kg-bw/day), the EPA determined a dietary dose of 0.078 mg/kg-bw/day. No lower effects concentration test doses were reported in any of the other avian toxicity studies evaluated by the EPA. As there were no lower treatment concentrations in the mallard studies, the EPA assigned this dietary dose as the LOAEL to be used in avian wildlife value calculations. For the GLI, the EPA (1995b) concluded that the mallard studies best fit the data preferences, providing a chemical-specific dose-response curve and demonstrating effects that "...clearly have potential consequences on populations of mallards exposed to methylmercury."

Although mercury toxicity has been studied extensively using avian species, both before and after the GLI effort, Heinz' (1979) multi-generational mallard work has been used almost exclusively in subsequent efforts to derive water quality values for methylmercury that are protective of avian wildlife (U.S. Department of Energy, 1994-1996; U.S. Environmental Protection Agency, 1997a; Nichols *et al*., 1999; Canadian Council of Ministers of the Environment, 2000; Buchanan *et al*., 2001; California Regional Water Quality Control Board - Central Valley Region, 2001; Evers *et al*., 2002). In large part, this is because few other studies have attempted to establish oral dose-response data from long-term feeding studies. There is a

great deal of scientific literature devoted to methylmercury residues in various avian tissues (*e.g.*, muscle, liver, egg); however, these studies were generally not designed to determine chronic dietary doses. The literature search for this evaluation only revealed a few additional studies, described below, that could be used for evaluating dietary concentrations associated with subchronic or chronic effects.

In a broad survey of freshwater lakes in Canada, which were contaminated with mercury and experienced unnatural water level fluctuations and turbidity, Barr (1986) examined the population dynamics of common loons. Loons in these systems preyed on fish containing various concentrations of methylmercury. Based on his observational data, Barr concluded that adverse reproductive effects in loons (*i.e.*, reductions in egg laying, and nest site and territorial fidelity) were associated with mean fish tissue concentrations ranging from 0.3 - 0.4 mg/kg methylmercury. As this study was not designed as a controlled feeding experiment, Barr did not convert these concentrations into daily ingested doses (*i.e.*, mg/kg-bw/day). However, Barr's reported average body weights for male and female loons (~ 4.0 kg) and assumed food consumption rate of 20 percent body weight per day (0.8 kg/day) allowed for comparison with the 0.078 mg/kg-bw/day dietary dose from the Heinz (1979) mallard work. Multiplying the lowest concentration Barr associated with adverse effects (0.3 mg/kg in fish) and the assumed average food ingestion rate (0.2 kg/kg-bw/day) produces a daily dietary dose of 0.06 mg/kg-bw/day. While the limitations of the Barr study (*i.e.*, no controlled oral dose-response data) prevent the use of this daily value as the appropriate test dose for this evaluation, it serves to support the test dose selected by the EPA for the GLI effort.

Effects of controlled methylmercury dosing on captive great egret nestlings were reported in Bouton *et al*. (1999) and Spalding *et al*. (2000a,b). In these studies, 16 great egret nestlings were captured from the wild and separated into various dosing groups (0, 0.5, 5.0 mg/kg methylmercury chloride in diet) for 14 weeks. Methylmercury was administered via gelatin capsules, and doses were maintained based on daily food consumed. Although dietary concentrations were maintained, the daily amount of methylmercury consumed per kilogram of body weight varied from 0.048 to 0.135 mg/kg-bw/day. This was because nestling body weights and food consumption rates are very dynamic during this intense growth phase. The variation in daily dietary doses limited the usefulness of these studies for determining an appropriate avian test dose for this evaluation; however, analysis of effects observed in the 0.5 mg/kg dose group for each of the three studies (described below) allowed for comparison with the LOAEL concentration from the Heinz (1979) effort.

Bouton *et al*. (1999) measured behavioral effects in the captive egrets during the period of the experiment (10-14 weeks) approximate to post-fledging in wild egrets (11 weeks of age). These researchers concluded that adverse effects, including reduced activity, food intake, and willingness to hunt prey, were demonstrated in the 0.5 mg/kg dosing group. They also postulated that these behavioral effects may result in reduced juvenile survival in free-ranging birds.

Spalding *et al*. (2000a) examined the accumulation of methylmercury in tissues of the captive egrets and its effect on growth and appetite. These researchers hypothesized that nestling wading birds would be less at risk from ingested methylmercury than fledgling birds, due to depuration of the methylmercury into the rapidly growing feathers of the younger birds. Reduced appetite, and a subsequent decline in growth, was observed after the ninth week of the experiment in both the 0.5 and 5.0 mg/kg dose group, corresponding to the cessation of feather growth. Although the magnitude of weight loss was small, the study's authors concluded that the abundance of food in the controlled setting may have masked some of the effects that would have resulted had the birds been hunting on their own. The study results supported the conclusion that, relative to pre-fledging nestlings, post-fledging birds are at an elevated risk from methylmercury exposure at even the 0.5 mg/kg dietary concentration, during the period when feathers stop growing. The researchers noted that this period also coincides with the time that young birds face the multiple risk factors of having to forage on their own, leave the natal colony, and become exposed to novel predation and disease factors.

Spalding *et al*. (2000b) examined the same egrets for histologic, neurologic, and immunologic effects. Both dosing groups exhibited effects of varying magnitude. Birds in the 5.0 mg/kg dose group showed severe ataxia, as well as hematologic, neurologic, and histologic changes, with the most severe lesions in immune and nervous system tissues. The 0.5 mg/kg dosed birds also exhibited multiple effects for various endpoints, relative to birds in the control group. In comparing their findings with effects reported in studies of wild birds, the authors concluded that the thresholds for sublethal effects measured in captive birds were lower than those in wild birds. However, these researchers attributed this discrepancy to the increased detectability of effects in controlled experiments, and suggested that LOAELs from captive studies may be a more accurate predictor of effects for field situations than field-derived LOAELs applied to captive studies.

Taken together, these three studies (Bouton *et al*., 1999 and Spalding *et al*., 2000a,b) demonstrated adverse effects in juvenile piscivorous birds exposed to a diet containing 0.5 mg/kg methylmercury. The multitude of effects reported, while not directly associated with reproduction, could have significant implications for population viability. Even if the number of offspring produced is not affected by a diet containing 0.5 mg/kg methylmercury, the number of juvenile birds becoming breeding individuals may be reduced through impaired fitness or increased mortality. These studies provided validation for adverse effects to avian species resulting from a dietary concentration of 0.5 mg/kg methylmercury.

In a similar evaluation of methylmercury impacts to juvenile piscivorous birds, Henny *et al*. (2002) studied three bird species nesting in a mercury-contaminated watershed. Various tissues and endpoints from both adult and juvenile double-crested cormorants, black-crowned night herons, and snowy egrets were measured, including methylmercury concentrations in stomach contents. Based on stomach content analyses, it was determined that young of these species were fed diets averaging 0.36 - 1.18 mg/kg methylmercury through fledging. Although adult birds were exposed to the same prey pool and had higher total mercury concentrations in their livers than fledglings, the younger birds exhibited greater evidence of sublethal toxicity to their

immune, detoxification, and nervous systems. The strongest evidence of these effects was seen in the cormorants, which had the highest average methylmercury concentration reported from stomach content analysis (1.18 mg/kg). However, these effects were also observed in the other species, with average dietary concentrations of 0.36 mg/kg (snowy egrets) and 0.43 mg/kg (black-crowned night herons). No conclusions could be drawn regarding post-fledging survival, as the study concluded at about the time of fledging. However, noting that many of the fledglings remained in the watershed after leaving the nest area, the study authors suggested that the additional period of foraging in the contaminated system, coupled with the completion of feather growth, may have critically increased the body burden of mercury and its potential toxicity.

None of the studies described above (Barr, 1986; Bouton *et al*., 1999; Spalding *et al*., 2000a,b; Henny *et al*., 2002) provided a suitable avian oral test dose for methylmercury that could be used as an alternative to the one generated in the Heinz (1979) work with mallard ducks. They do, however, confirm that a concentration of methylmercury in food around 0.5 mg/kg is sufficient to cause significant adverse effects to avian reproduction and health that could have deleterious impacts at both the individual and population levels. A review of the scientific literature revealed no other dose-response studies that established appropriate oral test doses for avian species, and the Heinz (1979) work remains the most robust benchmark for evaluating impacts to birds from methylmercury in the diet.

The body of work on mercury toxicity to avian species includes a great deal of data on residue concentrations in various tissues (*e.g.*, brain, liver, feather). Often these studies have attempted to establish threshold concentrations in specific tissues correlated with adverse effects. The use of egg concentrations is often cited as a valuable endpoint in evaluating the toxicity of methylmercury, as developing embryos are more sensitive than adults (Wiener *et al*., 2002). Reviews of studies reporting data on mercury concentrations in eggs of both wild and captive birds can be found in Thompson (1996), Burger and Gochfeld (1997), Wolfe *et al*. (1998), and Eisler (2000). However, as important as these studies are for determining concentrations associated with embryotoxic effects, relatively few provide information on the dietary doses of the laying birds that resulted in the observed egg methylmercury concentrations.

The two most commonly cited studies reporting egg methylmercury concentrations and adverse effects resulting from controlled feeding studies examined pheasants (Fimreite, 1971) and mallards (Heinz, 1979). The mallard study is the same as the one discussed above, used in determining the LOAEL dietary test dose for the GLI. From a dietary concentration of 0.5 mg/kg methylmercury, Heinz (1979) reported an average concentration over three generations of 0.83 mg/kg wet weight in eggs. Although mallard embryos were not examined for signs of toxicosis, the egg concentrations reported resulted from a dietary dose causing adverse reproductive effects. Fimreite's (1971) controlled dosing experiment with ring-necked pheasants demonstrated reduced hatchability, expressed as the percentage of eggs incubated, in egg samples containing between 0.5 - 1.5 mg/kg methylmercury. This range is similar in magnitude to the average egg concentration (0.83 mg/kg) reported by Heinz (1979), and the lower end (0.5 mg/kg) is often

cited as a LOAEL for avian eggs (Wolfe *et al*., 1998). Based on the egg concentrations and associated adverse reproductive effects reported in these two studies, it is generally accepted in the scientific literature that eggs of pheasants are more sensitive to methylmercury than mallard eggs. However, the dietary concentrations (~ 2-5 mg/kg) resulting in the range of egg concentrations observed in pheasants by Fimreite (1971) were substantially higher than the 0.5 mg/kg dietary concentration causing the similar egg values reported in mallards by Heinz (1979). This indicates a substantial difference between these species in the transfer efficiency from methylmercury in the maternal diet to methylmercury in the egg.

Recent and ongoing efforts by Heinz (pers. comm., 2003) are focused on more closely examining interspecies differences in sensitivity to egg methylmercury concentrations. Through direct injection into the eggs of various bird species, different concentrations of methylmercury can be evaluated as to their effects on developing embryos. Preliminary results seem to confirm the findings from the feeding studies described above that pheasant eggs are more sensitive than mallard eggs. In addition, there appears to be a broad range of species sensitivity, both more and less sensitive than mallard eggs. While the data from these efforts, when published, will provide important information concerning the relative magnitude of sensitivity exhibited by different species, their utility for evaluating effects from dietary methylmercury is limited by two constraints. First, it requires less methylmercury to cause adverse effects in eggs when it is injected than when naturally deposited by the mother. Therefore, species-specific LOAELs for eggs cannot be determined from injected concentrations until a relationship to maternally-deposited concentrations can be accurately determined. Second, as seen with the pheasant and mallard feeding studies, there may be wide variations among species in diet-to-egg transfer efficiency. Selecting an egg LOAEL based on the most sensitive species examined in injection studies may correspond to a higher dietary concentration, relative to other species with higher egg LOAELs.

As no other toxicity data were found that could provide a more appropriate oral test dose for avian species, the results of the Heinz (1979) study with mallard ducks was used for this evaluation. However, discrepancies were noted in the scientific literature regarding how these results were used to convert the dietary concentration (mg/kg in food) to a daily dose (mg/kg-bw/day). As described above, the EPA used the average food consumption rate for 2nd and 3rd generation mallards in the treatment group (0.156 kg/kg-bw/day) to calculate a dietary dose of 0.078 mg/kg-bw/day for use in the GLI avian wildlife criterion derivation (U.S. Environmental Protection Agency, 1995d). In a departure from this approach, the U.S. Department of Energy (1993-1996) used the average food consumption rate for the study's control group (0.126 kg/kg-bw/day) to calculate a dietary dose of 0.064 mg/kg-bw/day for the derivation of toxicological benchmarks for wildlife. This lower value has been used in Wolfe and Norman (1998) and California Regional Water Quality Control Board - Central Valley Region (2001), while the higher value has been used in Nichols *et al*. (1999), Canadian Council of Ministers of the Environment (2000), Buchanan *et al*. (2001), and Evers *et al*. (2002). Further confounding the matter, the MSRC used the higher value in one volume (Vol. VI) (U.S. Environmental Protection Agency, 1997a) and the lower value in a different volume (Vol. VII) (U.S. Environmental

Protection Agency, 1997b), although the higher value was used in the Report to calculate water quality criteria.

In an effort to understand the rationale for using the control group's food consumption rate to calculate a LOAEL, the author of the 1979 mallard study was contacted (Heinz, pers. comm., 2002). Heinz stated that the difference in his reported ingestion rates for the two study groups was not due to greater wastage on the part of the treatment group, and further, that the reported rates were probably not very accurate for either group. He explained that the ability to distinguish wasted food from the debris at the bottom of test subject cages (fecal matter, undigested food, *etc*.) was insufficient to calculate feeding rates with a great degree of precision. However, based on his understanding of work subsequent to the 1979 study, Heinz believes that true mallard feeding rates are likely even lower than the rates he reported (0.1 kg/kg-bw/day vs. 0.128 and 0.156). While Heinz did not suggest a 0.1 kg/kg-bw/day ingestion rate be used to determine the LOAEL, he did caution against using the 0.156 kg/kg-bw/day rate reported for his 1979 treatment group. This conversation supported the use of the 0.064 mg/kg-bw/day LOAEL calculated with Heinz' control group feeding rate as the appropriate dietary dose for evaluating risk to avian species, with the acknowledgment that true mallard feeding rates may suggest the need for a lower LOAEL.

III.D. Determination of Reference Doses

As noted previously, a reference dose (RfD) may be defined as the daily exposure to a toxicant at which no adverse effects are expected, analogous to NOAEL doses determined from toxicity tests. However, RfDs are intended to protect all species likely to be at risk from exposure to the contaminant, from each taxonomic class for which test doses were determined. Ideally, toxicity tests to determine chronic effects of a contaminant will be of sufficient duration and dose spacing to allow for establishment of a reliable NOAEL. For a variety of reasons, the duration and dose spacing of many toxicity tests are not suitable for this, and NOAELs must be extrapolated from the test information available. In addition, any NOAELs established may only be applicable for the species tested. Extrapolating any given test dose into a RfD at which no adverse effects are expected, for potentially a broad range of species, involves some amount of uncertainty.

In order to determine the RfD for a given taxonomic group, the test dose selected to represent that group may need to be adjusted by uncertainty factors to incorporate variability in toxicological sensitivity among species and to extrapolate for duration (subchronic-to-chronic) or dose spacing (LOAEL-to-NOAEL) issues. The RfD is calculated using the following equation:

$$\mathbf{RfD} = \frac{\mathbf{TD}}{\mathbf{UF_A} \times \mathbf{UF_S} \times \mathbf{UF_L}} \qquad \mathbf{(7)}$$

RfD = Reference Dose (mg/kg-bw/day)
TD = Test Dose (mg/kg-bw/day)
UF_A = Interspecies Uncertainty Factor (unitless)
UF_S = Subchronic-to-Chronic Uncertainty Factor (unitless)
UF_L = LOAEL-to-NOAEL Uncertainty Factor (unitless)

The concept of adjusting test doses to account for these types of uncertainty has been widely used in efforts to develop avian and mammalian reference doses for methylmercury that would be protective of a range of wildlife species (U.S. Department of Energy, 1993-1996; Canadian Council of Ministers of the Environment, 2000; Buchanan *et al*., 2001; California Regional Water Quality Control Board - Central Valley Region, 2001; Evers *et al*., 2002). However, the majority of these efforts have used the same uncertainty factors originally determined in either the GLI effort (U.S. Environmental Protection Agency, 1995d) or the MSRC (U.S. Environmental Protection Agency, 1997a,b). Guidance on determining the appropriate values for each uncertainty factor can be found in two EPA documents: *Technical Basis for Recommended Ranges of Uncertainty Factors used in Deriving Wildlife Criteria for the Great Lakes Water Quality Initiative* (Draft Report) (Abt Associates Inc.,1995) and Great Lakes Water Quality Initiative *Technical Support Document for Wildlife Criteria* (U.S. Environmental Protection Agency,1995a).

Mammalian RfD: As described previously in Section IV,C (Determination of Test Doses), the EPA selected studies by Wobeser *et al*. (1976a,b), in both the GLI and the MSRC, to determine the appropriate mammalian test dose for calculating the RfD. However, the two efforts applied different assumptions and arrived at different test doses. For the GLI, a test dose of 0.16 mg/kg-bw/day was determined to be the NOAEL, while the MSRC concluded the test dose of 0.055 mg/kg-bw/day was the appropriate NOAEL. In addition to this difference, each effort then applied different uncertainty factors to each test dose to determine the RfD.

In the GLI, the UF_A and UF_L were both assigned a value of 1. This was because the experimental animal (mink) and the representative species to be protected (river otter) are closely related and assumed to be similarly sensitive, and because the study identified a NOAEL. The UF_S was set at a value of 10 because the study chosen (Wobeser *et al*., 1976b) was of subchronic duration. Applying these three combined uncertainty factors to the test dose of 0.16 mg/kg-bw/day resulted in a mammalian RfD of 0.016 mg/kg-bw/day.

For the MSRC, the UF_A and UF_L were also both assigned a value of 1, for the same reasons outlined above. However, the UF_S for this effort was set at a value of 3 because the effects observed at the subchronic NOAEL (Wobeser *et al*., 1976a) were not associated with overt signs of toxicity (Nichols *et al*., 1999). Applying these three uncertainty factors to the test dose of 0.055 mg/kg-bw/day resulted in a mammalian RfD of 0.018 mg/kg-bw/day.

So despite the discrepancy regarding the appropriate test dose for mammals, both efforts arrived at roughly the same mammalian RfD. The single mammalian species of concern for this

evaluation is the southern sea otter (*Enhydra lutris nereis*), in the same taxonomic family (*Mustelidae*) as the mink and river otter. Therefore, no further adjustments to the UF_A or UF_L were necessary. The analyses regarding the mammalian test dose and UF_S presented in the MSRC represent the most current comprehensive assessment of these Wobeser *et al*. (1976a,b) studies. As a result, **a mammalian RfD of 0.018 mg/kg-bw/day** was used in this evaluation (Table 1.).

Avian RfD: Similar discrepancies concerning uncertainty factors for the avian RfD were noted between the GLI and the MSRC. Both of these efforts agreed on an avian test dose (0.078 mg/kg-bw/day) from the three generation mallard duck study (Heinz, 1979), and both agreed that the UF_S should be assigned a value of 1 because the study was of sufficient chronic duration. However, varying assumptions regarding LOAEL-to-NOAEL relationships and interspecies sensitivity resulted in each effort assigning different UF_L and UF_A values.

Regarding the UF_L, a value of 2 was assigned for the GLI because the LOAEL identified by the EPA from the mallard study, 0.078 mg/kg-bw/day, "...appeared to be very near the threshold for effects of mercury on mallards." As explained in Nichols *et al*. (1999), a range of 1 - 10 was used to set the UF_L values in the GLI, based on an evaluation of chronic toxicity studies with wildlife species using five chemicals (cadmium, DDT, DDE, dieldrin, and mercury). This conclusion was reached after determining that 97 percent of the LOAEL-to-NOAEL ratios examined were less than or equal to 10 and 50 percent were less than or equal to 3.

In contrast, the authors of the MSRC evaluated toxicity studies with methylmercury only. Twenty LOAEL-to-NOAEL ratios were calculated, with the majority between 1 - 2 or 4 - 5 (Nichols *et al*., 1999). For the final calculations of wildlife criteria values in the MSRC, the UF_L was assigned a value of 3. The MSRC (Vol. VI) concluded that "Given the substantial uncertainties in all the values used to calculate the WC for mercury exposure, neither two nor three can be considered to be the only correct value" (U.S. Environmental Protection Agency, 1997a).

The conceptual basis for use of a UF_A is that toxicokinetic and/or toxicodynamic differences among species may result in variable responses to the same applied dose. Empirical data from acute and chronic toxicity tests with wildlife species support the use of a UF_A ranging from 1 to 100 when extrapolating toxicological effects across species. Values tending toward the lower end of this range may be justified by several factors including: 1) the amount and quality of available testing data, 2) a close taxonomic relationship between the tested species and the species of interest, 3) similarity in size of the tested species and the species of interest, and 4) toxicokinetic and / or toxicodynamic information which would suggest that the tested species is likely to be more sensitive than the species of interest.

For the GLI, a UF_A greater than 1 was recommended because of the need to extrapolate mallard data to species in different taxonomic orders, and because of the possibility that another of the species (pheasant) examined in toxicity studies might prove more sensitive if given a longer

exposure duration. However, because the analysis of suitable avian toxicity values reviewed for the GLI indicated that the mallard was possibly the most sensitive to mercury of the six species examined, the conclusion was drawn that a UF_A of 10 would likely be overly conservative. A UF_A of 3 (half-way between 1 and 10 on a log 10 scale) was therefore applied as a reasonable protection for those species that may be more sensitive than mallards.

The question of interspecies sensitivity was revisited in the MSRC. The three species selected in the GLI to represent avian wildlife (belted kingfisher, herring gull, bald eagle) are piscivorous birds. The authors of the MSRC cited literature suggesting that piscivorous birds possess, in comparison to non-piscivorous birds, a greater capacity to demethylate and thereby detoxify methylmercury. Although piscivorous birds are likely faced with the greatest exposure to methylmercury, the MSRC authors concluded that these birds are unlikely to be more sensitive than mallard ducks (an omnivorous species) to the toxic effects of methylmercury, and that application of a UF_A greater than 1 was unwarranted for piscivorous species. Research conducted since publication of the MSRC has provided additional support for the existence of a protective demethylating capability in piscivorous birds (Henny *et al*., 2002). As the species selected in the MSRC to represent avian wildlife (belted kingfisher, loon, osprey, bald eagle) are also piscivorous, the UF_A for that effort was assigned a value of 1. In summary, the uncertainty factors used in both the GLI and the MSRC to adjust the mallard test dose to an avian RfD were as follows:

	GLI	MSRC
UF_A	3	1
UF_S	1	1
UF_L	2	3

For this evaluation, two of the federally-listed avian species of concern are primarily (bald eagle) or exclusively (California least tern) piscivorous. For these species, the rationale used in the MSRC to assign a UF_A of 1 is therefore applicable. This effort differs, however, from both the GLI and MSRC efforts insofar as it includes consideration of four species (California clapper rail, light-footed clapper rail, Yuma clapper rail, and snowy plover) which feed extensively on invertebrates, including (in the case of the snowy plover) invertebrates of non-aquatic origins.

No information could be found regarding the capability of clapper rails or snowy plovers to detoxify methylmercury. Henny *et al*. (2002) provided some data indicating that adult birds whose diet consists largely of aquatic invertebrates may also possess this detoxifying capacity. In this study, Henny *et al*. examined three bird species nesting in a mercury-contaminated watershed. Examination of stomach contents for two of these species, black-crowned night herons (*Nycticorax nycticorax*) and snowy egrets (*Egretta thula*), revealed diets ranging from 100 percent fish to 100 percent large aquatic insect larvae. The diet of the third species, double-crested cormorant (*Phalacrocorax auritus*), was comprised entirely of fish. Analysis of livers from all three species indicated that hepatic demethylation, possibly in a dose-dependent

relationship, allowed adult birds to tolerate relatively high mercury concentrations without apparent adverse effects. Fledglings did not exhibit the same degree of tolerance to liver mercury concentrations; however, the study ended before it could be determined whether hepatic demethylation would become more pronounced as the fledglings matured. The results of this study lend support to the idea that even birds that are not strictly piscivorous, but still primarily consume aquatic biota, may be less sensitive to methylmercury than the non-piscivorous mallard.

However, as described previously in the section on avian test doses, there has been recent work on interspecies sensitivity to methylmercury using egg injection studies (Heinz, pers. comm., 2003). The clapper rail is one of the species examined thus far whose sensitivity to methylmercury in the egg appears to be greater than the mallard, perhaps closer in sensitivity to the pheasant. These results are preliminary only, and presently it is impossible to translate differences in sensitivity of clapper rail and mallard duck eggs to an injected dose of methylmercury into an ecologically meaningful comparison. No information was available from this work on the amount of methylmercury in food necessary to achieve any observed egg effects concentrations or on the relationship of observed effects concentrations to a maternally-deposited dose. The diet-to-egg transfer efficiency can vary widely between different species, as evidenced by the controlled feeding studies with mallards (Heinz, 1979) and pheasants (Fimreite, 1971). It would be imprudent to assume that similar sensitivities to egg concentrations between the clapper rail and the pheasant would necessarily be caused by the same dietary concentration. However, although no definitive conclusions can presently be drawn as to whether the clapper rail is more or less sensitive to methylmercury in food than the mallard, the need for a greater UF_A for this species in determining a reference dose could not be ruled out.

Based on the information outlined above, the uncertainty factors presented in the MSRC are more generally appropriate than those from the GLI for determining the avian reference dose. However, because several of the bird species considered in this effort are not obligate piscivores, the argument presented in the MSRC for using a UF_A of 1 may not be appropriate for these species. For this reason the derivation and subsequent assessment of WVs was based on a UF_A of 1 for piscivorous avian species (least tern and bald eagle) and UF_As of both 1 and 3 for the snowy plover and clapper rails. The UF_A of 3 was selected using the same rationale from the GLI (*i.e.*, half-way between 1 and 10 on a log scale). The alternative reference doses generated by the two UF_As provided for a comparative analysis of protection afforded by both evaluation approaches.

Based on the avian TD of 0.064 mg/kg-bw/day from the Heinz (1979) mallard duck study, and the uncertainty factors from the MSRC, **an avian RfD of 0.021 mg/kg-bw/day** was used in this evaluation (Table 1.). An **alternative avian RfD of 0.007 mg/kg-bw/day** was also presented for the three clapper rail subspecies and the snowy plover.

Table 1. Test Doses, Uncertainty Factors, and Reference Doses for Birds and Mammals

	Mammals	All Birds	Clapper Rails / Snowy Plover
Test Dose	0.055 mg/kg-bw/day	0.064 mg/kg-bw/day	0.064 mg/kg-bw/day
UF_A	1	1	3
UF_S	3	1	1
UF_L	1	3	3
RfD	0.018 mg/kg-bw/day	0.021 mg/kg-bw/day	0.007 mg/kg-bw/day

IV. CALCULATING WILDLIFE VALUES: BODY WEIGHTS, DIETARY COMPOSITION, FOOD INGESTION RATES

Once the RfDs for each taxonomic group were determined from the appropriate test doses, species-specific WVs were calculated (Equation 6; see page 7). This required information on average adult female body weights (kg) and species-specific daily food ingestion rates (FIR *in* kg food/day). References for body weights are provided in each species account below.

Allometric calculations to determine FIRs for numerous wildlife species have been developed by Nagy (1987 and 2001), based on measurements of free-living metabolic rates (FMR) and the metabolizable energy (ME) in various foods (*e.g.*, fish, birds, mammals). Generic allometric equations from Nagy (1987) to calculate FIRs for broad categories (*e.g.*, all birds, passerines, seabirds) were presented in the *Wildlife Exposure Factors Handbook* (U.S. Environmental Protection Agency, 1993). These equations provide FIR in grams of dry matter per day, which can then be converted to wet weight based on percent moisture in the food. More recent work by Nagy (2001) expanded on the development of generic allometric equations, providing both dry weight and wet weight calculations for a broader range of distinct wildlife categories (*e.g.*, Charadriiformes, Galliformes, Insectivorous Birds, Carnivorous Birds). However, because all the generic allometric equations are based on the compilation of metabolic data from a wide range of species, they may not provide the most accurate estimate of FIRs for specific species of concern. If available, estimates of FMR, dietary composition, and assimilation efficiency (AE) for the species of concern should be considered, as this information will provide a more accurate estimate of daily food requirements.

Dietary composition, the amount of each food type consumed on a daily basis, is a critical component in determining FIR, as different foods provide different amounts of gross energy (*e.g.*, kcal/g food matter) to the consumer. For example, the gross energy (GE) available from aquatic invertebrates is greater than that available from aquatic algae (U.S. Environmental

Protection Agency, 1993). The AE values for different foods may also vary substantially. For example, a bird eating aquatic invertebrates assimilates the available energy at a substantially higher efficiency (77%) than if it were eating aquatic vegetation (23%) (U.S. Environmental Protection Agency, 1993). Therefore, the amount of aquatic invertebrate food necessary to fulfill the energetic requirements of a bird consumer would be substantially less than the amount of aquatic vegetation needed to meet the same requirements.

In addition to providing the percentages of each food type in a wildlife consumer's diet, feeding ecology studies can establish the trophic level composition of the diet. While this information is not necessary for calculating WVs, it is essential for evaluating whether either of the TRC trophic level approaches presented here will result in an exceedance of the WVs. Ideally, dietary information on both food type amounts and trophic level composition can be determined in percent biomass, as this provides the most accurate representation of actual ingestion. However, due to the difficulty inherent in determining the exact daily dietary composition of any free-living animal, dietary studies often rely on frequency of feeding observations or analysis of prey remains or a combination of both. These types of data pose less of a problem if the prey species are the same kind (*e.g.*, all fish) and roughly the same size. As the diversity of the prey base increases, however, the relative contribution from each prey item to the daily ingested biomass can be over- or under-represented if reported on the basis of occurrence frequency. For example, observations of predation may indicate an animal consumes small crabs and clams in equal amounts (*i.e.*, 50% clams:50% crabs). However, clams may provide more biomass per animal consumed than crabs, indicating the need for a different dietary ratio (*e.g.*, 70% clams:30% crabs) in estimating food ingestion rates and determining whether WVs will be exceeded.

The following accounts present the best available information regarding dietary composition and FIRs for the species of concern in this evaluation. When species-specific information regarding metabolic needs and assimilation efficiencies for various food types was not available, FIRs were determined using the most appropriate allometric equations from Nagy (2001). When this information was available, FIRs were determined using equations to estimate FMR (Nagy, 1987) and the methodology described in the *Wildlife Exposure Factors Handbook* (U.S. Environmental Protection Agency, 1993). The reader is directed to the three references mentioned for a complete explanation of the allometric methodology.

As the goal of the evaluation was to consider potential effects to animals living and breeding in California, every attempt was made to find the most rigorous dietary data for resident animals. For some species, few detailed feeding studies have been conducted. As a result, some of the following dietary information is based on only one or two studies, some conducted several decades ago. Until new data are generated, however, these studies remain the best source for dietary information.

IV.A. Southern Sea Otter (*Enhydra lutris nereis*):

Sea otters are the largest member of the Mustelidae family but one of the smallest marine mammals (Riedman and Estes, 1988). Based on length measurements of dead sea otters in California, the predicted average weights of healthy animals are 29.0 kg (males) and 19.8 kg (females) (Riedman and Estes, 1990). Although individual body weights may vary from these values, the predicted **average weight for female otters (19.8 kg)** was used for the calculation of wildlife values in this evaluation.

Information on southern sea otter diet was taken primarily from Riedman and Estes (1988, 1990). The diet of southern sea otters rarely or never includes fish, instead being comprised almost exclusively of benthic macroinvertebrates. Over 60 different invertebrate species have been identified as prey items of southern sea otters. However, sea otter diet is influenced by prey species availability, length of time otters have occupied an area, habitat type, and time of year.

Southern sea otters are primarily associated with subtidal habitats characterized by rocky substrata, although they are also found in areas with soft-sediment substrata. The main prey items in rocky subtidal habitats are abalones (*Haliotis* spp.), rock crabs (*Cancer* spp.), and red sea urchins (*Strongylocentrotus* spp.) (Riedman and Estes, 1988). Abalones and sea urchins are predominantly herbivorous, while rock crabs (*e.g.*, red crab, Dungeness crab) are carnivorous on small crustaceans, clams, and oysters (Morris *et al*., 1980). Sea otters in soft-sediment substrata also rely heavily on bivalve molluscs (*e.g.*, Pismo, Washington, and gaper clams), although the 13 soft-sediment species identified as prey in these habitats include rock crabs and the Lewis's moon snail (*Polinices lewisii*) (Kvitek and Oliver, 1988). The moon snail is primarily a predator on clams (Morris *et al*., 1980).

In addition to the aforementioned invertebrates, southern sea otter diets can include a wide variety of prey: kelp crabs (*Pugettia* spp.), turban snails, mussels (*Mytilus* spp.), octopus (*Octopus* spp.), barnacles (*Balanus* spp.), scallops (*Hinnites* spp.), fat innkeeper worms, sea stars (*Pisaster* spp.), and chitons (*Cryptochiton* spp.) (Riedman and Estes, 1990). Seasonal abundance can also play a role in determining important food items. Squid, spawning during fall and spring in Monterey Bay, constitute a large component of some sea otter diets (Riedman and Estes, 1990). Sea otters also occasionally prey on various seabirds, including western grebes (*Aechmophorous occidentalis*), surf scoters (*Melanitta perspicillata*), cormorants (*Phalacrocorax* spp.), common loons (*Gavia immer*), and gulls (*Larus* spp.). However, observations of this foraging behavior suggest that it is rare and that male otters may be responsible for the majority of seabird predation (Riedman and Estes, 1990).

The diet of southern sea otters may include a number of species considered trophic level 3 organisms (*e.g.*, octopus, squid, rock crab, moon snail, sea stars), although trophic level 2 organisms (*e.g.*, abalones, clams, mussels, urchins) appear to be the predominant prey. However, diet and foraging strategy appear to vary between individual otters, even within the same foraging habitat (Riedman and Estes, 1988). Sea otters appear to specialize on certain available

prey species, and these preferences may be maintained for several years. Observations of tagged female sea otters in Monterey Bay provided examples of this specialization, with one female preferentially eating kelp crabs, turban snails, and purple urchins, while another female foraged on abalones and rock crabs (Riedman and Estes, 1988).

This apparent foraging specialization, coupled with the diverse array of prey known to be consumed by sea otters, makes it difficult to assign a particular dietary trophic level composition. In a study of foraging in soft-sediment habitats, clams (trophic level 2) were captured and eaten on more than 75 percent of successful foraging dives (Kvitek and Oliver, 1988). Crabs considered trophic level 3 organisms (*Cancer* spp.) appeared to account for only a small percentage (~ 4%) of the diet, with other, lower trophic level crabs (*e.g.*, mole crab, kelp crab) and molluscs comprising the remainder. No comparable estimations of dietary composition were found for otters in rocky habitats, although it appears generally accepted that trophic level 2 organisms like abalones and sea urchins account for the majority of food consumed by these otters. However, based on the availability of a variety of trophic level 3 prey and the potential for individual otters to specialize on certain species, the dietary composition used for evaluating the TRC trophic level approaches for sea otters was **20 percent trophic level 3, 80 percent trophic level 2**. These are not static values and further research may indicate the need for an alternate estimation of dietary composition.

It has been estimated that free-ranging adult sea otters may consume food equivalent to 23-33 percent of their body weights per day (Riedman and Estes, 1990). Using the high end of this range (*i.e.*, 33%) as a conservative approach to represent the assumed higher metabolic needs of a breeding female sea otter, and the predicted average female weight of 19.8 kg results in a daily food ingestion rate of 6.5 kg/day. This estimate of FIR is substantially higher than what would be expected using any of the allometric equations described previously. However, this apparent discrepancy may be explained by considering the sea otter's metabolism and energetic requirements. Sea otters are small relative to other marine mammals, and lack the blubber layer which provides insulation and an energy reserve. Sea otters compensate for the thermal stress of a marine existence by maintaining a high level of internal heat production; 2.4 - 3.2 times that expected for a terrestrial mammal of similar size (Riedman and Estes, 1990). Based on the otter's elevated energetic requirements, it has been estimated that a 20 kg adult would need between 4,295 and 5,750 kcal/day (Riedman and Estes, 1990), roughly twice the FMR estimated using Nagy's allometric equation for all placental mammals (U.S. Environmental Protection Agency, 1993).

FIR for southern sea otter = 6.5 kg wet weight/day

IV.B. California Least Tern (*Sterna antillarum browni*):

The least tern is the smallest of the tern species that nest on open beaches and islands free of vegetation (Thompson *et al*., 1997). Adult female body weights presented in this reference range from 36 - 62 g; however, this range includes three geographic subspecies: *S. a. antillarum* (U.S.

Atlantic/Gulf coasts, West Indies); *S. a. athalassos* (interior U.S.); and *S. a. browni* (California coast, west coast of Mexico). The mean weight for *S. a. antillarum* is 49.3 g, while that of *S. a. athalassos* is 42.5 g. The reported weight for *S. a. browni* (39.8 g) was only based on one specimen. Dunning (1993) reported a mean weight of 43.1 g (unknown sex) for breeding birds in Kansas (most likely *S. a. athalassos*). Using the mean weights reported in Thompson *et al.* (1997) for the two coastal subspecies results in an **average adult female body weight of 45 g**.

Although other subspecies' diets include small crustaceans and insects (Thompson *et al.*, 1997), the California least tern appears to be strictly piscivorous (Massey, 1974). Breeding colonies may form on beach sites along the coast or on suitable alternative substrates set back from the ocean (U.S. Fish and Wildlife Service, 1985a). Colonies are generally located either near the coast, or near lagoons, estuaries, or rivers (Thompson *et al.*, 1997).

Individuals from three breeding colonies near the coast, that had little or no freshwater or estuarine habitats nearby, were found to forage almost exclusively in relatively shallow, nearshore ocean waters in the vicinity of major river mouths (Atwood and Minsky, 1983). Terns were observed to feed on three primary forage fish species: northern anchovy (*Engraulis mordax*) and two species in the silversides family - topsmelt (*Atherinops affinis*) and jacksmelt (*Atherinopsis californiensis*). Prey size at two coastal colonies varied for each tern age class, with chicks consuming smaller fish than adults or juveniles. However, 73 percent of the three primary forage fish species eaten by all age classes were less than 5 cm in length (Atwood and Kelly, 1984).

In contrast to tern colonies which foraged mainly in nearshore ocean waters, terns from breeding colonies located near estuarine habitats fed primarily in shallow saltmarsh channels and tidal estuaries (Atwood and Minsky, 1983; Atwood and Kelly, 1984). The dominant forage fish species in these waters, and the majority (82%) of fish dropped at a colony in Anaheim Bay, were the topsmelt and California killifish (*Fundulus parvipinnis*). Atwood and Kelly (1984) found that fish dropped at breeding tern colonies, either accidentally or from lack of hunger, were generally valid indicators of the principal prey species consumed. Two other forage fish, deepbody anchovies (*Anchoa compressa*) and slough anchovies (*Anchoa delicatissima*), were the most abundant prey dropped at two southerly colonies, although no distinction was made as to where terns from these colonies foraged (Atwood and Kelly, 1984). Although a total of 49 forage fish species, all represented by individuals less than 1 year old, were found at 10 breeding tern colonies, Atwood and Kelly (1984) concluded that five fish (northern anchovy, topsmelt, jacksmelt, deepbody anchovy, slough anchovy) represented the main food items at least tern breeding colonies in California.

Foraging ecology for a tern breeding colony located near San Francisco Bay has been monitored for numerous years, providing a long-term assessment of the colony's dietary preferences (Elliott and Sydeman, 2002). Prey fish dropped at the colony by foraging birds were collected and identified from 1981-1982, 1984-1995, and 2000-2001. Although minor variations in forage fish species abundance were reported between years, the combined data from all years revealed that

three fish (topsmelt, jacksmelt, northern anchovy) accounted for more than 86 percent of all samples collected. The next most abundant prey (> 7% of total) were various surfperch species (*Embiotocidae*).

Based on the above information, the diet of adult female California least terns is comprised solely of small fish from various species. Several of these species (northern anchovy, topsmelt, jacksmelt, California killifish) appear to account for the majority of prey items taken by both courting and nesting terns, including those birds that forage in estuarine and tidal waters. In addition, data indicate that the majority of fish captured by breeding terns are small (5 cm or less) and all are young-of-year (Atwood and Kelly, 1984). According to the *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals* (Vol. III) (U.S. Environmental Protection Agency, 1995b), these prey species are generally considered trophic level 3. Even juvenile fishes from this group (*e.g.*, topsmelt, northern anchovy) are listed as trophic level 3 by this reference.

It is important to note that all of these forage fish species exhibit some amount of omnivory, feeding to varying degrees on primary producers and detritus. Juvenile northern anchovies generally consume small crustaceans and other zooplankton, although algae and other phytoplankton may constitute a substantial portion of their diet (Wang,1986). Anchovies can be filter-feeding or biting planktivores, indicating the ability to selectively prey on individual organisms (California Department of Fish and Game, 2001). Similarly, the diet of the California killifish consists primarily of benthic and planktonic invertebrates, with juveniles more likely than adults to feed on terrestrial insects and zooplankton (Moyle, 2002). West and Zedler (2000) examined gut contents of adult killifish and reported algae and detritus as minor dietary items. Nonetheless, both anchovy and killifish appear to feed primarily on trophic level 2 organisms.

In contrast to the anchovy and killifish, the feeding habits of the other two primary tern prey fish (topsmelt and jacksmelt) indicate a greater dietary dependence on trophic level 1 food. Wang (1986) listed the major food items for juvenile jacksmelt as algae, detritus, and small crustaceans. In addition, amphipods were described as a common food item. The same reference (Wang, 1986) states that juvenile topsmelt feed on crustaceans, diatoms, algae, detritus, chironomids, and amphipods. The California Department of Fish and Game (2001) states that topsmelt inhabiting intertidal areas consume algae and fly larvae, as well as crustaceans. Moyle (2002) points out that the diet of small topsmelt (4.9 - 5.6 cm) in one estuary consisted primarily of diatoms and filamentous algae (50% by volume), and detritus (29%), with chironomid midge larvae and amphipods comprising an additional 20 percent.

While all of these forage fish may incorporate some amount of primary producers and detritus in their diets, none can be considered exclusively trophic level 2 consumers. California least terns are not species-specific predators; therefore, their overall dietary composition will vary depending on the relative abundance of suitable prey species. At any given time or location, it is impossible to predict whether prey fish are primarily consuming plant material or the trophic level 2 organisms that feed on plant material. In order to adequately evaluate the full potential

impact of the methylmercury TRC on the endangered California least tern, a diet of **100 percent trophic level 3 fish** is assumed.

The FMR for least terns was estimated using Nagy's allometric equation for all birds (*in* U.S. Environmental Protection Agency, 1993):

FMR (kcal/day) = 2.601 × (body weight in g)$^{0.640}$
FMR = 2.601 × 45 $^{0.640}$
FMR = 29.7 kcal/day

The FIR was then calculated using the equation:

FIR = FMR ÷ metabolizable energy from food (ME)

where ME equals the gross energy (GE) from the food type times the assimilation efficiency (AE) of the animal consuming that food. The GE of bony fishes is 1.2 kcal/g wet weight. The AE for birds consuming fish is 79%. Therefore, the ME for the least tern is 0.948 kcal/g fish.

FIR = 29.7 kcal/day ÷ 0.948 kcal/g fish

FIR for California least tern = 0.031 kg wet weight/day

IV.C. California Clapper Rail (*Rallus longirostris obsoletus*):

The California clapper rail (*R. l. obsoletus*) is the largest of the three rail subspecies considered in this evaluation, followed in descending order by the light-footed and Yuma clapper rails (U.S. Fish and Wildlife Service, 1976). In the only literature found for this particular subspecies that provided body weights, nineteen female California clapper rails from south San Francisco Bay were examined as part of a Master's Degree thesis (Albertson, 1995). Weights ranged from 300 to 400 g, with a **mean weight of 346.1 g**. This mean value was used for the calculation of a wildlife value for this subspecies.

The most comprehensive assessment of the California clapper rail diet is presented by Moffitt (1941). Stomach contents from 18 birds were examined and the food items identified and measured as a volumetric percentage. On average, animal matter accounted for approximately 85 percent of the diet, with the remainder composed of seed and hull fragments of marsh cordgrass. Over half (56.5%) of the overall diet was comprised of plaited horse mussels (*Modiolus demissus*). Spiders of the family Lycosidae (wolf spiders) accounted for 15 percent of the diet, while little macoma clams (*Macoma balthica*) (7.6%), yellow shore crabs (*Hemigrapsis oregonensis*) (3.2%), and worn-out nassa snails (*Ilyanassa obsoletus*) (2.0%) were the remaining important dietary items. Worms, insects, and carrion combined accounted for a total of 1.1 percent of the remaining diet found by Moffitt (1941) in the 18 clapper rail stomachs. The importance of crabs in the clapper rail diet was confirmed by Varoujean (1972), who observed

rails eating striped shore crabs (*Pachygrapsus crassipes*).

Although Moffitt (1941) reported that plant matter accounted for approximately 15 percent on average of the clapper rail diets, the author stated that this percentage probably represented the maximum of a vegetable diet. This conclusion was based on the fact that the birds were collected in early February, a time when animal food items would typically be at lowest abundance. However, it is important to note that this reported average for plant food (~15%) was calculated from a wide range of percentages in the 18 birds examined (0% - 58% plant food). As with other omnivorous species, the amount of any particular food item consumed at any given time may vary substantially depending on a number of factors. While clapper rails most likely do not eat a set amount of plant matter daily, it is clear from Moffitt (1941) that vegetation generally constitutes a substantial dietary item over time.

Based on Moffitt's (1941) assumption that his mid-winter gut analyses represented a maximum for vegetation in the clapper rail diet, and the knowledge that clapper rails nest during a time when animal foods would be in greater abundance (mid-March - July) (U.S. Fish and Wildlife Service, 1984), the overall rail diet for this effort is assumed to be 10 percent vegetation and 90 percent animal matter. For the purposes of this evaluation, the vegetation portion of the diet will be considered as food not contributing to the daily ingested dose of methylmercury. Although mercury is known to accumulate in aquatic plants (Gupta and Chandra, 1998; Ellis and Eslick, 1997; Breteler *et al*., 1981), the scientific literature indicates that accumulation is primarily in the roots rather than in the rhizomes or above-ground tissues (Boening, 2000; Breteler *et al*., 1981).

The primary animal foods of clapper rails according to Moffitt (1941) appear to be mussels, wolf spiders, clams, shore crabs, and snails. Mussels and clams are mainly filter-feeders on plankton, which may include zooplankton, and both are designated as trophic level 2.2 (U.S. Environmental Protection Agency, 1995b). However, phytoplankton and detritus make up the bulk of these organism's diets; therefore, mussels and clams are considered trophic level 2 for this evaluation. Although the EPA classifies snails as trophic level 2 organisms (U.S. Environmental Protection Agency, 1995b), the EPA notes that some marine forms are carnivorous. According to Morris *et al*. (1980), the species of nassa snails consumed by clapper rails are primarily herbivorous deposit feeders; however, Morris *et al*. note that at least one San Francisco Bay population is also carnivorous, preying on polychaete worms. This feeding behavior warrants the classification of trophic level 3 for nassa snails consumed by California clapper rails. The EPA views crabs as trophic level 3.3 organisms; however, this assumption was based on larger, more predatory crabs (*e.g.*, blue crabs) consuming small fish, other crabs, molluscs, and other invertebrates (U.S. Environmental Protection Agency, 1995b). The two crab species identified as food for the California clapper rail, *Hemigrapsis oregonensis* and *Pachygrapsus crassipes*, are primarily herbivorous, feeding on algae and diatoms (Morris *et al*., 1980; Roth and Brown, 1980). Therefore, it is more appropriate to classify these crab species as trophic level 2 organisms for this evaluation.

Evaluating the importance of wolf spiders in the clapper rail diet presents a unique challenge.

Spiders are generally classified as trophic level 3 organisms due to their predatory nature (U.S. Environmental Protection Agency, 1995b). Spiders are also generally regarded as terrestrial species, with limited involvement with aquatic food webs. However, wolf spiders are active hunters and those inhabiting the wetland habitats of clapper rails may be preying on trophic level 2 aquatic invertebrates. At least one species in this family, *Arctosa serii*, inhabits the sandy intertidal zone in the Gulf of California and actively preys on amphipods and ground beetles (Roth and Brown, 1980). If the wolf spiders consumed by California clapper rails exhibit the same feeding behavior, this would suggest a direct accumulation pathway, similar to the consumption of a trophic level 3 fish. However, it is unknown what effect the physiological processes involved with the capture and ingestion of spider prey (*e.g.*, venom immobilization, digestion) would have on the bioavailability of any methylmercury in that prey. In addition, although Moffitt (1941) reported wolf spiders comprising up to 73 percent of the animal matter in clapper rail stomachs, the relative importance in the overall diet may be minor. Moffitt's (1941) analyses were based on volumetric percentages, not on mass. The small amount of digestible body mass in spiders, relative to mussels, clams, crabs, and snails, suggests spiders may be an insignificant component of the overall diet and of the daily ingested dose of methylmercury.

For this evaluation, 90 percent of the California clapper rail diet is assumed to be from aquatic animal matter and 10 percent from vegetation. Based on the trophic level analyses presented above, **5 percent of the overall diet is assumed to be from trophic level 3 organisms (*i.e.*, nassa snails) and the remaining 85 percent from trophic level 2 organisms (*i.e.*, mussels, clams, and crabs)**. While these values are not static, and individual birds may consume varying percentages of each food type or additional prey items, this trophic level breakdown represents a reasonable dietary composition for California clapper rails based on the best available information.

Clapper rails may consume a wide variety of foods. Values for the gross energy content for some of these foods (*e.g.*, shell-less bivalves, shelled crabs) and the efficiency at which rails assimilate them can be found in the *Wildlife Exposure Factors Handbook* (U.S. Environmental Protection Agency, 1993). However, because rails do not consume set amounts of these food types, FIR must be estimated using one of the generic allometric equations from Nagy (2001). Out of the 17 avian categories for predicting FIRs presented by Nagy (2001), Charadriiformes is the taxonomic order most closely related to rails (Gill, 1995). In addition, the rail's feeding ecology most closely resembles that of birds in the Charadriiformes category (*i.e.*, shore birds, gulls, auks). Therefore, the FIR for California clapper rails was calculated using the following equation:

FIR (wet weight) = $1.914 \times (\text{body weight in g})^{0.769}$
FIR = $1.914 \times 346.1^{0.769}$
FIR = 171.63 g/day wet weight

FIR for California clapper rail = 0.172 kg wet weight/day

IV.D. Light-footed Clapper Rail (*Rallus longirostris levipe*):

As the light-footed clapper rail is smaller than the California clapper rail (U.S. Fish and Wildlife Service, 1976), the body weight for the California rail was not considered appropriate for this subspecies. No subspecies-specific information on body weights was found in the scientific literature. Dunning (1993) reported an average weight of 271 g for seven female clapper rails (*R. longirostris*, unidentified subspecies) from South Carolina. While an average body weight for the light-footed subspecies may be slightly more or less than the average reported by Dunning (1993), this value (**271 g**) was used in the calculation of a wildlife value in this effort.

Light-footed clapper rails occupy coastal marsh habitats, similar to the California clapper rail. The most robust documentation of the light-footed clapper rail's diet is presented by Zembal and Fancher (1988). Through direct observations of foraging and from analyses of food materials regurgitated by light-footed clapper rails, a list of prey items were identified. Observations of foraging revealed that clapper rails hunted in marsh vegetation over 90 percent of the time. During these foraging bouts, rails focused on invertebrates at the base of plants or under dried pieces of vegetation and debris. According to the observations of successful capture and swallowing, rails consumed hundreds of these invertebrates per hour. These small organisms could not be identified but appeared to be very mobile, as they would scatter rapidly when discovered by the rails. Due to the amount of time rails foraged on these organisms and the large numbers swallowed during foraging bouts, the researchers concluded that these invertebrates were important dietary items.

When not foraging in vegetation, rails would switch strategies and hunt tidal creek banks, mudflats, and open water. Rails were observed catching and swallowing various shore crabs (*i.e.*, *Pachygrapsus crassipes*, *Hemigrapsus oregonensis*) and fiddler crabs (*Uca crenulata*) from the creek banks. Both fish (*i.e.*, longjaw mudsucker - *Gillicthys mirabilis*) and ribbed horse mussels (*Ischadium demissum*) were taken from the mudflat habitats. However, observations of foraging on the mussels suggests that only portions of the animals were consumed, as the mussels would close upon first attack and rails appeared unable to reopen them. Other rails in open water were seen capturing California killifish (*Fundulus parvipinnis*) and tadpoles of the Pacific treefrog (*Hyla regila*). Scavenging on fish carcasses was also observed, although the rails may have been eating insect larvae on the carcasses.

Examination of regurgitated pellets provided additional information on clapper rail diets. The most abundant items were the remains of the shore crab species mentioned above. The next most abundant items were the remains of California horn snails (*Cerithidea californica*) and salt marsh snails (*Melampus olivaceous*). Other animal remains identified in regurgitated pellets included crayfish, beetles, isopods, and decapods. These additional items were not ranked according to abundance, although regurgitated pellets collected along a freshwater ditch were composed primarily of crayfish exoskeletons. Plant remains were rare in the regurgitated pellets, with the exception of two pellets that contained 75 elderberry seeds (representing about 25 fruits). The only other plant remains were three small unidentified seeds and several cordgrass seeds. The

researchers noted that only three clapper rails were ever observed feeding on plants, two consuming tips of pickleweed stems and one extracting and swallowing pith from broken cordgrass stems.

Light-footed clapper rails appear similar to other omnivorous birds in that a wide range of both plant and animal foods may be included in the diet, the composition of which may vary depending on any number of environmental or physiological factors. No information was provided by Zembal and Fancher (1988) regarding the percentage of specific food items in the rail diet; however, the authors offered some conclusions about the relative importance of certain organisms. Crabs and snails were considered important prey because of their large size and abundance in rail habitats. The two shore crabs and two snails identified above as prey for clapper rails are all trophic level 2 organisms, feeding on plants or detritus (Morris *et al*., 1980). Fiddler crabs feed primarily on detritus (Barnes, 1980; Kozloff, 1990); therefore, they are also considered trophic level 2 organisms. The small invertebrates consumed by clapper rails were also considered important in the diet because of the large numbers eaten and the amount of time rails spent foraging on them. Although these invertebrates could not be identified by the researchers, the small size of the animals and their tendency to cluster in large concentrations indicates that they should be classified as trophic level 2 organisms.

Zembal and Fancher (1988) did not offer any conclusions regarding the importance of other dietary items such as fish, mussels, tadpoles, and crayfish. However, they observed rails capturing fish numerous times and suggested that fish consumption may be more common than their results would indicate. The two fish species identified as prey, California killifish and longjaw mudsucker, are trophic level 3 predators (Moyle, 2002). In addition to trophic level 3 fish, crayfish were identified in pellets regurgitated by clapper rails. The EPA classifies crayfish at an intermediate trophic level (2.4), noting that crayfish are primarily herbivorous and that animal food is a minor part of the diet if vegetation is available (U.S. Environmental Protection Agency, 1995b). However, Slotton *et al*. (2000) found that signal crayfish (*Pacificasticus leniusculus*) in California can accumulate mercury to high concentrations, similar to predatory fish. While *P. leniusculus* is in a different genus than those identified in the pellets regurgitated by light-footed clapper rails, the omnivorous nature of all crayfish indicates the potential for a greater reliance on animal food than on plant material. For this evaluation, a higher intermediate trophic level (*i.e.*, 2.8) was assigned to crayfish consumed by light-footed clapper rails. Assuming 10 percent of the overall diet is crayfish, 8 percent of this contribution was assigned to trophic level 3 and 2 percent to trophic level 2 (*i.e.*, TL2.8 = 80% TL3, 20% TL2). Further assuming the trophic level 3 fish prey contributes 10 percent of the diet, a total of 18 percent of the overall diet was assigned to trophic level 3 (*i.e.*, 8% from crayfish, 10% from fish).

As noted above, plants appeared to play a minor role in the light-footed clapper rail diet, with the exception of elderberry fruits near a freshwater ditch (Zembal and Fancher, 1988). The fact that rails were only seen eating vegetation by the researchers on three occasions, despite approximately 180 hours of visual contact between March 1979 and August 1987, indicates that vegetation may be an insignificant food source, relative to the overall diet. For this reason, the

breakdown of dietary trophic level composition is based on an assumption of 100 percent animal foods.

The predominant foods of the light-footed clapper rail appear to be trophic level 2 crabs, snails, and small invertebrates. Other important foods, from a bioenergetic standpoint, include trophic level 3 fish and crayfish. Although no specific information was found regarding the percentage of each trophic level contributing to the overall diet, a reasonable assumption of **82 percent trophic level 2 and 18 percent trophic level 3** was used in the calculation of wildlife values for the light-footed clapper rail.

Although differing from the California clapper rail, in that fish and crayfish are important dietary items and vegetation appears insignificant, the similarly indefinite composition of the light-footed clapper rail's diet requires that FIR be estimated using the same allometric equation (Charadriiformes group) from Nagy (2001). For this effort, the body weight for the light-footed rail was estimated to be 271 g.

FIR (wet weight) = $1.914 \times (\text{body weight in g})^{0.769}$
FIR = $1.914 \times 271^{0.769}$
FIR = 142.2 g/day wet weight

FIR for light-footed clapper rail = 0.142 kg wet weight/day

IV.E. Yuma Clapper Rail (*Rallus longirostris yumaensis*):

The Yuma clapper rail is considered smaller than the both the California and light-footed clapper rails (U.S. Fish and Wildlife Service, 1976). However, there was no defensible way to determine a lower body weight for the Yuma rail than the one used for the light-footed rail. No subspecies-specific information on body weights was found in the scientific literature. Subsequently, the **average body weight of 271 g** reported by Dunning (1993) was used in the calculation of a wildlife value in this effort.

The Yuma clapper rail is unique from other clapper rail subspecies in that it resides and breeds in freshwater marshes (Anderson and Ohmart, 1985). Early literature on Yuma clapper rails suggested that the majority of the birds wintered in brackish marshes along the western coast of Mexico and then returned to their freshwater breeding grounds in the U.S. along the Colorado River and the Salton Sea for the spring and summer nesting period (U.S. Fish and Wildlife Service, 1976; Anderson and Ohmart, 1985). Both the California and light-footed clapper rails are considered non-migratory, although the California clapper rail is known to "wander" from its breeding grounds in fall and early winter (U.S. Fish and Wildlife Service, 1976). The Yuma clapper rails that did overwinter in freshwater habitats in the U.S. were considered a small part of the overall population (U.S. Fish and Wildlife Service, 1976; 1983). One possible explanation given for this migratory behavior was that it was in response to reduced food resources in the winter months (Anderson and Ohmart, 1985). However, radio telemetry work conducted

between February 1985 and December 1987 revealed that at least 70 percent of the population along the lower Colorado River remains resident (Eddleman, 1989). Therefore, the dietary information for birds residing in freshwater marshes is assumed on a year-round basis.

Comprehensive dietary information was presented by Ohmart and Tomlinson (1977), who examined stomach contents from 11 Yuma clapper rails collected from California and Arizona. Four birds from the Colorado River Delta in Mexico were also examined. Crayfish (*Procambarus* spp. and *Oropectes* spp.) were by far the most dominant prey items in the nine birds collected from along the Colorado River, averaging 95 percent by volume (range: 80-100%) of the stomach contents. Other food items included various insects, spiders, and molluscs. A small mammal bone was found in one stomach and plant seeds in another. Of the two birds collected from the confluence of the Gila and Colorado Rivers, one stomach contained an introduced freshwater clam (*Corbicula* sp.) (98%) and the other contained isopods (97%). The remaining food items in these two stomachs were unidentified insect parts. The birds collected in Mexico showed a more diverse food assemblage, with the predominant foods being water beetles (56%) and unidentified fish (32%). Fish do not appear to be important dietary items outside of the river delta habitats. A small amount of vegetative matter was also found in these birds, although plant matter appears to play an insubstantial role in the diet for all birds.

The trophic level dietary composition for Yuma clapper rails is based on 100 percent animal foods. It is clear that Yuma clapper rails residing along the Colorado River rely heavily on various freshwater crayfish. While it was once thought that these crayfish became dormant during the winter months, precipitating migratory behavior in the rails, evidence indicates that crayfish are present year-round in at least some locations and reproduce in autumn and early winter (Eddleman, 1989). As noted above in the analysis for light-footed clapper rails, crayfish are considered trophic level 2.8 organisms for determining the dietary composition. However, it is unlikely that Yuma clapper rails feed exclusively on crayfish, based on evidence that the birds supplement their diets with other foods ranging from terrestrial and aquatic insects to molluscs, depending on location and availability. Some of these supplemental food items may be aquatic (*e.g.*, isopods, damselfly nymphs, molluscs) or removed from the aquatic ecosystem (*e.g.*, grasshoppers, weevils, ground beetles). Assuming a reasonable high volume diet of 90 percent crayfish, 72 percent of this contribution can be assigned to trophic level 3 and 18 percent to trophic level 2 (*i.e.*, TL2.8 = 80% TL3, 20% TL2). Based on the dietary assessment provided by Ohmart and Tomlinson (1977), the diet for the Yuma clapper rail can therefore be assumed as **72 percent trophic level 3 organisms (from crayfish), 23 percent trophic level 2 organisms (from crayfish and other TL2 foods), and 5 percent non-aquatic organisms**.

The FIR for Yuma clapper rails was estimated using the same allometric equation (Charadriiformes group) from Nagy (2001). For this effort, the body weights for all three clapper rail subspecies were estimated to be equal (271 g). Therefore, the FIR calculation for the Yuma clapper rail will be identical to the one for the California and light-footed clapper rails.

FIR (wet weight) = 1.914 × (body weight in g)$^{0.769}$
FIR = 1.914 × 271$^{0.769}$
FIR = 142.2 g/day wet weight

FIR for Yuma clapper rail = 0.142 kg wet weight/day

IV.F. Western Snowy Plover (*Charadrius alexandrinus nivosus*):

Snowy plovers are small shorebirds weighing from 34 - 58 g, ranging in length from 15 - 17 cm (U.S. Fish and Wildlife Service, 2001). Dunning (1993) reports a mean weight of 41.4 g from 38 specimens of *Charadrius alexandrinus* (unknown gender) from California, with a range from 37 - 49 g. No information was found indicating gender-specific differences in weight. Therefore, **a weight of 41 g** was used in the calculation of wildlife values for western snowy plovers.

The snowy plover diet consists primarily of aquatic and terrestrial invertebrates (Page *et al*., 1995), with little quantitative information about specific food habits (U.S. Fish and Wildlife Service, 2001). A wide variety of food items are reported for coastal birds: mole crabs, crabs, polychaetes, amphipods, tanaidaceans, flies, beetles, clams, and ostracods (Page *et al*., 1995). Plovers on beaches forage above and below the mean high-tide line, gathering invertebrates from the sand surface, kelp, foredune vegetation, and marine mammal carcasses (Page *et al*., 1995). Flies, beetles, moths, and lepidopteran caterpillars were taken by birds at San Francisco Bay salt-evaporation ponds (Page *et al*., 1995). Plovers in California have been observed pecking small flying insects from mid-air (U.S. Fish and Wildlife Service, 2001), and are known to charge with open mouth into aggregations of adult flies (Page *et al*., 1995).

Tucker and Powell (1999) examined snowy plover fecal samples from a southern California coastal breeding site. Results indicated that the primary prey were terrestrial insect families (*i.e.*, various flies and beetles), although mole crab and nassa snail parts were also identified. Insect larvae were found in 25 percent of the fecal samples. The authors concluded that their results were consistent with findings from other snowy plover diet studies in that the major prey items are flies and beetles. However, the authors noted that polychaete worms are digested too completely to be identified by their technique, and stated that these worms may be important prey items.

Although it appears that snowy plovers mainly feed on non-aquatic insects, of both larval and adult forms, at least some aquatic organisms are included in the diet. These aquatic prey (mole crabs, nassa snails, polychaete worms, amphipods, ostracods, clams, tanaidaceans) can all be classified as trophic level 2 organisms based on their diets (U.S. Environmental Protection Agency, 1995b; Morris *et al*., 1980). For this evaluation, an assumption was made that **trophic level 2 organisms constituted 25 percent** of the overall snowy plover diet. The remaining portion of the diet **(75%) was assumed not to be significantly contributing to the daily ingested dose of methylmercury**. Additional research into the possible relationship between methylmercury in an aquatic system and its bioavailability to terrestrial insects may remove some

of the uncertainty in this assumption.

Due to the wide variety of potential prey items and the subsequent variability in gross energy content and assimilation efficiencies, the FIR for snowy plovers was determined using Nagy's (2001) allometric equation for Charadriiformes (shore birds, gulls, auks):

FIR (wet weight) = $1.914 \times (\text{body weight in g})^{0.769}$
FIR = $1.914 \times 41^{0.769}$
FIR = 33.3 g/day wet weight

FIR for western snowy plover = 0.033 kg wet weight/day

IV.G. Bald Eagle (*Haliaeetus leucocephalus*):

The bald eagle was a representative species used for the derivation of wildlife criteria in the aforementioned GLI (U.S. Environmental Protection Agency, 1995c). For that effort, the bald eagle body weight used in criteria calculations (4.6 kg) was based on the mean of average male and female eagle body weights, although it was noted that female eagles are approximately 20 percent heavier than males. As the avian reference dose for methylmercury is based on adverse reproductive effects manifested by laying females, it is more appropriate to use average female body weights in the calculation of wildlife values.

In the GLI, the EPA presented an average body weight of 5.2 kg for female bald eagles. This value was based on the weights of 37 birds, taken from Snyder and Wiley (1976). Dunning (1993) presented an average female body weight of 5.35 kg, also based on the weights of 37 birds, taken from Palmer (1988). Taking both values into consideration, a **body weight of 5.25 kg** was used in the calculation of wildlife values for this evaluation.

The bald eagle diet has been extensively studied throughout the country. Although generally known as a piscivorous species, bald eagles are opportunistic predators and carrion scavengers (Buehler, 2000). Various birds, mammals, reptiles, amphibians, and crustaceans may serve as additional bald eagle prey (Buehler, 2000). As explained in the introduction to this section, FIRs can be most accurately estimated for an animal consuming different food types (*e.g.*, fish and birds) when there is information about the metabolic energy available from these foods and a reliable estimate of the amount of each food type consumed daily (*e.g.*, 75% fish, 25% birds). Information presented in the Wildlife Exposure Factors Handbook (U.S. Environmental Protection Agency, 1993) regarding the metabolizable energy available from various prey types and the ability of bald eagles to assimilate this energy allows for the use of this method to estimate daily food requirements. However, attempting to quantify a specific dietary composition for bald eagles is more difficult than for other species with a narrower range of prey types, and is further confounded by the fact that food preferences may vary both geographically and temporally.

An additional difficulty in calculating a general FIR for deriving the WV for bald eagles arises because the trophic level composition of the diet can also vary substantially between seasons, locations, or individuals. Calculating the FIR based solely on the percentage of various food types in the diet may not result in a WV representative of the greatest risk from methylmercury in the diet. For example, the daily FIR for an eagle with a diet of 95 percent fish / 5 percent birds will be greater than the FIR for an eagle with a diet of 80 percent fish / 20 percent birds (*i.e.*, less energy available from fish prey requires a greater amount consumed to satisfy bald eagle's free-living metabolic rate). The higher FIR, in turn, results in a lower WV, which may seem the most desirable outcome of this methodology. However, if the bulk of the 95/5 diet consists of trophic level 2 fish and terrestrial birds, the methylmercury concentration in the eagle's overall diet will remain substantially below the WV, regardless of the trophic level approach used. By contrast, the higher WV calculated from the 80/20 diet may be substantially exceeded by either trophic level approach if the diet consists primarily of trophic level 4 fish and piscivorous birds.

In this example, using the dietary composition resulting in the lowest WV as a surrogate for all eagles would give the misleading impression that all eagles may be protected (false negative) by the TRC, while using the higher WV would indicate that all eagles may be at risk from the TRC (false positive). However, the goal of this analysis is to evaluate the protectiveness of the two trophic level approaches, using data for birds with the greatest potential for methylmercury exposure through their diet. Therefore, the FIR used to calculate the WV must be based on the most reliable bald eagle diet with the highest combined percentage of trophic level 4 fish and aquatic-dependent avian prey, and the lowest percentage of terrestrial prey (*i.e.*, no connection to methylmercury in the aquatic environment).

The feeding ecology of avian prey of bald eagles is critical for this analysis because prey birds that consume aquatic biota represent an additional exposure pathway for bald eagles, as methylmercury in fish and aquatic invertebrates is biomagnified as it moves through successively higher trophic level organisms. The biomagnification of methylmercury through piscivorous avian prey was factored into the GLI effort, as data showed piscivorous herring gulls (*Larus argentatus*) were an important dietary component (5.6% of the dietary biomass on average) of Lake Superior bald eagles (U.S. Environmental Protection Agency, 1995d). The study used to determine the bald eagle diet for the GLI effort (Kozie and Anderson, 1991) also found various waterfowl in eagle prey remains. These waterfowl species were not considered piscivorous, yet for some, trophic level 2 aquatic biota can constitute a substantial part of their diet. These waterfowl were not included in the GLI estimate of methylmercury exposure, as the bulk of the bird prey component was comprised of herring gulls. However, in areas where bald eagles consume large numbers of these aquatic-dependent birds, the biomagnification of methylmercury from trophic level 2 organisms into waterfowl tissues may contribute substantially to the bald eagle's daily ingestion of methylmercury.

Several efforts to develop protective mercury criteria (*e.g.*, U.S. Environmental Protection Agency, 1997a; Buchanan *et al*., 2001; California Regional Water Quality Control Board - Central Valley Region, 2001) have used the dietary composition developed in the GLI (U.S.

Environmental Protection Agency, 1995c). Using information on bald eagles nesting on islands and along the shore of Lake Superior in Wisconsin (*from* Kozie and Anderson, 1991), and adjustment factors to estimate the relative number of birds and fish delivered to a nest based on the prey remains found under the nest, the EPA determined that 92 percent of the dietary biomass was comprised of fish and 8 percent comprised of birds or mammals. The adjustment factor was developed to account for the inherent error in estimating a dietary composition based solely on the analysis of prey remains. The Kozie and Anderson (1991) study used to determine bald eagle diets reported that fish comprised 50 percent and birds comprised 48.4 percent of the nest site prey remains. However, direct observations of three nests during part of the study period revealed that fish constituted 97 percent of the captured prey. To address this discrepancy, the EPA's adjustment factors (*i.e.*, - the ratios between the number of each prey type found in nest remains and the number of each prey type observed in nest deliveries during the same period) were applied to the prey remain data for all nest sites in the study. This allowed for an estimate of the total number of birds and fish consumed by bald eagles. Then, using standard body weights for the bird and fish species identified, the percentage of biomass for each food type was calculated.

Using this dietary composition of 92 percent fish and 8 percent birds, along with information about the energetic needs of adult eagles and their ability to assimilate the caloric content of these food types, the GLI presented estimates of the amount of each food type ingested daily: 0.464 kg fish and 0.040 kg birds/mammals (U.S. Environmental Protection Agency, 1995c). The fish component of the overall diet was further broken down as 74 percent trophic level 3 (0.371 kg) and 18 percent trophic level 4 (0.0928 kg), based on data indicating the average trophic level for the fish component of Lake Superior bald eagles is 3.2 (*i.e.*, 80% TL3, 20% TL4). The remaining bird/mammal component of the overall diet was delineated as 5.6 percent piscivorous herring gulls (0.0283 kg) and 2.4 percent non-piscivorous other food (0.0121 kg). Although the GLI breakdown of the bald eagle diet has been used as a default composition in subsequent wildlife criteria efforts, studies of bald eagle diets from other parts of the country reveal a wide range of possible composition preferences. Several of these studies are summarized below.

A study of bald eagles in a desert riparian habitat in central Arizona found that fish comprised 77 percent of the total prey remains found under nests (Haywood and Ohmart, 1986). Mammals accounted for an additional 12 percent, birds 11 percent, and reptiles or amphibians 0.6 percent. The same study compared the findings from prey remains with direct observations of prey capture (73% fish, 5% mammals, 1% birds, 4% reptiles or amphibians, and 17% unidentifiable) and found only a minimal difference in percent composition.

By contrast, bald eagles nesting at various sites along the coast of Washington displayed a stronger dietary preference for birds, which accounted for 53 percent of the total prey remains (N = 1198) found under nests in three different regions (Knight *et al.*, 1990). Fish comprised 34 percent of the total remains, with mammals (9%) and invertebrates (4%) making up the rest. There were composition differences between the three sites evaluated, but in each case, birds accounted for the majority of food. Birds comprised 78 percent of all prey remains at Olympic

Peninsula nest sites, but down to 48 percent at San Juan Island sites. The researchers also compared their findings from collected prey remains with direct observations of prey delivery (*N* = 47) and concluded that birds were over-represented in prey collections beneath nests and fish were over-represented in observations of prey carried to nests. The high incidence of bird prey remains (53%) during the observation period is in contrast to the frequency of observations in which birds were delivered to the nest (8%). The frequency of observed fish deliveries was high (92%), but was much lower in prey remain collections (44%) during the observation period. Birds may be over-represented in nest collections due to a greater persistence than fish remains in the environment, while over-representation of fish in observations may be due to the relative ease of identification (Mersmann *et al*., 1992; Knight *et al*., 1990). However, this study indicates that birds are important prey for coastal bald eagles.

Dietary habits of resident bald eagles from three nesting areas in southcentral Oregon were studied between 1979 and 1983 (Frenzel, 1984). Nest site prey remain collections and direct observations of 16 eagles fitted with radio transmitters were the methods used. The three study areas were Upper Klamath Lake, outer Klamath Basin, and the Cascade Lakes region. Discrepancies between prey remain collections and observations of predation were also found in this study. At the Upper Klamath Lake site, fish comprised only 25 percent of the prey remains but accounted for 62 percent of the observed prey taken during the breeding season. The amount of fish observed taken at this site increased to 69 percent during the post-breeding season, but then dropped to less than 20 percent in fall and winter. Birds became the dominant food during these seasons, accounting for over 82 percent of the observed prey taken. Mammals were observed taken throughout the breeding and post-breeding seasons, but were not observed during the fall and winter. At Wickiup Reservoir in the Cascade Lakes study area, fish accounted for 100 percent of the observed prey taken during the breeding and post-breeding seasons. The same study looked at the diets of wintering-only bald eagles in the Klamath Basin. For these eagles, wintering and staging waterfowl were the primary food source, supplemented with some mammal prey. No fish remains were found in bald eagle castings from communal roosts, and no foraging attempts on fish were observed through the study.

In addition to the above studies, Volume III of *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals* (U.S. Environmental Protection Agency, 1995b), presented summaries of bald eagle dietary habit studies throughout the U.S. and British Columbia, along with estimated prey trophic levels. The diets presented in these summaries confirm the wide variability of prey types inherent with an opportunistic forager like the bald eagle. While none of the studies described provided one definitive diet composition preferred by bald eagles, they show that fish are generally the predominant food item during the spring and summer breeding seasons. Birds are second in importance, followed by mammals.

As mentioned previously, the dietary composition developed for the bald eagle in the GLI has been used in various places for the derivation of avian wildlife criteria. However, this dietary composition was specifically determined for the aquatic ecosystem of the Great Lakes and may not be an appropriate default for other parts of the country. Califomia supports both wintering

and resident bald eagles, with a broad array of suitable foraging habitats. Because of this variety, eagle diets in California likely span a wide range of possible food types and trophic level combinations. It is not possible in the scope of this analysis to determine all the potential bald eagle diets in California and evaluate them with regard to the trophic level approaches for the methylmercury criterion.

Instead, a weighted risk approach was taken to determine the appropriate eagle diet for calculation of wildlife values. The goal of this approach was to establish a diet based on the highest trophic level composition reasonably likely to occur, from the predominant habitat type characteristic of California's breeding bald eagles. The primary breeding habitats are mountain and foothill forests and woodlands close to reservoirs, lakes, and rivers (California Department of Fish and Game, 2000). Wintering bald eagles can be found in these same habitats throughout the State, but also forage in a variety of different habitats, such as rangelands and coastal wetlands. Basing the diet on the main habitat of resident breeding birds rather than on some other localized habitat used by non-resident birds is a more appropriate method for evaluating potential adverse reproductive effects from the methylmercury criterion, as it is impossible to predict maternal body burdens of methylmercury once wintering eagles reach their breeding grounds outside of California.

Bald eagles are known to nest in several locations and habitat types dispersed throughout California, including in the central and southern Sierra Nevada range, the central coast range, inland southern California, and on Santa Catalina Island. However, most breeding territories are in the northern part of the State (California Department of Fish and Game, 2000). The results of a 1977-1978 study of 95 bald eagle nest sites revealed that 91 percent of the nesting territories were located in five northern counties (Lehman, 1979). A large majority of these nests (87%) were within one mile of a waterbody, and 70 percent of the nests were associated with reservoirs. Two studies of foraging ecology in these characteristic northern California breeding habitats provided detailed assessments of the trophic level composition of bald eagle diets.

Through collection of nest site prey remains, direct observations of foraging eagles, and time-lapse photography of nest activity, the dietary composition was estimated for bald eagles nesting along a hydrologically-regulated section of northern California's Pit River (Hunt *et al*., 1992). The study area encompassed 24.5 km of reservoirs and 45.8 km of flowing, regulated river. The study took place over a period of two years, with results indicating that fish comprised approximately 87 percent of the total prey items, while birds (9%) and mammals (4%) comprised the remainder. Based on estimates of edible biomass determined from the prey remains around eight nests, the biomass comprised of fish ranged from 43.8 to 92.6 percent. For all nesting eagle pairs, one fish species (Sacramento sucker - *Catostomus occidentalis*) was the dominant prey; however, eagles at one reservoir (Lower Britton) foraged on a greater percentage of cyprinid fish (*e.g.*, hardhead, tui chub, Sacramento pikeminnow) than the other study regions. While trophic levels for various species of *Catostomus* range from 2 to 3 (U.S. Environmental Protection Agency, 1995b), the food of Sacramento suckers can be dominated by algae, detritus, or invertebrates, depending on the size of the fish, location, or time of year (Moyle, 2002). The next

two most important fish species in all study areas were the hardhead (*Mylopharodon conocephalus*) and Sacramento pikeminnow (*Ptychocheilus grandis*). These fish should be classified as trophic level 3 and 4, respectively, based on their diets (Moyle, 2002).

A variety of avian species were identified in the prey remains collected in this study, amounting to 102 individual birds. In terms of edible biomass, the percentage of the diet comprised of birds ranged from 4.9 to 46.3 percent among the eight nests sampled. While the bird species composition or estimated biomass of birds consumed were not presented for each individual study nest, 18 (17.6%) of the total 102 birds identified were piscivorous species. Based on the overall percentage of all birds in the eagle diets (9%), piscivorous birds accounted for roughly 1.6 percent of the total eagle diet (*i.e.*, - 0.09 × 0.176 × 100 = 1.58%).

While this study (Hunt *et al*., 1992) presents estimates of the percent biomass for each food type at each study site, including a breakdown for individual fish species, the estimates were based solely on an analysis of prey remains. The prey remains analysis conducted in this study was quite rigorous, in that individual fish scales were included in the collections and used to determine total numbers of fish prey. Other studies of bald eagle diets (*e.g.*, Kozie and Anderson, 1991) relied solely on samples of bones and feathers collected from nest sites. However, in a subset of the entire Hunt *et al*. (1992) study, diets were analyzed for three nests using a comparison of prey remains with time-lapse photographic observations of prey delivered to the nests. The number of fish delivered to the nests during this period ($N = 117$) was almost twice the number estimated from prey remains during the same period ($N = 64$). The biomass estimated from photographic observations of fish prey (55.1 kg) was also substantially greater than the estimate from prey remains (37.6 kg). The authors suggested that some remains may have been dropped or taken from the nests and that other prey items may have been entirely consumed. Further confounding the analysis, the authors reported that a total of 236 prey deliveries were recorded by the time-lapse cameras, yet only the 117 fish deliveries were presented in the journal article. If the 119 unidentified prey deliveries were birds or mammals, this suggests that fish only accounted for 49.5 percent of the diet during the observation period. Although these discrepancies make it difficult to assign a general dietary composition from this study, the author's comparison of prey remains data and photographic observations indicated that larger fish species were not over-represented in prey remains because of larger and more persistent bones, and smaller fish were not under-represented in prey remains because of softer, less persistent bones.

In an expansion of the previous work, prey remains from 56 eagle nesting territories in three major drainage basins (Sacramento-San Joaquin, Lahontan, Klamath) were collected between 1983 and 1992 (Jackman *et al*., 1999). The total study area comprised numerous rivers, lakes, and reservoirs. Over 80 percent of studied nesting territories were near reservoirs, with the remainder on natural lakes. Riverine habitats were also available as foraging sites for all nesting eagles. Prey remains were collected from in and below nests, sometimes during the late nestling stage but primarily after the young had fledged. Sample collections included bones, fur, feathers, and fine nest lining, the latter containing fish scales and fine bones. The authors acknowledged

that the dietary analysis was biased in that it was based exclusively on prey remains (*i.e.*, no comparison of remains with prey deliveries). However, as demonstrated in the earlier Pit River study, the authors noted that their inclusion of fish scale analysis from the nest lining samples helped to mitigate the potential over- or under-representation of certain fish types. In addition, fish scales may have a greater environmental persistence at nest sites than fish bones, which are typically used in prey remain analyses. Although it is commonly suggested that birds and mammals may be over-represented in dietary studies due to a greater environmental persistence of their prey remains compared with fish remains (*i.e.*, feathers vs. bones), the inclusion of fish scales in the dietary analysis may also help to mitigate this potential bias.

From the 56 nesting territories sampled in this study, 2,351 individual prey items were identified. Fish accounted for over 70 percent of both overall prey numbers and total estimated biomass (1,637 kg). The mean standard lengths of the most commonly taken fish were over 30 cm, with the exception of tui chub (28 cm) and brown bullhead (24 cm). Birds contributed approximately 22 percent and mammals less than 6 percent to total prey numbers and biomass. Western pond turtles and crayfish were the only other prey items identified, and contributed insignificant amounts to the overall diet (<1%). The prey composition varied substantially between 19 waterway study groups, with fish accounting for greater than 50 percent of prey numbers and biomass at most locations. However, birds and mammals were the predominant prey at several individual locations isolated from large rivers. Overall, 20 species of fishes, 41 species of birds, and 15 species of mammals were identified from prey remains.

Of the 20 fish species identified (71.2% of total biomass in overall bald eagle diet), the four primary prey species were brown bullhead (*Ameiurus nebulosus*), Sacramento sucker (*Catostomus occidentalis*), common carp (*Cyprinus carpio*), and tui chub (*Gila bicolor*). The majority of the 20 fish species identified should be classified as trophic level 3 consumers based on their diets of trophic level 2 organisms (Moyle, 2002). However, at the body sizes estimated from the prey remain analysis and the dietary habits presented in Moyle (2002), several fish species identified should be classified as trophic level 4 piscivores: Sacramento pikeminnow (*Ptychocheilus grandis*), rainbow trout (*Onchorhyncus mykiss*), largemouth bass (*Micropterus salmoides*), and Sacramento perch (*Archoplites interruptus*). In addition to the identified fish species, numerous other fish remains could only be identified to family: Centrarchidae, Ictaluridae, Cyprinidae, Salmonidae, and Catostomidae. Of these, it can be assumed that the fish prey identified as Salmonidae should be classified as trophic level 4 organisms.

With the exception of largemouth bass, the majority of the Centrarchid prey remains could not be identified to species, although bass (*Micropterus* spp.), smallmouth bass (*Micropterus dolomieui*), sunfish (*Lepomis* spp.), and bluegill (*Lepomis macrochirus*) were noted in the general Centrarchid grouping. It was impossible to assign a single trophic level to the general Centrarchidae dietary contribution, as large bass should be considered trophic level 4 fish and smaller sunfish and bluegills should be considered trophic level 3 fish (Moyle, 2002). Therefore, an intermediate trophic level (*i.e.*, 3.5) was assigned to the non-specific Centrarchidae contribution to the bald eagle diet. This resulted in 50 percent of the "Other sunfish

(Centrarchidae)" grouping assigned to each of trophic level 3 and 4 (*i.e.*, TL3.5 = 50% TL3, 50% TL4).

The two Ictalurids identified in the study [brown bullhead and channel catfish (*Ictalurus punctatus*)] are opportunistic omnivores, consuming whatever prey they can locate. Benthic invertebrates often constitute the majority of the diet for smaller Ictalurids; however, as bullheads and catfish increase in size, small trophic level 3 fish can become the predominant prey item (Moyle, 2002; U.S. Environmental Protection Agency, 1995b). The fish lengths determined from Ictalurid prey remains in this study ranged from 12.9 - 35.6 cm for brown bullhead and 25.1 - 55.1 cm for channel catfish, suggesting that an intermediate trophic level of 3.5 be assigned to all Ictalurids eaten by bald eagles. As with the non-specific Centrarchids, 50 percent of the Ictalurid biomass contribution to the bald eagle diet, whether identified to species or family, was assigned to each of trophic levels 3 and 4.

With the exception of the Sacramento pikeminnow, Cyprinid minnows in California should be considered trophic level 3 (Moyle, 2002). Therefore, the dietary contribution from fish prey grouped under "Unidentified minnows (Cyprinidae)" was assigned as trophic level 3 for this effort. All fish prey under the "Unidentified suckers (Catostomidae)" grouping were assigned as trophic level 3.

Using the intermediate trophic level breakdown for Centrarchids and Ictalurids, together with the other trophic level 4 fish identified from the prey remains, indicates that 12.7 percent of the overall estimated biomass in the entire study area was comprised of trophic level 4 fish. The remainder of the overall fish component to the biomass (58.5%) is classified as trophic level 3.

Of the 41 bird species identified (22.8% of total biomass in overall bald eagle diet), the two most commonly seen in prey remains were American coot (*Fulica americana*) and mallard (*Anas platyrhynchos*), representing 4.2 and 3.2 percent, respectively, of the total estimated biomass. Several of the species identified are exclusively terrestrial (*e.g.*, mountain quail); however, the majority are dependent on the aquatic ecosystem. Several of these aquatic-dependent species are primarily piscivorous: western grebe (*Aechmophorus occidentalis*), gull (*Larus* spp.), pied-billed grebe (*Podilymbus podiceps*), and common merganser (*Mergus merganser*). These piscivorous birds accounted for approximately 5 percent of the total estimated biomass of the bald eagle diet. Eagles also consumed waterfowl (*e.g.*, *Anas* spp., diving ducks, coots) that depend to varying degrees on prey that are considered trophic level 2 organisms (*e.g.*, aquatic invertebrates and zooplankton). These birds contributed approximately 13 percent (including the 4.2% and 3.2% represented by American coots and mallards) to the total estimated biomass in the overall bald eagle diet.

Based on the dietary analysis presented by Jackman *et al*. (1999), and the trophic level assessment provided above, a generic composition for the bald eagle diet can be estimated as 6 percent mammals, 71.2 percent fish (58.5% TL3, 12.7% TL4) and 22.8 percent birds (13.2% TL2 consumers, 4.8% TL3 consumers, 4.8% non-aquatic consumers). These figures represent an

average dietary composition for all bald eagles in the study area. However, the study also presented dietary composition results from 19 separate sub-areas, described as waterway territory groups. The data from these sub-areas do not provide the level of taxonomic detail regarding prey species as was presented for the entire study area, but they do reveal that substantial differences exist between nesting territories in the relative contribution of birds, mammals, and trophic level 4 fish to the bald eagle diet. Trophic level 4 fish constituted over 35 percent of the dietary biomass in several of the sub-areas, while at three different sub-areas, birds contributed over 60 percent of the dietary biomass. At one sub-area, birds and mammals accounted for 70.6 and 24.7 percent, respectively, of the dietary biomass.

The dietary compositions for each sub-area were presented in percent biomass of major prey groups (*i.e.*, fish, birds, mammals), with the fish group further divided into seven categories (*e.g.*, trout, suckers, sunfish). This sub-area breakdown illustrates the broad range of dietary compositions possible in these characteristic bald eagle habitats, and allowed for an estimation of a bald eagle diet with the greatest potential for methylmercury exposure (*i.e.*, the highest percentage of TL4 fish and aquatic-dependent birds, with the lowest percentage of terrestrial prey). Because the data were only presented in terms of major prey groups and broad fish categories, the degree of certainty in estimating specific trophic level diets varied with each sub-area. For example, fish represented by the "Minnow" category could be considered trophic level 3 (*e.g.*, Sacramento blackfish) or trophic level 4 (*e.g.*, Sacramento pikeminnow). Similarly, the general "Bird" category could include any combination of aquatic-dependent and/or terrestrial species. Jackman *et al*. (1999) provided a level of species-specific detail for each sub-area that allowed for a reasonable determination of the trophic composition of each fish category; however, sub-area specific detail for bird prey was lacking. By evaluating the estimated biomass contribution of each bird species for the entire study area, a general percentage breakdown of the three bird types (*i.e.*, TL2 consumers, TL3 consumers, non-aquatic consumers) could be determined and applied to the overall bird contribution to each sub-area. For the entire study area, birds that consume aquatic invertebrates (TL2 consumers) accounted for approximately 58 percent, piscivorous birds (TL3 consumers) accounted for approximately 21 percent, and terrestrial birds (non-aquatic consumers) accounted for 21 percent of the total avian prey biomass. Using this breakdown, the relative contribution of birds in the diet for each sub-area could be delineated. For example, if the percentage biomass of birds for a particular sub-area was reported as 25 percent, the relative contribution of each bird type was delineated as 14.5 percent TL2 consumers (25 × 0.58), 5.25 percent TL3 consumers (25 × 0.21), and 5.25 percent non-aquatic consumers (25 × 0.21).

The data for all 19 sub-areas were analyzed to identify the bald eagle diet with the greatest potential exposure to methylmercury. Prey remains from one eagle pair foraging at the inflow of the North Fork Feather River to the Oroville Reservoir indicated that fish and birds comprised 83 and 17 percent, respectively, of the total dietary biomass. **The fish component of this total was comprised of both trophic level 4 (39%) and trophic level 3 (44%) species. The avian component of this total was comprised of TL2-consuming birds (10%), TL3-consuming birds (3.5%), and non-aquatic consuming birds (3.5%)**. This diet represented the highest

combined percentage of trophic level 4 fish and aquatic-dependent birds from the entire study area.

The bald eagle FIR based on this diet (83% fish / 17% birds) was calculated using the methodology in the aforementioned *Technical Support Document for Wildlife Criteria* (U.S. Environmental Protection Agency, 1995c), wherein the animal's free-living metabolic rate (FMR) is divided by the metabolizable energy (ME) from the animal's prey. The FMR was determined by Nagy's (1987) allometric equation relating FMR for birds to body weight:

FMR (kcal/day) = 2.601 × body weight (g)$^{0.640}$
FMR = 2.601 × 5250$^{0.640}$
FMR = 625 kcal/day

According to the *Wildlife Exposure Factors Handbook* (U.S. Environmental Protection Agency, 1993), metabolizable energy equals the gross energy (GE) of the food in kcal/g wet weight times the assimilation efficiency (AE) of the consumer. The Handbook gives a GE value of 1.2 kcal/g for bony fishes, while bird GEs are given as either 1.9 (passerines, gulls, terns) or 2.0 (mallard). Although the majority of avian prey species identified in the Jackman *et al*. (1999) study are more closely related to mallards than to the other bird types, the lower value was used in this analysis because the GE for mallards was for consumption of flesh only. The AEs for eagles consuming birds and fish are given as 78 and 79 percent, respectively.

ME_{fish} = 1.2 kcal/g × 0.79 = **0.948 kcal/g fish**

ME_{birds} = 1.9 kcal/g × 0.78 = **1.482 kcal/g birds**

Following the process in the TSD, if:

Y = grams of birds consumed, and
4.88Y = grams of fish consumed (*i.e.*, 83% fish ÷ 17% birds = 4.88)

then the FIR for each food can be determined by the equation:

FMR = [Y(g) × 1.482(kcal/g birds] + [4.88Y(g) × 0.948 kcal/g fish]

625 kcal/day = 1.482Y + 4.626Y

625 kcal/day = 6.108Y

Y = 102 g birds consumed/day

4.88Y = 498 g fish consumed/day

The total FIR for bald eagles becomes:

FIR = [102 g birds + 498 g fish]/day
FIR = 600 g wet weight/day

FIR for bald eagle = 0.600 kg wet weight/day

V. SPECIES-SPECIFIC WILDLIFE VALUES

Species-specific input parameters, using the RfD generated with a UF_A of 1, and the resulting WVs are presented in Table 2. Table 3 provides WVs using the RfD generated with a UF_A of 3. Wildlife Values were calculated using Equation 6, described previously:

$$\mathbf{WV} = \frac{\mathbf{RfD} \times \mathbf{BW}}{\sum \mathbf{FIR_i}}$$

Table 2. Wildlife Values for Methylmercury Calculated Using Reference Dose Generated with an Interspecies Uncertainty Factor (UF_A) of 1

Species	RfD (mg/kg/day)	Body Weight (kg)	FIR (kg/day)	WV (mg/kg diet)
Southern sea otter	0.018	19.8	6.5	0.055
California least tern	0.021	0.045	0.031	0.030
California clapper rail	0.021	0.346	0.172	0.042
Light-footed clapper rail	0.021	0.271	0.142	0.040
Yuma clapper rail	0.021	0.271	0.142	0.040
Western snowy plover	0.021	0.041	0.033	0.026
Bald eagle	0.021	5.25	0.600	0.184

Table 3. Wildlife Values for Methylmercury Calculated Using Reference Dose Generated with an Interspecies Uncertainty Factor (UF_A) of 3

Species	Alternate RfD (mg/kg/day)	Body Weight (kg)	FIR (kg/day)	WV (mg/kg diet)
California clapper rail	0.007	0.346	0.172	0.014
Light-footed clapper rail	0.007	0.271	0.142	0.013
Yuma clapper rail	0.007	0.271	0.142	0.013
Western snowy plover	0.007	0.041	0.033	0.009

VI. BIOMAGNIFICATION INTO AVIAN PREY OF BALD EAGLES

The next step in the approach was to evaluate the protectiveness of the TRC under each trophic level approach. To do this required the trophic level breakouts (*i.e.*, %TL2, %TL3, %TL4) for the diet of each species of concern, the trophic level concentrations determined in each TRC evaluation approach, and Equation 1:

DC = (%TL2 × FDTL2) + (%TL3 × FDTL3) + (%TL4 × FDTL4)

However, additional information was required to perform this evaluation for the bald eagle. As mentioned previously, bald eagles may consume substantial numbers of birds that feed from the aquatic environment. These aquatic-dependent species may be omnivorous (*i.e.*, - feed to varying degrees on plant matter and trophic level 2 biota) or primarily piscivorous. The biomagnification of methylmercury into these prey birds represents a potentially important additional exposure for bald eagles that must be factored into the estimate of a daily ingested dose. For the GLI effort (U.S. Environmental Protection Agency, 1995d), bald eagle consumption of piscivorous herring gulls (*Larus argentatus*) was included in the criteria derivation because herring gulls in the Great Lakes feed primarily on trophic level 3 fish. The EPA applied a biomagnification factor (BMF) of 10 in the calculation of wildlife criteria to account for the biomagnification from these trophic level 3 fish into herring gull tissues. In effect, the BMF is analogous to a food chain multiplier (FCM) because it represents the amount of methylmercury transfer between a prey organism (TL3 fish) and its predator (piscivorous bird). Although the GLI effort did not consider biomagnification into omnivorous waterfowl, the contribution of methylmercury from this pathway should also be included in the risk assessment

for bald eagles. In order to include the consumption of piscivorous and omnivorous birds in the evaluation for bald eagles, additional terms must be incorporated into Equation 1:

$$DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL3) + (\%TL4 \times FDTL4) + (\%OB \times FDOB) + (\%PB \times FDPB)$$

%OB - percent of omnivorous birds (TL2-consumers) in diet
FDOB - methylmercury concentration in omnivorous bird prey
%PB - percent of piscivorous birds in diet
FDPB - methylmercury concentration in piscivorous bird prey

As the two trophic level approaches presented in this evaluation are based only on estimated methylmercury concentrations in aquatic organisms, the terms FDOB and FDPB need to incorporate the biomagnification of methylmercury from the aquatic trophic levels into the tissues of birds consumed by bald eagles. In effect:

FDOB = FDTL2 (concentration in TL2 organisms) × **MOB** (*i.e.*, some BMF value representing biomagnification into omnivorous bird prey)

FDPB = FDTL3 (concentration in TL3 organisms) × **MPB** (*i.e.*, some BMF value representing biomagnification into piscivorous bird prey)

VI.A. Biomagnification Factor for Trophic Level 3 Fish to Piscivorous Bird Prey: **MPB**

The BMF of 10 used in the GLI to represent the biomagnification from trophic level 3 fish into herring gulls was arrived at from data indicating that tissue mercury concentrations in piscivorous birds tends to be from 3 to 12 times higher than the tissue mercury concentrations in the fish that the birds feed on (U.S. Environmental Protection Agency, 1995d). An analysis of the three studies used for the EPA's determination (Vermeer *et al*., 1973; Norheim and Froslie, 1978; and Wren *et al*, 1983) is provided below.

Vermeer *et al*. (1973) examined total mercury residues in herring gull eggs and in breast muscle from 83 ducks (six species) from Clay Lake in western Ontario. Only four of the 83 ducks were adults, the rest being flightless ducklings or immature birds. Many of the immature birds were also flightless. Breast muscle samples from five of the collected birds were also analyzed for methylmercury content. The authors concluded that elevated total mercury residues in herring gull eggs did not affect reproductive success, but no information was provided about methylmercury in herring gull tissues or the gull's prey. No conclusions about BMF values can be drawn from the herring gull portion of this study.

In addition to the duck breast muscle samples, food items were collected from the esophagi and stomachs of three of the duck species and analyzed for total mercury concentrations. These food items included yellow perch (*Perca flavescens*) and shiners (*Notropis* sp.) consumed by common mergansers (*Mergus merganser*), and a variety of aquatic invertebrates consumed by common goldeneyes (*Bucephala clangula*) and hooded mergansers (*Lophodytes cucullatus*). Breast

muscle sampled from the five individual ducks was analyzed for methylmercury, which accounted for 69-99 percent of total mercury concentrations. However, the food items from the three mentioned duck species were analyzed for total mercury, making direct assessments of methylmercury biomagnification difficult. While it is commonly accepted that the majority of mercury in fish muscle is methylmercury, it is unclear whether the same holds true for the various molluscs, crayfish, insects, and annelids found as food items in these ducks. In addition, the information regarding biomagnification from these non-fish prey items into duck tissues would have had limited value for the estimation of a BMF to herring gulls for the GLI.

Ten yellow perch collected from esophagi and stomachs of common mergansers during this study averaged 2.7 mg/kg (range 1.6 - 3.6) total mercury. Common merganser breast muscle was not analyzed for methylmercury, but a mean concentration of 6.79 mg/kg (range 4.4 - 13.1) total mercury was reported from 17 analyzed birds. Assuming the relative proportion of mercury to methylmercury is similar in fish tissue and duck breast muscle, an average methylmercury BMF for these birds would be 2.5. An important consideration in evaluating this BMF, however, is that the birds sampled were either ducklings or sub-adults. If the birds were in a stage of substantial feather growth, much of the ingested methylmercury could have been shunted into the feathers instead of muscle tissue (Elbert, 1996; Wiener *et al*., 2002). Body burdens of methylmercury in adult female muscle tissue prior to egg laying may have been substantially greater than the values reported for ducklings and sub-adults.

In the work of Norheim and Froslie (1978), the degree of methylation and organ mercury distribution in several raptorial species in Norway was examined. While this study provided data on methylmercury concentrations in various raptor tissues and evidence of demethylation in raptor organs, prey items were not evaluated. Because of this data gap, no conclusions can be drawn regarding the biomagnification of methylmercury from the diet into tissues of the raptors examined.

Wren *et al*. (1983) examined the bioaccumulation and biomagnification of 21 naturally occurring elements into abiotic and biotic components in an undisturbed Precambrian Shield lake in Ontario. Among the biotic samples were 5 herring gulls, 20 rainbow smelt (*Osmerus mordax*), and 20 bluntnose minnows (*Pimephales notatus*), although it is not clear from the report whether all 20 of the minnows were analyzed. Breast muscle samples from the herring gulls and dorso-lateral muscle samples from the fish were analyzed for mercury. It appears from the report that analysis was for total mercury; however, as has been discussed previously, mercury in fish and avian muscle tissues is primarily methylmercury. This allows for a reasonable estimation of a methylmercury BMF. Average mercury concentration in herring gull breast muscle was 1.7 mg/kg (range 0.66 - 4.0). Average concentration in bluntnose minnow muscle was 0.12 mg/kg (range 0.05 - 0.26), and in rainbow smelt the average concentration was 0.32 mg/kg (range 0.15 - 0.67). The mean length of collected rainbow smelt and bluntnose minnows was 17.3 and 7.4 cm, respectively.

The authors of this study (Wren *et al*., 1983) offered no indication of what the sampled herring gulls preyed upon, except to say that the gulls would "...generally feed on small fish which contain relatively low Hg levels." Herring gulls in the lower Great Lakes were reported to feed primarily on alewife and smelt, with females feeding more on the smaller smelt (mean length: 9 cm) and males feeding more on alewife (mean length: 16 cm) (U.S. Environmental Protection Agency, 1995c). If female herring gulls on the Wren *et al*. (1983) study lake preyed primarily on the smaller bluntnose minnows, a BMF of 14.2 can be calculated (*i.e.*, 1.7 mg/kg in gull breast muscle divided by 0.12 mg/kg in minnow muscle). However, if rainbow smelt are the primary prey, a BMF of 5.3 is calculated (*i.e.*, 1.7 mg/kg divided by 0.32 mg/kg). Taking the average of these two values results in a BMF just under 10, the BMF used by the EPA in the GLI effort.

There has been a great deal of research over the past several decades examining the relationship between dietary mercury concentrations and the resultant concentrations in avian tissues. Controlled laboratory feeding studies, as well as field studies examining mercury concentrations in bird tissues and in the organisms the birds generally feed on, can provide data with which BMFs can be calculated. However, these studies typically are designed to evaluate mercury concentrations in individual tissues such as the liver, kidney, feathers, blood, or brain. While these types of data, and the information they generate regarding biomagnification, are extremely valuable in understanding the toxicokinetics and toxicodynamics of mercury in the exposed bird, they are of limited value for determining BMFs from food into a "whole body" concentration. Whole body concentrations are needed when evaluating the consumption of exposed birds by a predator such as the bald eagle. Ideally, all edible tissues of a dosed bird would be analyzed to provide the averaged methylmercury concentration for the entire bird. Then, knowing the methylmercury concentration in the food, the most accurate BMF for the consumer can be calculated.

Lacking studies where all edible tissues of an exposed bird are analyzed, the most appropriate BMF when considering consumption of the exposed bird by a bald eagle should be based on the relationship between concentrations in the muscle of the test bird and the concentrations in its food. Muscle tissue represents the majority of edible matter in a consumed bird; the pectoralis major and supracoracoideus muscles of the breast by themselves account for between one-fifth and one-third of body weight in flying birds (Proctor and Lynch, 1993). Therefore, methylmercury concentrations in muscle should serve as the best surrogate for whole body concentrations. Muscle tissue concentrations may underestimate the actual whole body concentration, as methylmercury levels in other tissues may be substantially higher; however, the relatively small contribution of these other tissues to the overall edible mass should help to minimize these differences.

As described, two of the studies used to determine a BMF in the GLI effort for trophic level 3 fish to piscivorous birds examined muscle tissues in the target birds. While these studies provide some information regarding mercury biomagnification into piscivorous birds that could be consumed by bald eagles, there was sufficient uncertainty in their extrapolation of BMFs to warrant further analysis for this current effort. An attempt was made to find data directly

connecting methylmercury concentrations in documented food items to methylmercury concentrations in the muscle tissue of adult piscivorous birds.

The work done by Henny *et al*. (2002), previously discussed in Section IV.C (Determination of Test Doses), provided an assessment of mercury in the food and tissues of three piscivorous birds nesting along the lower Carson River in Nevada. Various tissues from both adult and juvenile double-crested cormorants (DCC), black-crowned night-herons (BCNH), and snowy egrets (SE) were analyzed, including methylmercury concentrations in stomach contents. Based on stomach content analyses, it was determined that mean total mercury concentrations in the diets of the three species in 1998 were 0.515 mg/kg (BCNH), 0.905 mg/kg (SE), and 1.44 mg/kg (DCC). Methylmercury accounted for most of the mercury detected, with mean concentrations of 0.48 mg/kg (BCNH), 0.775 mg/kg (SE), and 1.18 mg/kg (DCC).

In 1998, total mercury was measured in liver, kidney, brain, blood, and feathers of all three species examined. Using these concentrations and the data for total mercury in stomach contents, it is possible to calculate total mercury BMFs for each of these specific tissues. However, these values do not allow for an estimate of whole body methylmercury concentrations for two reasons: 1) mercury found in the liver and kidney samples was predominantly inorganic due to postabsorptive demethylation, and 2) the relative contribution of the analyzed tissues to the total edible biomass of each bird is small compared to the contribution of muscle tissue. Although no muscle tissue from any of the bird species was analyzed in this study, it was possible to estimate muscle methylmercury concentrations based on an assumed relationship in piscivorous birds between muscle and brain tissue concentrations. Once muscle methylmercury concentrations were estimated for the birds in the Henny *et al*. (2002) study, a methylmercury BMF from food into a whole body concentration could be calculated.

Additional analyses in the Henny *et al*. (2002) study on a small number of BCNH egg, feather, blood, and brain samples confirmed that mercury residues in these types of avian tissues are essentially 100 percent methylmercury. Brain tissue concentrations were selected to establish the relationship with muscle tissue for several reasons: 1.) no egg concentration values were reported, 2.) feathers were only collected from nestling/fledgling birds, 3.) no studies were found in the scientific literature in which both avian blood and muscle tissue were analyzed for mercury, and 4.) scientific studies examining mercury in avian muscle tissues most commonly include liver, kidney, and brain samples in the analyses.

In reviewing the scientific literature for studies reporting tissue mercury concentrations in piscivorous birds, work done by Elbert (1996) and Elbert and Anderson (1998) with western and Clarke's grebes (*Aechomorphorus occidentalis* and *Aechomorphorus clarkii*) in California provided the most useful data for establishing a brain / muscle relationship. Twenty-three adult birds were collected from three California lakes in 1992, with liver, kidney, breast muscle, and brain tissues analyzed for total mercury. All three lakes are representative of the characteristic habitat used for determining the bald eagle diet used in this analysis; however, one of the three (Clear Lake) is known to be impaired by mercury contamination. Of the other two study sites,

Eagle Lake is relatively pristine, while Tule Lake has previously had problems with organochlorine compounds in the eggs of nesting western grebes (Elbert and Anderson, 1998). Neither of these two lakes are known to have elevated mercury concentrations.

For all birds sampled from the three Elbert and Anderson (1998) study lakes, mean muscle and brain mercury concentrations were 0.79 and 0.22 mg/kg, respectively. These results suggest breast muscle mercury concentrations in piscivorous birds are approximately 3.6 times the concentrations found in brain tissues. Examining the data from each lake, however, reveals variations in this ratio. Mean muscle and brain mercury concentrations in birds at Tule Lake were 0.46 and 0.16 mg/kg, respectively, resulting in a ratio of approximately 2.9. At Eagle Lake, the values for muscle and brain were 0.43 and 0.13 mg/kg, resulting in a ratio of 3.3. Mercury concentrations in birds at Clear Lake were substantially higher, with 1.06 and 0.28 mg/kg in muscle and brain tissue, respectively. These data suggest breast muscle mercury concentrations in piscivorous birds at a mercury contaminated site are approximately 3.8 times the concentrations found in brain tissue.

Because the birds examined in the study by Henny *et al*. (2002) were also sampled from mercury contaminated sites, the mean mercury concentrations reported for brain tissues were multiplied by 3.8 to estimate the concentrations expected in breast muscle. Estimated muscle concentrations for the three species are: BCNH - 6.61 mg/kg (brain = 1.74), SE - 8.74 mg/kg (brain = 2.30), DCC - 42.79 mg/kg (brain = 11.26). Taking the estimated muscle concentrations and dividing by mean methylmercury concentrations in the stomach contents for each species provides BMF values.

BCNH:	6.61 mg/kg in muscle ÷ 0.48 mg/kg in food = **13.77**
SE:	8.74 mg/kg in muscle ÷ 0.775 in food = **11.27**
DCC:	42.79 mg/kg in muscle ÷ 1.18 mg/kg in food = **36.26**

The BMFs estimated for night-herons and egrets are similar in magnitude to the value used for the EPA's GLI effort, while the estimated BMF for the double crested cormorant is more than three times the GLI value. One possible reason for this disparity may be the degree of piscivory exhibited by cormorants compared with the other two species. Henny *et al*. (2002) reported that the stomachs of all the cormorants sampled contained only fish, whereas the contents of the night-heron and egret stomachs varied from 100 percent fish to 100 percent aquatic insects. Based on the percentage volume of stomach items for these two species, the average diet for night-herons and egrets was approximately 34 and 49 percent fish, respectively. It is possible that methylmercury biomagnification from fish into avian muscle tissue is substantially greater for those bird species that are almost exclusively piscivorous, such as the double-crested cormorant and belted kingfisher (*Ceryle alcyon*).

While the remains of both double-crested cormorants and belted kingfishers were found at the nest sites examined in the study used to develop the bald eagle diet for this effort (Jackman *et al*., 1999), their contribution to the overall prey biomass was minimal. Therefore, the BMFs

estimated for black-crowned night-herons and snowy egrets served as the more appropriate surrogates for developing the MPB value for this evaluation.

Averaging the estimated BMFs for the black-crowned night-heron and snowy egrets results in an **MPB** value of **12.5**, used in this evaluation for the bald eagle.

VI.B. Biomagnification for Trophic Level 2 Organisms to Omnivorous Bird Prey: **MOB**

The majority of research on methylmercury and its biomagnification through the aquatic food chain into avian species has focused on piscivorous birds, as the consumption of fish (*i.e.*, higher trophic level biota) represents a pathway with the greatest potential exposure. A review of the scientific literature revealed little that was useful in developing a standardized biomagnification factor for omnivorous waterfowl. However, some data were examined that allowed estimation of a reasonable BMF for this effort.

The Vermeer *et al*. (1973) study discussed in the previous section examined mercury levels in the breast muscle of several species of piscivorous and omnivorous waterfowl, as well as in the stomach contents from individuals of three of these species. Breast muscle samples from 21 common goldeneyes (*Bucephala clangula*), an omnivorous species, showed a mean total mercury concentration of 7.80 mg/kg (range: 0.9 - 19.4). Two individual goldeneyes were further sampled to compare total mercury to methylmercury levels. In these two samples, methylmercury accounted for 73 and 77 percent of the total mercury values. Applying a value of 75 percent methylmercury to the mean total concentration of 7.80 mg/kg results in a mean methylmercury value of 5.85 mg/kg.

Food items from the esophagi and stomachs from seven of the collected goldeneyes confirmed the predominantly invertebrate diet of this species. These food items were analyzed for total mercury; however, the results were reported in a manner that prevents calculation of a precise average concentration. Average total mercury concentrations in the various food items (*e.g.*, bivalves, aquatic insect nymphs, crayfish) ranged from 0.30 to 7.1 mg/kg. Based on the reported values, the average total mercury concentration in the goldeneye diet is approximately 2 mg/kg. As previously noted, making direct assessments of methylmercury biomagnification from this concentration is difficult because it is unknown what percentage of the total mercury in the various invertebrates is methylmercury. In a recent review of mercury ecotoxicology (Wiener *et al*., 2002), the authors point out that the percentage of total mercury present as methylmercury in aquatic invertebrates can vary substantially. Examples of this variation include methylmercury ranging from 9 to 82 percent of total in aquatic insects from northern Wisconsin lakes, and from 20 to 95 percent of total in benthic aquatic insects (detritivores and predatory dragonflies, respectively) from hydroelectric reservoirs in northern Quebec.

With these wide variations possible, the approximate total mercury concentration of 2.0 mg/kg in the goldeneye diet from the Vermeer *et al*. (1973) study could translate into methylmercury

concentrations of 0.18 mg/kg (9% of total) to 1.9 mg/kg (95% of total). Biomagnification factors for the transfer from prey items into goldeneye breast muscle could therefore range from 32.5 (5.85 mg/kg ÷ 0.18 mg/kg) to 3.08 (5.85 mg/kg ÷ 1.9 mg/kg). The true value is likely toward the lower end of the range, as many of the invertebrate prey identified were themselves predatory, possibly resulting in a higher percentage of mercury in the methylated form. However, as discussed previously, an important consideration in evaluating biomagnification from these data is that the birds sampled were either ducklings or sub-adults. If the birds were in a stage of intense feather growth, much of the ingested methylmercury could have been shunted into the feathers instead of muscle tissue (Elbert, 1996; Wiener *et al*., 2002). In addition, body burdens of methylmercury in adult female muscle tissue prior to egg laying may have been substantially greater than the values reported for ducklings and sub-adults.

In an expansion on the previous study, Fimreite (1974) examined 184 piscivorous and omnivorous waterfowl specimens from five different lakes in the same locale of northwestern Ontario. Liver, breast muscle, and stomach contents from twelve of these birds, including three common goldeneyes representing predominantly invertebrate feeders, were analyzed for total and methylmercury. Invertebrates from the three goldeneye stomachs were not identified; however, the contents of each bird were analyzed separately. Methylmercury concentrations in these stomach contents were reported as 0.09, 0.19, and 0.36 mg/kg. These values represented 100, 56, and 47 percent, respectively, of total mercury concentrations. The corresponding breast muscle samples contained 0.11, 0.23, and 0.51 mg/kg methylmercury. For each bird, the reported values indicate biomagnification from diet into breast muscle is only slightly greater than 1 (~ 1.2 - 1.4).

Although life stage was not reported, the three birds sampled were most likely adults. In a separate component of this study, breast muscle and liver from 12 adult and 3 duckling goldeneyes were analyzed for methylmercury. Results showed that mean methylmercury concentrations in duckling breast muscle (7.10 mg/kg) were substantially higher than in adult breast muscle (0.76 mg/kg). While the data suggest biomagnification from food into adult goldeneye breast muscle is low, the timing of sample collection may have masked a greater level of biomagnification prior to the study than indicated from the results. Birds for this study were collected during the periods 20 July - 5 August 1970 and 20 June - 28 July 1971. These periods coincide with the periods of greatest postnuptial molt of goldeneyes in central Ontario, as well as the late stages of duckling growth (Eadie *et al*., 1995). It is possible that adult body burdens of methylmercury were being depurated into replacement feathers, while the young may have finished producing their adult plumage and were no longer eliminating ingested methylmercury through this pathway. Biomagnification into muscle tissue during non-molt periods or after cessation of juvenile feather growth may be substantially greater. If these late stage ducklings were consuming invertebrates with the same methylmercury concentrations as observed in adult stomach contents, biomagnification factors from food into breast muscle could range from approximately 20 to 80 (*e.g.*, 7.10 mg/kg ÷ 0.9 mg/kg = 78.8).

Depuration of methylmercury into growing feathers, excretion in the feces, and deposition into eggs are the principal means of mercury elimination in adult female birds (Wiener *et al*., 2002).

For many of the omnivorous waterfowl species that would be consumed by California bald eagles, molting and egg laying would occur in the spring and summer on northern breeding grounds outside of California. Such was the case with the common goldeneyes in both of the above studies (Vermeer *et al*., 1973; Fimreite, 1974). Although neither study was designed to determine biomagnification factors, the data they generated could considerably underestimate the extent of biomagnification in California birds.

In order to minimize this potential underestimation, an attempt was made to find data for omnivorous birds in California waters. Eared grebes (*Podiceps nigricollis*) and samples of their invertebrate prey were collected from Eagle Lake, California (Eagles-Smith *et al*., in prep.). Eagle Lake, a relatively pristine body not known to have substantial mercury contamination, is the same location where Elbert and Anderson (1998) examined western and Clarke's grebes. This is a breeding area for eared grebes, while their wintering habitats are Pacific coastal regions, southwestern United States, Baja California, and Mexico (Cullen *et al*., 1999).

In the Eagle Lake work, six adult (3 male, 3 female) and three juvenile birds were collected between August and September of 2000. All adults had completed breeding, and were flightless at the time of collection (*i.e.*, both primary and body feather molt). As with the previous two studies discussed, feather replacement during this molt cycle could be an important elimination pathway for the bird's methylmercury body burden. Breast muscle from each bird was sampled and analyzed for total mercury. Concentrations ranged from 0.031 to 0.104 mg/kg (converted from dry weight using 71.5% moisture), with an average of 0.069 mg/kg.

Eared grebes are known to feed predominantly on brine shrimp and brine flies at fall staging areas prior to their winter migration (Cullen *et al*., 1999). However, their diet at freshwater breeding lakes consists mainly of caddisfly and mayfly larvae (~50%), amphipods (~20%), water beetles (~20%), aquatic snails (~10%), and an occasional fish (Eagles-Smith *et al*., in prep.). Approximately 50 invertebrate samples were collected from Eagle Lake, from locations where grebes were taken, and analyzed for total mercury after being sorted into general taxonomic groups. Based on the general dietary composition presented above, the analytical results were combined in a weighted average approach to provide an overall mercury concentration for the integrated eared grebe diet. The average total mercury concentration for this integrated diet was 0.02 mg/kg dry weight. Using a general value of 75 percent moisture for these aquatic invertebrates results in a wet weight concentration of 0.005 mg/kg total mercury.

Neither the grebe muscle nor invertebrate samples were analyzed for methylmercury. Applying the same value of 75 percent observed in common goldeneyes from the Vermeer *et al*. (1973) study to represent the ratio of total mercury to methylmercury, the average methylmercury concentration in the eared grebe breast muscle was 0.052 mg/kg. As discussed previously, the methylmercury percentage in aquatic invertebrates can vary considerably, depending on factors such as the organism's trophic position. For the invertebrates sampled in the Eagle Lake study, it was estimated that methylmercury accounted for approximately 60 - 70 percent of total mercury (Eagles-Smith *et al*., in prep). Of the two primary grebe prey items, only the caddisfly larvae are

considered omnivorous, occupying a higher trophic position, while mayfly larvae are strictly herbivorous (Kozloff, 1990). The amphipods and naucorids consumed by grebes may also exhibit varying degrees of omnivory. These higher trophic level prey, combined with the occasional fish, allow for a reasonable justification for using the higher value of 70 percent methylmercury in invertebrates. This results in an average methylmercury concentration in the grebe's invertebrate diet of 0.0035 mg/kg.

Dividing the average grebe breast muscle concentration (0.052 mg/kg) by the average integrated invertebrate diet concentration (0.0035 mg/kg) results in a biomagnification factor for methylmercury of slightly less than 15 (14.86). Considering these data were generated from a time when a substantial amount of the grebe's methylmercury body burden may have been shunted into replacement feathers, non-molt biomagnification may be substantially greater. These data demonstrate that methylmercury biomagnification in omnivorous waterfowl can be substantially higher than previous studies would indicate.

Assigning an omnivorous waterfowl biomagnification factor for this effort was complicated by numerous factors, including the fact that the various species consumed by bald eagles can exhibit widely varying degrees of omnivory. The eared grebe feeds exclusively on animal matter while other species, such as the American coot (*Fulica americana*), Northern pintail (*Anas acuta*), or American wigeon (*Anas americana*), rely on animal foods to a much lesser extent (Brisbin and Mowbray, 2002; Mowbray, 1999; Austin and Miller, 1995). For every eagle prey bird like the eared grebe having a biomagnification factor of 15 or greater, there may be another exhibiting biomagnification at less than a factor of five. The processes of molting and egg production also contribute to the difficulty in estimating muscle concentrations at any given time of year. It would be virtually impossible to determine true field biomagnification for all omnivorous waterfowl consumed by bald eagles; however, given the information presented above, it is reasonable to assign a general biomagnification factor of 10 for that portion of the bald eagle diet consisting of omnivorous waterfowl.

An **MOB** value of **10** was used in the evaluation for the bald eagle.

VII. EVALUATION OF THE HUMAN HEALTH METHYLMERCURY CRITERION

Once these additional terms for the bald eagle were defined, the modified Equation 1 was used to evaluate the human health criterion for all species of concern.

$$DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL3) + (\%TL4 \times FDTL4) + (\%OB \times FDOB) + (\%PB \times FDPB)$$

Inclusion of the additional terms for bald eagles did not affect the calculations for the other species evaluated in this effort, as they only resulted in zero values for those components of the equation (*i.e.*, if %OB = 0, then [%OB × FDOB] = 0). The modified Equation 1 yields the expected overall dietary concentration (DC) resulting from the amount of food eaten from each trophic level, in conjunction with the trophic level methylmercury concentrations estimated from

each of the two TRC trophic level approaches. The DC values calculated for each species could then be compared to the species-specific WV concentrations generated using reference doses, body weights, and food ingestion rates. This simple comparison showed whether either trophic level approach will result in dietary concentrations higher or lower than the protective WV. If lower, then it may be assumed that the species should not be at risk from dietary exposure to methylmercury. If higher, it could be assumed that the species would likely have a dietary exposure that may place it at risk for adverse effects from methylmercury toxicity. In these latter instances, the methodology outlined in the Average Concentration Trophic Level approach can be used to calculate the trophic level-specific methylmercury concentrations necessary to maintain the DC at or below that species' WV.

VII.A. Average Concentration Trophic Level Approach

As explained previously (see Section II.A.), applying the Average Concentration Trophic Level Approach to the TRC of 0.3 mg/kg yields the following trophic level-specific concentrations in aquatic biota:

FDTL2 = 0.029 mg/kg
FDTL3 = 0.165 mg/kg
FDTL4 = 0.66 mg/kg

For the bald eagle, the two biomagnification factors determined previously were used to estimate methylmercury concentrations in the eagle's avian prey:

FDOB = FDTL2 × MOB
FDOB = 0.029 mg/kg × 10
FDOB = 0.29 mg/kg

FDPB = FDTL3 × MPB
FDPB = 0.165 mg/kg × 12.5
FDPB = 2.06 mg/kg

Then, applying these predicted methylmercury concentrations and the trophic level dietary breakouts determined for each species of concern to the modified Equation 1 yielded the total dietary concentrations (DC) presented in Table 4.

Table 4. Predicted Dietary Concentrations (DC) of Methylmercury Under Average Concentration TL Approach

Modified Equation 1:

$$DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL3) + (\%TL4 \times FDTL4) + (\%OB \times FDOB) + (\%PB \times FDPB)$$

Species	%TL2	%TL3	%TL4	%OB	%PB	%OF*	DC (mg/kg)
Southern sea otter	0.80	0.20	na	na	na	na	0.056
California least tern	na	1.00	na	na	na	na	0.165
California clapper rail	0.85	0.05	na	na	na	0.10	0.033
Light-footed clapper rail	0.82	0.18	na	na	na	na	0.053
Yuma clapper rail	0.23	0.72	na	na	na	0.05	0.125
Western snowy plover	0.25	na	na	na	na	0.75	0.007
Bald eagle	na	0.44	0.39	0.10	0.035	0.035	0.431

* - The term '%OF' (*i.e.*, other foods) represents dietary items not expected to significantly contribute dietary methylmercury, and is presented in the table only to provide the full dietary composition assessment for each species. These %OF items include plants, terrestrial insects, or avian prey not dependent on aquatic biota. The term was not included in the equation to determine DC values because the assumed absence of significant methylmercury in these food items would only result in a zero value for that component of the equation, thus having no effect on the final DC value:

[%OF × FDOF (methylmercury concentration in other foods)]
[%OF × 0] = 0

The DC values from Table 4., representing the methylmercury concentration in the overall diet of the species resulting from the trophic level-specific concentrations generated by the Average Concentration Trophic Level Approach, were directly compared with the species-specific WVs (Table 5). These comparisons allowed for the presentation of the DC value as a percentage of the corresponding WV, which provided a measure of the protectiveness afforded by the TRC under this approach.

Table 5. Ratio of DC Values to WVs Under Average Concentration TL Approach

Species	DC Values	WVs*	Ratio (DC/WV)
Southern sea otter	0.056	0.055	102%
California least tern	0.165	0.030	550%
California clapper rail	0.033	0.042 (0.014)	79% (236%)
Light-footed clapper rail	0.053	0.040 (0.013)	133% (408%)
Yuma clapper rail	0.125	0.040 (0.013)	313% (962%)
Western snowy plover	0.007	0.026 (0.009)	27% (77%)
Bald eagle	0.431	0.184	234%

* - Values in parentheses represent the WVs generated from the alternative RfD for clapper rails and snowy plover generated using the UF_A of 3, and the subsequent relationships to the DC values.

Wildlife values for the California least tern, light-footed clapper rail, Yuma clapper rail, and bald eagle would be significantly exceeded if their prey contained methylmercury concentrations allowed under the Average Concentration Trophic Level Approach. Wildlife values determined for all three clapper rail subspecies using the alternative RfD would be exceeded under this approach. The WV for the southern sea otter appears as though it would not be significantly exceeded under this approach, while the DC for the western snowy plover would remain well below the WV regardless of the RfD used.

VII.B. Highest Trophic Level Approach

As explained previously (see Section II.B.), applying the Highest Trophic Level Approach to the TRC of 0.3 mg/kg yields the following trophic level-specific concentrations:

FDTL2 = 0.013 mg/kg
FDTL3 = 0.075 mg/kg
FDTL4 = 0.3 mg/kg

For the bald eagle, the two biomagnification factors determined previously were used to estimate methylmercury concentrations in the eagle's avian prey:

FDOB = FDTL2 × MOB
FDOB = 0.013 mg/kg × 10
FDOB = 0.13 mg/kg

FDPB = FDTL3 × MPB
FDPB = 0.075 mg/kg × 12.5
FDPB = 0.94 mg/kg

Then, applying these predicted methylmercury concentrations and the trophic level dietary breakouts determined for each species of concern to the modified Equation 1 yielded the total dietary concentrations (DC) presented in Table 6.

Table 6. Predicted Dietary Concentrations (DC) of Methylmercury Under Highest TL Approach

Modified Equation 1:

$$DC = (\%TL2 \times FDTL2) + (\%TL3 \times FDTL3) + (\%TL4 \times FDTL4) + (\%OB \times FDOB) + (\%PB \times FDPB)$$

Species	%TL2	%TL3	%TL4	%OB	%PB	%OF*	DC (mg/kg)
Southern sea otter	0.80	0.20	na	na	na	na	0.025
California least tern	na	1.00	na	na	na	na	0.075
California clapper rail	0.85	0.05	na	na	na	0.10	0.015
Light-footed clapper rail	0.82	0.18	na	na	na	na	0.024
Yuma clapper rail	0.23	0.72	na	na	na	0.05	0.057
Western snowy plover	0.25	na	na	na	na	0.75	0.003
Bald eagle	na	0.44	0.39	0.10	0.035	0.035	0.196

* - The term '%OF' (*i.e.*, other foods) represents dietary items not expected to significantly contribute dietary methylmercury, and is presented in the table only to provide the full dietary composition assessment for each species. These %OF items include plants, terrestrial insects, or avian prey not dependent on aquatic biota. The term was not included in the equation to determine DC values because the assumed absence of significant methylmercury in these food items would only result in a zero value for that component of the equation, thus having no effect on the final DC value:

[%OF × FDOF (methylmercury concentration in other foods)]
[%OF × 0] = 0

The DC values from Table 6., representing the methylmercury concentration in the overall diet of the species resulting from the trophic level-specific concentrations generated by the Highest Trophic Level Approach, were directly compared with the species-specific WVs (Table 7). These comparisons allowed for the presentation of the DC value as a percentage of the corresponding WV, which provided a measure of the protectiveness afforded by the TRC under this approach.

Table 7. Ratio of DC Values to WVs Under Highest TL Approach

Species	DC Values	WV Values*	Ratio (DC/WV)
Southern sea otter	0.025	0.055	45%
California least tern	0.075	0.030	250%
California clapper rail	0.015	0.042 (0.014)	36% (107%)
Light-footed clapper rail	0.024	0.040 (0.013)	60% (185%)
Yuma clapper rail	0.057	0.040 (0.013)	143% (438%)
Western snowy plover	0.003	0.026 (0.009)	12% (33%)
Bald eagle	0.196	0.184	107%

* - Values in parentheses represent the WVs generated from using the alternative RfD for clapper rails and snowy plover generated using the UF_A of 3, and the subsequent relationships to the DC values.

Wildlife values for the California least tern and Yuma clapper rail would be substantially exceeded if their prey contained methylmercury concentrations allowed under the Highest Trophic Level Approach. The bald eagle WV would only be slightly exceeded by this approach. Using the alternative RfD, the WV for the light-footed and Yuma clapper rails would be substantially exceeded under this approach, while the WV for the California clapper rail would only be slightly exceeded. The DC for the western snowy plover would remain substantially below the WV regardless of the RfD used.

VIII. EVALUATION RESULTS

VIII.A. Southern Sea Otter

The southern sea otter was federally listed as threatened in 1977 (42 Federal Register 2965). Critical habitat for the species has not been designated. A revised recovery plan was published in 2003 (U.S. Fish and Wildlife Service, 2003).

Life History: Generally, the home ranges of southern sea otters consist of several heavily used areas with travel corridors between them. Animals often remain in an area for a long period of time and then suddenly move long distances; these movements can occur at any time of the year. Male southern sea otters have larger home ranges and are less sedentary than females. Juvenile males move further from natal groups than do juvenile females, likely due to territorial and aggressive behavior exhibited toward juvenile males by older males. Most male southern sea otters leave the central portion of the range and travel to its ends during the pupping season, which occurs primarily in the winter and spring (Riedman and Estes, 1990). Southern sea otters mate and pup throughout the year. A peak period of pupping occurs from January to March, and a secondary pupping season occurs in late summer and early fall. Parental care is provided solely by the female. Because of their ability to eat large quantities of marine invertebrates, sea otters play an extremely important role in the nearshore marine community.

Historic and Current Range: Southern sea otters once ranged from the central coast of Baja California north to at least northern California, although they may have ranged as far north as Prince William Sound in Alaska (Riedman and Estes, 1990; Wilson *et al*., 1991). Prior to being protected from hunting for their pelts in 1911, southern sea otters were reduced to only a remnant colony near Bixby Creek along the Big Sur coast in California. Since 1911, the species has expanded north and south from the Bixby Creek colony. Currently, the range of the southern sea otter extends from about Half Moon Bay to Point Conception, with a small translocated colony at San Nicolas Island in southern California.

Rangewide Trends and Current Threats: Historically, the number of southern sea otters was probably between 16,000 and 20,000 (California Department of Fish and Game, 1976). By the end of the 19th century, the sea otter had been hunted nearly to extinction throughout its range. Southern sea otters along the central coast of California experienced a general recovering trend, increasing from as few as 50 animals in 1911 to an estimated 1,789 in 1976. Limitations on set-net fisheries imposed by the California Department of Fish and Game contributed to population increases in the late 1970s and early 1980s (Estes, 1990). Population counts declined from 1995 through 1999 but have since stabilized or increased. During the spring of 2003, a total of 2,505 sea otters were counted.

Current threats to the southern sea otter include disease, exposure to environmental contaminants, intentional take (shooting), and entanglement in fishing gear. Oil spills, which could occur at any time, threaten the southern sea otter with catastrophic decimation or localized

extinction (U.S. Fish and Wildlife Service, 2003).

Evaluation Results: Although the southern sea otter is at risk of exposure to methylmercury from the aquatic organisms in its diet, the analyses performed under each Trophic Level Approach indicate that the EPA's human health TRC (0.3 mg/kg) is not likely to result in a dietary exposure that would place sea otters at risk from methylmercury toxicity (see Tables 5 & 7). Due to the preponderance of trophic level 2 organisms in the otter's diet, neither the Average Concentration nor Highest Trophic Level Approach would result in dietary concentration (DC) values significantly above the calculated Wildlife Value (WV). The DC value generated from the otter's dietary composition and the trophic level methylmercury concentrations determined in the Average Concentration TL Approach is essentially the same as the calculated WV (DC - 0.056 mg/kg, WV - 0.055 mg/kg). The DC value generated in the Highest TL Approach is substantially below the WV (DC - 0.025 mg/kg, WV - 0.055 mg/kg).

VIII.B. California Least Tern

The California least tern was federally listed as endangered in 1970 (35 Federal Register 16047). A detailed account of the taxonomy, ecology, and biology of the California least tern is presented in the approved Recovery Plan for this species (U.S. Fish and Wildlife Service, 1985a).

Life History: California least terns are migratory. They arrive in California in April to breed and depart to wintering areas in Central and South America by the end of September. Little is known about least tern wintering areas. While in California, least tern adults court, mate, and select nest sites; lay, incubate, and hatch eggs; and raise young to fledging prior to departing from the breeding site.

After their eggs hatch, breeding adults catch and deliver small fish to the flightless young. The adults shift their foraging strategy when chicks hatch in order to obtain the very small sized fish suitable for nestlings (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). The young begin to fly at about 20 days of age, but continue to be fed and are taught how to feed by their parents for some time after fledging. Most foraging activity is conducted within a couple miles of the colony (Atwood and Minsky, 1983). After fledging, the young terns do not become fully proficient at capturing fish until after they migrate from the breeding grounds.

Historic and Current Range: The California least tern continues to occupy nesting sites distributed throughout its historic range. The historic breeding range extended along the Pacific Coast from Moss Landing, Monterey County, California, to San Jose del Cabo, southern Baja California, Mexico (American Ornithologists Union, 1957; Dawson, 1924; Grinnell, 1928; Grinnell and Miller, 1944). However, least terns were nesting several miles north of Moss Landing at the mouth of the Pajaro River, Santa Cruz County, California, at least from 1939 (W.E. Unglish, Western Foundation of Vertebrate Zoology egg collection) to 1954 (Pray, 1954); and although nesting at San Francisco Bay was not confirmed until 1967 (Chandik and Baldridge, 1967), numerous spring and summer records for the area suggest nesting may have

occurred previously (Allen, 1934; Chase and Paxton, 1965; Grinnell and Wythe, 1927; Sibley, 1952). Since 1970, nesting sites have been documented in California from San Francisco Bay to the Tijuana River at the Mexican Border; and in Baja California from Ensenada to San Jose del Cabo at the tip of the peninsula.

Rangewide Trends and Current Threats: There are no reliable estimates describing the historic numbers of California least terns along the Pacific Coast (U.S. Fish and Wildlife Service, 1985a). Early accounts describe the existence of substantial colonies along the southern and central California coast (Bent, 1921), including a colony of about 600 breeding pairs along a 3-mile stretch of beach in San Diego County (Shepardson, 1909). At the time of its Federal listing as endangered in 1970, the total U.S. population of the California least tern was estimated to be 600 breeding pairs (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). The dramatic decline in breeding least terns has been attributed to the degradation or loss of breeding sites, colonies, and foraging areas, which resulted from human development and disturbance, and pollution (U.S. Fish and Wildlife Service, 1985a).

The current U.S. population of the California least tern is grouped into 5 geographically discrete clusters, which support multiple active and historic breeding sites. These clusters include: (1) San Diego County, (2) Los Angeles/Orange Counties, (3) Ventura County, (4) San Luis Obispo/Santa Barbara Counties, and (5) San Francisco Bay area. Since its listing, the statewide population of the least tern has reached an estimated 4,009 breeding pairs in 1997 (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). Despite this dramatic increase in breeding pairs, statewide monitoring has revealed threats to the least tern which emphasize the importance of demography to the least tern's survival and recovery.

California least terns were once common along the central and southern California coast. The decline of the California least tern is attributed to prolonged and widespread destruction and degradation of nesting and foraging habitats, and increasing human disturbance to breeding colonies. Conflicting uses of southern and central California beaches during the California least tern nesting season have led to isolated colony sites that are extremely vulnerable to predation from native, feral, and exotic species, overwash by high tides, and vandalism and harassment by beach users. Control of predators constitutes one of the most crucial needs at California least tern nesting sites.

Evaluation Results: In contrast to the evaluation results for the southern sea otter, applying the TRC under either of the trophic level approaches examined here is likely to result in a dietary exposure that may place California least terns at risk for adverse effects from methylmercury toxicity. Due to the tern's relatively small body size and its exclusively piscivorous diet, the WV (0.030 mg/kg) would be significantly exceeded by the DC values generated from the trophic level concentrations under each TL approach. In the case of the Highest TL Approach, the trophic level concentrations would result in a DC value (0.075 mg/kg) 250 percent of the tern's WV (see Table 7). The trophic level concentrations under the Average Concentration TL Approach would result in an even greater DC value (0.165 mg/kg), 550 percent of the WV (see Table 5). While

the extent of any potential adverse effects from either DC value cannot be quantified, the degree of WV exceedance under each TL approach suggests a high probability that dietary methylmercury exposure from the TRC could reach a level at which adverse effects to least terns may be expected. Based on the analyses performed in this effort, methylmercury concentrations in TL3 fish, the tern's sole prey base, would have to be substantially lower than the TL3 concentrations expected under each TL approach in order to maintain dietary exposure at the protective WV for California least terns.

VIII.C. California Clapper Rail

The clapper rail was federally listed as endangered in 1970 (35 Federal Register 16047). A detailed account of the taxonomy, ecology, and biology of the clapper rail can be found in the approved Recovery Plan for this species (U.S. Fish and Wildlife Service, 1984).

Life History: Clapper rails are non-migratory residents of San Francisco Bay tidal marshes. Research in a north San Francisco Bay marsh concluded that the clapper rail breeding season, including pair bonding and nest construction, may begin as early as February (Evens and Page, 1983). Field observations in south San Francisco Bay marshes suggest that pair formation also occurs in February in some areas (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). The clapper rail breeding season has two nesting peaks, one between mid-April and early-May and another between late-June and early-July. Harvey (1988) and Foerster *et al.* (1990) reported mean clutch sizes of 7.27 and 7.47 for clapper rails, respectively. The end of the breeding season is typically defined as the end of August, which corresponds with the time when eggs laid during renesting attempts have hatched and young are mobile.

Historic and Current Range: Of the 193,800 acres of tidal marsh that bordered San Francisco Bay in 1850, about 30,100 acres currently remain (Dedrick, 1993). This represents an 84 percent reduction from historical conditions. Furthermore, a number of factors influencing remaining tidal marshes limit their habitat values for clapper rails. Much of the east San Francisco Bay shoreline from San Leandro to Calaveras Point has undergone erosion, resulting in a potential loss of local clapper rail populations. In addition, an estimated 600 acres of former salt marsh along Coyote Creek, Alviso Slough, and Guadalupe Slough, had been converted to fresh- and brackish-water vegetation marshes due to freshwater discharge from south San Francisco Bay wastewater facilities. Converted marshes are of lower quality for clapper rails.

The suitability of many marshes for clapper rails is further limited, and in some cases precluded, by their small size, fragmentation, and lack of tidal channel systems and other micro-habitat features. These limitations render much of the remaining tidal marsh acreage unsuitable or of low value for the species. In addition, tidal amplitudes are much greater in the south Bay than in San Pablo or Suisun bays (Atwater *et al.*, 1979). Consequently, many tidal marshes are completely submerged during high tides and lack sufficient escape habitat, likely resulting in nesting failures and high rates of predation. The reductions in carrying capacity in existing marshes necessitate the restoration of larger tracts of habitat to maintain stable populations.

Several years ago, the clapper rail population was estimated to be approximately 500 to 600 individuals in the southern portion of San Francisco Bay, while a conservative estimate of the north San Francisco Bay population, including Suisun Bay, was 195 to 282 pairs (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). Historic populations at Humboldt Bay, Elkhorn Slough, and Morro Bay are now extinct; therefore, the 30,100 acres of tidal marsh remaining in San Francisco Bay represent the current distribution of this subspecies.

Rangewide Trends and Current Threats: As described above, the clapper rail's initial decline resulted from habitat loss and degradation, and reduction in range. Throughout San Francisco Bay, the remaining clapper rail population is besieged by a suite of mammalian and avian predators. At least 12 native and 3 non-native predator species are known to prey on various life stages of the clapper rail (Albertson, 1995). Artificially high local populations of native predators, especially raccoons, result as development occurs in the habitat of these predators around the Bay margins (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). Encroaching development not only displaces lower order predators from their natural habitat, but also adversely affects higher order predators, such as coyotes, which would normally limit population levels of lower order native and non-native predators, especially red foxes (Albertson, 1995).

Hunting intensity and efficiency by raptors on clapper rails also is increased by electric power transmission lines, which criss-cross tidal marshes and provide otherwise-limited hunting perches (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). Non-native Norway rats (*Rattus norvegicus*) long have been known to be effective predators of clapper rail nests (DeGroot, 1927; Harvey, 1988; Foerster *et al.*, 1990). Placement of shoreline riprap favors rat populations, which results in greater predation pressure on clapper rails in certain marshes. These predation impacts are exacerbated by a reduction in high marsh and natural high tide cover in marshes.

The proliferation of non-native red foxes into tidal marshes of the south San Francisco Bay since 1986 has had a profound effect on clapper rail populations. As a result of the rapid decline and almost complete elimination of rail populations in certain marshes, the San Francisco Bay National Wildlife Refuge implemented a predator management plan in 1991 (Foerster and Takekawa, 1991) with an ultimate goal of increasing rail population levels and nesting success through management of red fox predation. This program has proven successful in increasing the overall south San Francisco Bay populations from an all-time low; however, it has been difficult to effectively conduct predator management over such a large area as the south San Francisco Bay, especially with the many constraints associated with conducting the work in urban environments (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000).

Predator management for clapper rails is not being regularly practiced in the north San Francisco Bay, and rail populations in this area remain susceptible to red fox predation. Red fox activity has been documented west of the Petaluma River and along Dutchman Slough at Cullinan Ranch. Along Wildcat Creek near Richmond, where recent red fox activity has been observed,

the rail population level in one tidal marsh area has declined considerably since 1987, even though limited red fox management was performed in 1992 and 1993 (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000).

In addition to habitat loss and predation pressures, pollutants in the aquatic environment appear to be a continuing threat to California clapper rail populations. Schwarzbach *et al*. (in press) examined factors affecting clapper rail reproductive success in San Francisco Bay, including predation, flooding, and contaminant exposure. Both predation and contaminants appeared to contribute to observations of low hatching success and overall fecundity for clapper rail nests in six intertidal salt marshes in the Bay. Egg hatchability was depressed in all marshes, with observations of deformities, embryo hemorrhaging, and embryo malpositions. Failed-to-hatch eggs contained various levels of trace element and organochlorine contaminants, with mercury at elevated concentrations in at least some eggs from all six marshes. The researchers stated that mercury appeared to consistently be the contaminant most likely to produce the low hatchability observed in all marshes sampled.

Evaluation Results: As explained previously in this document, the analyses for all three rail subspecies and the western snowy plover included evaluations using two WVs, based on RfDs generated from different interspecies uncertainty factors (UF_A). The WV calculated for the California clapper rail with the UF_A of 1 is 0.042 mg/kg. Comparing this WV with the expected DC values from the trophic level concentrations under both the Average Concentration TL Approach (DC - 0.033 mg/kg) and the Highest TL Approach (DC - 0.015 mg/kg) indicate that the TRC is not likely to result in dietary exposure that would place California clapper rails at risk for adverse effects from methylmercury toxicity, as both DC values are substantially below the WV (see tables 5 & 7).

However, the WV calculated with the UF_A of 3 (0.014 mg/kg) produces different results. The DC value from the Average Concentration TL Approach (0.033 mg/kg) is 236 percent of this WV, indicating that dietary exposure in California clapper rails may place them at risk under this TL approach. The DC value from the Highest TL Approach (0.015 mg/kg) is only slightly above the WV. The small differential (<10%) between the two is well within reasonable bounds, recognizing the various uncertainties and assumptions inherent in this methodology, to conclude that dietary exposure resulting from applying the TRC under the Highest TL Approach should not place California clapper rails at risk for adverse effects from methylmercury toxicity.

The question of which UF_A is the most appropriate to represent the clapper rail's sensitivity relative to mallard ducks, the species used in establishing the avian test dose (Heinz, 1979), cannot yet be definitively answered. However, data collected in the last decade on California clapper rails in the San Francisco Bay region allows for a parallel evaluation of the protectiveness afforded by the two WV values and the UF_As on which they were based.

Schwarzbach *et al*. (in press) collected failed-to-hatch clapper rail eggs from various marshes around San Francisco Bay in 1991-1992 (south Bay) and 1998-1999 (north Bay). The eggs were

analyzed for a number of pollutants, including mercury. Mean egg total mercury concentrations were then calculated for both south Bay eggs (0.54 mg/kg fresh wet weight, range: 0.17 - 2.52) and north Bay eggs (0.36 mg/kg fww, range: 0.11 - 0.87). A subset of collected rail eggs was analyzed for methylmercury, with results demonstrating that methylmercury was on average 95 percent of the total mercury found. South and north Bay means could then be adjusted to 0.513 and 0.342 mg/kg methylmercury, respectively. The south Bay average is equivalent to the avian 'lowest observed adverse effects concentration' (LOAEC) seen in pheasants (Fimreite, 1971).

In a corollary investigation (Schwarzbach *et al.*, 1996), clapper rail prey organisms (*i.e.*, snails, crabs, mussels) were collected in 1992 and 1994 from the same Bay marshes used in rail egg collections. The prey collections from 1992 were analyzed for total mercury, while those from1994 were analyzed for methylmercury. Only the south Bay marsh collections included all three prey organisms. The mean methylmercury concentration for all prey organisms in the south Bay, assuming 75 percent moisture, was 0.036 mg/kg (range: 0.0357 - 0.0363). This value is lower than the WV (0.042 mg/kg) calculated to be protective of clapper rails using the UF_A of 1.

These data allowed the calculation of a diet-to-egg transfer factor for California clapper rails in south San Francisco Bay. Taking the mean rail egg concentration of 0.513 mg/kg divided by the mean prey concentration of 0.036 mg/kg results in a methylmercury diet-to-egg transfer factor of 14.25. Multiplying the WV (0.042 mg/kg) generated with the UF_A of 1 by the diet-to-egg transfer factor of 14.25 results in an estimated methylmercury concentration in the egg of 0.598 mg/kg, higher than what is presently found in south Bay rail eggs. Multiplying the alternate WV (0.014 mg/kg) generated with the UF_A of 3 results in an estimated methylmercury concentration in the egg of 0.199 mg/kg. Based on the egg injection work discussed previously (Heinz, pers. comm., 2003) and assessments of the rail's current reproductive status (Schwarzbach *et al.*, in press), it has been estimated that a value of 0.2 mg/kg fww methylmercury in rail eggs would be a reasonable and appropriate 'no observed adverse effects concentration' (NOAEC) (Schwarzbach, pers. comm., 2003).

Although these data are limited in that collecting failed-to-hatch eggs does not represent a random sample analysis of methylmercury concentrations, they did provide parallel support that a UF_A of 3 is necessary to determine an appropriately protective RfD (0.007 mg/kg bw/day), and subsequent WV (0.014 mg/kg), for the California clapper rail. Given this additional validation of the higher UF_A, it can then be concluded that applying the TRC only under the Highest TL Approach is necessary to maintain dietary exposure at the protective WV for California clapper rails.

VIII.D. Light-footed Clapper Rail

The light-footed clapper rail was federally listed as endangered on October 13, 1970 (35 Federal Register 16047) and state listed as endangered in California on June 27, 1971. The original recovery plan for this species was approved in July 1979 and a revision was published on June 24, 1985 (U.S. Fish and Wildlife Service, 1985b). Critical habitat has not been designated for

this species.

Life History: Rails use coastal salt marshes, lagoons, and their maritime environs (Zembal, 1989). The birds nest in the lower littoral zone of coastal salt marshes where dense stands of cordgrass (*Spartina foliosa*) are present. They also build nests in pickleweed (*Salicornia virginica*) (Massey *et al*., 1984). Rails have also been known to reside and nest in freshwater marshes, although this is not common (Thelander and Crabtree, 1994). They require shallow water and mudflats for foraging, with adjacent higher vegetation for cover during high water (Zeiner *et al*., 1990). Rails forage in all parts of the saltmarsh, concentrating their efforts in the lower marsh when the tide is out, and moving into the higher marsh as the tide advances (Zembal *et al*., 1989).

The pair bond in rails endures throughout the season, and often from year to year. Nesting usually begins in March and late nests have usually hatched by August. Nests are placed to avoid flooding by tides, yet in cover dense enough to be hidden from predators and to support the relatively large nest (Storey *et al*., 1988). Females lay approximately 4-8 eggs, which hatch in 18-27 days (U.S. Fish and Wildlife Service, 1985b). Both parents care for the young; while one forages, the other adult broods the chicks (U.S. Fish and Wildlife Service, 1985b). By the age of two days, chicks will accompany adults on foraging trips; however, adults have been observed feeding fully grown chicks of at least six weeks of age within 25 meters of their incubation nest (U.S. Fish and Wildlife Service, 1985b).

Very limited evidence exists for inter-marsh movements by rails, and this subspecies is resident in its home marsh except under unusual circumstances (Zembal, 1989). Within marsh movements are also confined and generally no greater than 400 meters (Zembal, 1989). Minimum home range sizes for nine rails that were studied using radio telemetry at Upper Newport Bay varied from approximately 0.3 to 1.7 hectares, with larger areas and daily movements by first year birds attempting to claim their first breeding territories (Zembal, 1989). Despite the lack of direct evidence for inter-marsh movement by rails, at least four sites where rails appeared to be extirpated for six or more years were subsequently re-occupied, indicating likely inter-marsh re-colonization (Zembal and Hoffman, 2001).

Historic and Current Range: The rail currently inhabits coastal marshes from the Carpinteria Marsh in Santa Barbara County, California, to Bahia de San Quintin, Baja California, Mexico (Zembal, 1989; Zembal *et al*., 1998). It is believed that most salt marshes along the coastline at one time supported clapper rails (Grinnell *et al*., 1918), but recent census data indicate that less than 50 percent of the coastal wetlands in California are currently occupied (Zembal *et al*., 1998).

Rangewide Trends and Current Threats: The first rail census in southern California was conducted in 1972-73, and the population was estimated at about 500 pairs (Wilbur, 1974). Annual surveys conducted from 1980 to 2001 showed an erratic trend in the population, with a peak estimate of 325 pairs in 1996 (Zembal and Hoffman, 2001). The most recent population census in 2001 found 217 pairs (Zembal and Hoffman, 2001). The three largest sub-populations

(at Newport Bay, Tijuana Estuary, and Seal Beach National Wildlife Refuge) comprised 86 percent of the breeding rails in southern California in 2001 (Zembal and Hoffman, 2001). Many smaller rail sub-populations are under threat of extirpation, but with appropriate management could become nuclei for recovery (U.S. Fish and Wildlife Service, 1985b). The number of marshes inhabited by breeding rails in coastal southern California has fluctuated widely since population censuses began in 1980. The number of occupied marshes declined from 19 marshes in 1984 to 8 in 1989, but increased to 16 occupied marshes in 1997 (Zembal *et al*., 1998).

Habitat loss at several major estuaries in southern California approaches ninety-nine percent (U.S. Fish and Wildlife Service, 1985b). Although salt-marsh habitat loss, degradation, and fragmentation are the leading threats to rails, they are also threatened by disturbance, diseases, contaminants, and predation by non-native red foxes (Thelander and Crabtree, 1994). Rails may also be hit by vehicles in marshes adjacent to or bisected by roads (Zembal *et al*., 1989).

Evaluation Results: As with the California clapper rail, two WVs were calculated for the light-footed clapper rail, based on UF_As of 1 or 3. However, due to the light-footed rail's smaller body weight, WVs are slightly less than those for the California rail. The UF_A of 1 resulted in a WV of 0.040 mg/kg, while the UF_A of 3 yielded a WV of 0.013 mg/kg.

Based on the light-footed rail's diet, which has a greater percentage of trophic level 3 organisms than in the California rail's diet, the trophic level concentrations expected under the Average Concentration TL Approach would produce a DC value of 0.053 mg/kg. This value is more than 400 percent of the lower WV (0.013 mg/kg). The Highest TL Approach produces a DC value of 0.024 mg/kg, 185 percent of the same WV. Both levels of WV exceedance demonstrate that, if 3 is the appropriate UF_A to determine a protective RfD and WV (0.013 mg/kg) for the light-footed clapper rail, the TRC under either TL approach is likely to result in dietary exposure that may place this subspecies at risk for adverse effects from methylmercury toxicity.

No information was found regarding diet-to-egg relationships for this subspecies, so no parallel assessment could be made regarding the appropriateness of 3 as the UF_A. Although it is reasonable to assume that both the light-footed and California clapper rails would be similarly sensitive to methylmercury, it is possible that the light-footed rail is better adapted to detoxify ingested methylmercury because of its more piscivorous diet (see Section III,D: Determination of Reference Dose). If so, then it may be more appropriate to consider the light-footed rail as an obligate piscivore, using the RfD and subsequent WV (0.040 mg/kg) generated with the UF_A of 1.

Comparison of the DC values expected from both TL approaches with the higher WV (0.040 mg/kg) produces variable results. The DC value from the Average Concentration TL Approach (0.053 mg/kg) is more than 130 percent of this WV, indicating dietary exposure is still likely to place these rails at risk of adverse effects from methylmercury toxicity. In contrast, the DC value from the Highest TL Approach (0.024 mg/kg) is only 60 percent of this higher WV, indicating a dietary exposure not likely to place light-footed rails at risk from the TRC.

Regardless of which UF_A (1 or 3) and subsequent WV (0.040 or 0.013) are used in the analysis, the trophic level concentrations expected under the Average Concentration TL Approach would result in a DC value substantially greater than either WV. Dietary exposure under this TL approach may place light-footed clapper rails at risk for adverse effects from methylmercury toxicity. However, comparison of the DC value expected from the Highest TL Approach with the two WVs results in conflicting conclusions. Assuming the UF_A of 1 is appropriate, the analysis suggests that applying the TRC under the Highest TL Approach would be sufficient to maintain dietary exposure at or below the corresponding protective WV (0.040 mg/kg). If the UF_A of 3 is the more appropriate value, then the TRC under this TL approach would result in a dietary exposure above the corresponding WV (0.013 mg/kg). Given the various uncertainties and assumptions used in these analyses (*e.g.*, dietary composition, food chain multipliers), the only conclusion that can be drawn at this point is that, of the two TL approaches evaluated, the Highest TL Approach poses less risk of a dietary exposure that could place light-footed clapper rails at risk for adverse effects from methylmercury toxicity. Further research must be conducted to verify whether the trophic level concentrations expected under the Highest TL Approach are sufficient or need to be lower to ensure adequate protection for the light-footed rail.

VIII.E. Yuma Clapper Rail

The Yuma clapper rail was federally listed as endangered on March 11, 1967 (32 Federal Register 4001). The Yuma Clapper Rail Recovery Plan, approved in 1983, provides background information on the species and identifies new or ongoing tasks necessary to achieve recovery of this species (U.S. Fish and Wildlife Service, 1983). The State of California added the bird to its list of rare wildlife in May of 1971 and later listed it as threatened on February 22, 1978.

Life History: Yuma clapper rail habitat is characterized by cattail (*Typha*), bulrush (*Scirpus*), or tule stands, and shallow, slow-moving water near high ground. Cattail and bulrush stands are often dissected by narrow channels of flowing water that may be covered by downed vegetation. These open channels are important for foraging. Rails commonly use areas with low stem densities and little residual vegetation. They are also found in the ecotone between emergent vegetation and higher ground, such as the shoreline, channel edge, or hummocks in a marsh. In studies conducted along the lower Colorado River, rails were found to use areas far from a vegetative edge during early winter (Conway *et al*., 1993). The depth of water used by clapper rails also varied with season, with shallower water used during the breeding season, and water of moderate depth used during the winter. Although clapper rails are often found in larger stands of vegetation, they have also been found to use patches of habitat within agricultural drains (Bennett and Ohmart, 1978).

The Yuma clapper rail begins breeding activities in February, with egg-laying from March to July in marshes along the Colorado River from the Nevada/California border south to the Colorado River Delta region in Mexico. Chicks generally fledge by mid-September (Eddleman and Conway, 1994). It builds its nest on a raised platform of vegetation concealed in dense marsh vegetation (Patten *et al*., in press). Males may build multiple nests, and the female chooses one

for egg-laying. Alternate nests are used as platforms for loafing, preening, and as brood platforms, but may also be useful for incubation if predators or high water disturb the primary nest (Eddleman and Conway, 1994). This subspecies is partially migratory, with many birds wintering in brackish marshes along the Gulf of California but some remain on their breeding grounds throughout the year (U.S. Bureau of Land Management, 2001). Yuma clapper rails are found around the Salton Sea, and in agricultural drains and canals that support marsh vegetation (i.e., cattail, giant bulrush, alkali bulrush, and common reed). This subspecies breeds only in the lower Colorado River Valley and in the Salton Sink, the latter area holding about 40 percent of the United States population (Setmire *et al*., 1990). The breeding site for the largest population of the Yuma clapper rail in the United States is at the Wister unit of the California Department of Fish and Game (CDFG) Imperial Wildlife Area, near the Salton Sea. The sea's elevation is important to the Yuma clapper rail (U.S. Department of the Interior, 1998) as clapper rails use shallow freshwater habitat that has formed at the mouths of many of the inflows to the Salton Sea. Yuma clapper rails avoid deeper water because it increases juvenile mortality (California Department of Fish and Game, 1990).

Historic and Current Range: The Yuma clapper rail occurs primarily in the lower Colorado River Valley in California, Arizona, and Mexico, and is a fairly common summer resident from Topock south to Yuma in the U.S. and at the Colorado River Delta in Mexico. There are also populations of this subspecies at the Salton Sea in California, and along the Gila and Salt Rivers to Picacho Reservoir and Blue Point in central Arizona (Rosenberg *et al*., 1991). In recent years, individual clapper rails have been heard at Laughlin Bay and Las Vegas Wash in southern Nevada (Nevada Division of Wildlife, 1998). Population centers for this subspecies include Imperial Wildlife Management Area (Wister Unit), Sonny Bono Salton Sea National Wildlife Refuge (NWR), Imperial NWR, Cibola NWR, Mittry Lake, West Pond, Bill Williams Delta, Topock Gorge, and Topock Marsh.

In California this species nests along the lower Colorado River, in wetlands along the Coachella Canal, the Imperial Valley, the upper end of the Salton Sea at the Whitewater River delta, and Salt Creek (NatureServe, 2001). Hydroelectric dams along the Colorado River have apparently increased the amount of marsh habitat, and population numbers of the Yuma clapper rail may have increased expanding the range northward in response to the increase in available habitat (U.S. Bureau of Land Management, 2001). Also, habitat was expanded through the creation of the Salton Sea in the early 1900s.

Rangewide Trends and Current Threats: The U.S. Fish and Wildlife Service (1983) estimated a total of 1,700 to 2,000 individuals throughout the range of the subspecies. Between 1990 and 1999, call counts conducted throughout the subspecies range in the U.S. have recorded 600 to 1,000 individuals. In 1985, Anderson and Ohmart (1985) estimated a population size of 750 birds along the Colorado River north of the international boundary. A substantial population of Yuma clapper rails exists in the Colorado River Delta in Mexico. Eddleman (1989) estimated that 450 to 970 rails inhabited this area in 1987. Piest and Campoy (1998) reported a total of 240 birds responding to taped calls in the Cienega de Santa Clara region of the Delta. These counts

are only estimates of the minimum number of birds present. The population is probably higher than these counts show, since up to 40 percent of the birds may not respond in call surveys (Piest and Campoy, 1998). Based on the call count surveys, the population of Yuma clapper rails in the U.S. appears stable (U.S. Fish and Wildlife Service, unpublished data). The range of the Yuma clapper rail has been expanding over the past 25 years, and the population may be increasing (Ohmart and Smith, 1973; Monson and Phillips, 1981; Rosenberg *et al*., 1991; McKernan and Braden, 1999). A recent genetic analysis showed that this subspecies is outbred; population numbers of the Yuma clapper rail have not become low enough to reduce genetic diversity (U.S. Bureau of Land Management, 2001).

The Yuma clapper rail apparently expanded its range in the early 1900's in response to changes in the vegetation along the Colorado River. Damming and associated changes in hydrology induced vegetation changes in some areas that favored rails. At the same time, damming and diversion of the Colorado River reduced the amount of water flowing into the Colorado River Delta, and reduced the availability of rail habitats in the Delta. Approximately two-thirds of the formerly extensive marshlands of the Delta disappeared following completion of Hoover Dam (Sykes, 1937).

Yuma clapper rail habitat has been further affected by channelization, fill, dredging projects, bank stabilization, and water management practices along the Colorado River. Rail habitat has also been adversely affected by the spread of salt cedar (*Tamarisk ramosissima*). Salt cedar consumes an unusually high amount of water, which results in reduced wetland areas for vegetation preferred by the rail.

Many of the currently occupied breeding sites in the United States are on State and Federal lands that are protected and managed for wildlife (U.S. Fish and Wildlife Service, 1983). However, adequate water supplies are needed to assure the long-term availability of this habitat. Wintering areas and needs are not well known and require further study before habitat preservation needs can be determined. Many of the Mexican breeding sites are located in the Rio Colorado Delta area and require adequate flows in the lower Colorado River for long-term use by Yuma clapper rails. The population of Yuma clapper rails at the Cienega de Santa Clara is threatened by the loss of the source of water that maintains the wetland habitat.
Other threats to the Yuma clapper rail include mosquito abatement activities, agricultural activities, development, and the displacement of native habitats by exotic vegetation (California Department of Fish and Game, 1991).

Evaluation Results: The two WVs (0.013 and 0.040 mg/kg) calculated for the Yuma clapper rail are the same as those used for the light-footed clapper rail. However, due to the Yuma rail's reliance on higher trophic level organisms for its diet, the DC values expected with each TL approach are substantially higher than those expected for either the light-footed or California clapper rails.

The WV for the Yuma rail calculated using the UF_A of 3 is 0.013 mg/kg. The DC value expected from trophic level concentrations under the Highest TL Approach is 0.057 mg/kg, more than 430 percent of the WV (see Table 7). The DC value from the Average Concentration TL Approach is 0.125 mg/kg, almost 1000 percent of the WV (see Table 5). Clearly, if 3 is the appropriate UF_A to determine a protective RfD and WV for the Yuma clapper rail, the TRC under either TL approach is likely to result in dietary exposure that may place this subspecies at risk for adverse effects from methylmercury toxicity.

The WV calculated using the UF_A of 1 is 0.040 mg/kg. This WV (0.040 mg/kg) is substantially closer than the previous WV to the DC value of 0.125 mg/kg expected from the Average Concentration TL Approach, but this DC is still more than 300 percent of this higher WV (see Table 5). This higher WV is even closer to the DC value of 0.057 mg/kg expected from the Highest TL Approach (see Table 7); however, a DC value exceeding the WV by more than 40 percent is still likely to result in a dietary exposure that may place Yuma rails at risk for adverse effects from methylmercury toxicity. Based on these comparisons, both TL approaches would still be insufficient to maintain dietary exposure in this subspecies at or below the calculated WVs.

VIII.F. Western Snowy Plover

The Pacific coast population of the western snowy plover was federally listed as threatened on March 5, 1993 (58 Federal Register 12864) and critical habitat was designated on December 7, 1999 (64 Federal Register 68508). A draft recovery plan for the species has been completed (U.S. Fish and Wildlife Service, 2001).

Life History: Western snowy plovers prefer coastal beaches that are relatively free from human disturbance and predation. Sand spits, dune-backed beaches, beaches at creek and river mouths, and salt pans at lagoons and estuaries are the preferred habitats for nesting. The attributes considered essential to the conservation of the coastal population of the western snowy plover can be found in the final ruling for the designation of critical habitat (64 Federal Register 68508). The primary constituent elements for the western snowy plover are those habitat components that are essential for the primary biological needs of foraging, nesting, rearing of young, roosting, and dispersal, or the capacity to develop those habitat components. The primary constituent elements of critical habitat for the species are provided by intertidal beaches (between mean low water and mean high tide), associated dune systems, and river estuaries. Important components of the beach/dune/estuarine ecosystem include surf-cast kelp, sparsely vegetated foredunes, interdunal flats, spits, washover areas, blowouts, intertidal flats, salt flats, and flat rocky outcrops. Several of these components (sparse vegetation, salt flats) are mimicked in artificial habitat types used less commonly by western snowy plovers (*i.e.*, dredge spoil sites and salt ponds and adjoining levees).

The breeding season for western snowy plovers extends from March to late September, with birds at more southerly locations breeding earlier. Most nesting occurs on unvegetated or

moderately vegetated, dune-backed beaches and sand spits. Other less common nesting habitats include salt pans, dredge spoils, and salt pond levees. Nest site fidelity is common, and mated birds from the previous breeding season frequently reunite. Nest sites are scrapes in the substrate, in which females lay eggs (typically three but up to six). Both sexes incubate eggs, with the female tending to incubate during the day and the male at night (Warriner *et al*., 1986). Snowy plovers often renest if eggs are lost. Hatching lasts from early April through mid-August, with chicks fledging approximately one month after hatching. Adult plovers tend chicks while feeding, often using distraction displays to lure predators and people away from chicks. Females generally desert both mates and broods by the sixth day after hatching, and thereafter the chicks are typically accompanied by only the male. While males rear broods, females obtain new mates and initiate new nests (Page *et al*., 1995)

Historic and Current Range: The Pacific coast population of the western snowy plover breeds primarily on coastal beaches from southern Washington to southern Baja California, Mexico. Historically, western snowy plovers bred or wintered at 157 locations on the Pacific coast, including 133 sites in California. Larger numbers of birds are found in southern and central California, in Monterey Bay (estimated 200 to 250 breeding adults), Morro Bay (estimated 85 to 93 breeding adults), Pismo Beach to Point Sal (estimated 130 to 246 breeding adults), Vandenberg Air Force Base (estimated 130 to 240 breeding adults), and the Oxnard Lowland (estimated 69 to105 breeding adults).

During the non-breeding season western snowy plovers may remain at breeding sites or may migrate to other locations. Most winter south of Bodega Bay, California. Many birds from the interior population winter on the central and southern coast of California.

Rangewide Trends and Current Threats: Historical records indicate that nesting western snowy plovers were once more widely distributed in coastal Washington, Oregon and California than they are currently. Only 1,200 to 1,900 adult western snowy plovers remain on the Pacific coast of the United States (Page *et al*., 1991). In 1995, approximately 1,000 western snowy plovers occurred in coastal California. Historically, western snowy plovers bred at 53 coastal locations in California prior to 1970. Only eight sites continue to support 78 percent of the remaining California coastal breeding population. These are San Francisco Bay, Monterey Bay, Morro Bay, the Callendar-Mussel Rock dunes area, the Point Sal to Point Conception area (Vandenberg Air Force Base), the Oxnard lowland, Santa Rosa Island, and San Nicolas Island (Page *et al*., 1991).

The Pacific coast population of the western snowy plover has experienced widespread loss of nesting habitat and reduced reproductive success at many nesting locations due to urban development and the encroachment of European beachgrass (*Ammophila arenaria*). Human activities such as walking, jogging, unleashed pets, horseback riding, and off-road vehicles can destroy the western snowy plover's cryptic nests and chicks. These activities can also hinder foraging behavior, cause separation of adults and their chicks, and flush adults off nests and away from chicks, thereby interfering with essential incubation and chick-rearing behaviors. Predation by coyotes, foxes, skunks, ravens, gulls, and raptors has been identified as a major factor limiting

western snowy plover reproductive success at many Pacific coast sites.

Evaluation Results: Compared to the other species considered in this evaluation, the western snowy plover is unique in that little of its overall diet is comprised of aquatic organisms. Although the species lives and nests along coastal and estuarine river beaches, the scientific literature indicates that the bulk of the plover diet comes from larval and adult terrestrial insects (primarily flies and beetles). Due to this dietary characteristic, all the analyses performed in this effort indicate that the TRC should not result in a dietary exposure that would place snowy plovers at risk for adverse effects from methylmercury toxicity (see Tables 5 & 7). Dietary concentration values expected from both of the TL approaches should remain substantially below the plover's calculated WV (0.026 mg/kg). Even when using the alternative reference dose (RfD) generated with the interspecies uncertainty factor (UF_A) of 3, expected DC values remain well below the corresponding lower WV (0.009 mg/kg).

These results must be interpreted with some caution, however, as recent research suggests plovers may be at risk from a unique dietary methylmercury exposure pathway not previously considered in toxicity assessments. Hothem and Powell (2000) collected 68 abandoned or inviable snowy plover eggs from five sites in southern California between 1994 and 1996. Twenty-three of these eggs were analyzed for metals and trace elements. Total mean mercury concentrations in these eggs ranged from 0.078 to 0.19 mg/kg. These values are substantially below accepted lowest observed adverse effects concentrations (LOAEC) for avian eggs, and the authors concluded that concentrations of mercury and other environmental contaminants were not sufficiently elevated in the study eggs to be contributing to population declines. However, snowy plover eggs collected in 2000 from Point Reyes National Seashore in northern California revealed highly elevated mercury concentrations (U.S. Fish and Wildlife Service, unpublished data). Nine failed-to-hatch eggs and two abandoned eggs were collected and analyzed for total mercury. Dry weight concentrations ranged from 0.9 to 12.48 mg/kg, with a mean of 2.56 mg/kg. Adjusted for percent moisture at the time of analysis and moisture loss from the time of laying, the mean fresh wet weight (fww) concentration in the failed and abandoned eggs was reported as 1.07 and 0.27 mg/kg, respectively, with a mean of 0.92 mg/kg for all 11 eggs. The maximum concentration detected from the failed eggs (12.48 mg/kg dry weight) adjusted to 3.1 mg/kg fww. This value is nearly as high as the highest concentration yet detected (3.3 mg/kg fww) in eggs of Fortser's terns, an exclusively piscivorous species, collected from the south San Francisco Bay area (Schwarzbach and Adelsbach, 2002). Mean and maximum concentrations in the failed eggs were substantially above accepted avian egg LOAECs [0.5 mg/kg (Fimreite, 1971); ~0.8 mg/kg (Heinz, 1979)], possibly high enough to account for egg failure through direct toxic effects to plover embryos.

The U.S. Fish and Wildlife Service investigators observed an order of magnitude variation in egg mercury concentrations between the different nests sampled along Point Reyes National Seashore in 2000, with no apparent spatial gradients. As mercury in eggs is thought to closely reflect recent dietary uptake (Walsh, 1990), the Point Reyes data indicated to the investigators that the degree of variation observed reflected a highly heterogenous source of dietary mercury. There

are no known mercury inputs to the coastal beaches used by breeding plovers; however, the investigators noted that an inoperative mercury mine continues to discharge mercury-laden sediments into Tomales Bay, east of the Point Reyes peninsula. Although breeding plovers likely do not forage in Tomales Bay, the investigators suggested that marine mammals foraging in this water body may serve as a mercury pathway into the plover diet. Marine pinnipeds are known to accumulate mercury, usually exhibiting the highest reported tissue concentrations among non-human mammals (Eisler, 2000). As snowy plovers are known to feed on insect larvae that develop on marine mammal carcasses (Page *et al*., 1995), the Point Reyes investigators hypothesized that the elevated plover egg mercury concentrations they observed were the result of localized consumption of invertebrates from pinniped carcasses washed ashore into plover breeding territories. This hypothesis is supported by the fact that at least four marine pinnipeds washed ashore at Point Reyes National Seashore during the 2000 plover breeding season, including a harbor seal carcass that was allowed to decompose on site near the plover nest with the maximum observed egg mercury concentration (Ruhlen and Abbott, 2000).

More work is needed to confirm whether plovers may be exposed to mercury via marine mammal carcasses, and it is not currently possible to incorporate this potential exposure pathway into the methodology developed for this evaluation. To do so would require an analysis of mercury biomagnification from pinniped prey items into the insect larvae developing on pinniped carcasses, information currently unavailable. Even if the hypothesis is confirmed, the mercury levels in Tomales Bay prey biota may already be substantially elevated above the trophic level concentrations expected under the human health TRC, due to the historic and ongoing mercury inputs from the upstream mine. As noted above, the analyses performed for this effort indicate that dietary exposure in snowy plovers should not place them at risk from methylmercury toxicity by either of the TL approaches described. However, given the uncertainties surrounding the potential marine mammal pathway and the plover's sensitive conservation status, applying the Highest TL approach to the TRC would provide the most reasonable assurance of protection.

VIII.G. Bald Eagle

The bald eagle was listed as federally endangered in 1978 (43 Federal Register 6230). The Pacific Bald Eagle Recovery Plan was released in 1986 for the recovery and maintenance of bald eagle populations in the 7-state Pacific recovery region (Idaho, Nevada, California, Oregon, Washington, Montana, and Wyoming) (U.S. Fish and Wildlife Service, 1986). In recent years, the status of bald eagle populations has improved throughout the United States. The bald eagle was downlisted from endangered to threatened on July 12, 1995, throughout the lower 48 states (60 Federal Register 36000). A proposed rule to remove the species from the list of endangered and threatened wildlife was made on July 6, 1999 (64 Federal Register 36454) but this rule has not been finalized. Critical habitat has not been designated for this species. In addition to the Endangered Species Act, the bald eagle is protected under the Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. §§703-712) and the Bald Eagle Protection Act of 1940, as amended (16 U.S.C. §§668-668d).

Life History: The species is long-lived, and individuals do not reach sexual maturity until four or five years of age. Breeding generally occurs February to July (Zeiner *et al*., 1990) but breeding can be initiated as early as January via courtship, pair bonding, and territory establishment. The breeding season normally ends approximately August 31 when the fledglings have begun to disperse from the immediate nest site. One to three eggs are laid in a stick platform nest 50 to 200 feet above the ground and usually below the tree crown (Zeiner *et al*., 1990). Incubation may begin in late February to mid-March, with the nestling period extending to as late as the end of June. From June thru August, the chicks remain restricted to the nest until they are able to move around within their environment.

Nesting territories are normally associated with lakes, reservoirs, rivers, or large streams and are usually within two miles from water bodies that support an adequate food supply (Lehman, 1979; U.S. Fish and Wildlife Service, 1986). Most nesting territories in California occur from 1000 to 6000 feet elevation, but nesting can occur from near sea level to over 7000 feet (Jurek, 1988). The majority of nests in California are located in ponderosa pine and mixed-conifer stands and nest trees are most often ponderosa pine (*Pinus ponderosa*) (Jurek, 1988). Other site characteristics, such as relative tree height, tree diameter, species, position on the surrounding topography, distance from water, and distance from disturbance, also appear to influence nest site selection (Lehman *et al*., 1980; Anthony and Isaacs, 1981). Bald eagles often construct up to five nests within a territory and alternate between them from year to year (U.S. Fish and Wildlife Service, 1986). Nests are often reused and eagles will add new material to a nest each year (DeGraaf *et al*., 1991). Lehman (1979) found that 73 percent of nest sites surveyed were within one-half mile of a waterbody, 87 percent within 1 mile, and 100 percent within 2 miles.

Isolation from disturbances is an important feature of bald eagle wintering habitat. Wintering habitat is associated with open bodies of water, with some of the largest wintering bald eagle populations in the Klamath Basin (Detrich, 1981, 1982). Smaller concentrations of wintering birds are found at most of the larger lakes and man-made reservoirs in the mountainous interior of the northern half of the state and at scattered reservoirs in central and southwestern California. Some of California's breeding birds winter near their nesting territories.

Historic and Current Range: The bald eagle once nested throughout much of North America near coasts, rivers, lakes, and wetlands. The species experienced population declines throughout most of its range, including California, due to exposure to environmental contaminants, habitat loss and degradation, shooting, and other disturbances (Detrich, 1981; Stalmaster *et al*., 1985; U.S. Fish and Wildlife Service, 1986). The species' status has improved since the initial listing under the Endangered Species Act.

The bald eagle continues to be found throughout much of North America and breeds or winters throughout California, except in the desert areas (Zeiner *et al*., 1990; DeGraaf *et al*., 1991). In California, most breeding occurs in Butte, Lake, Lassen, Modoc, Plumas, Shasta, Siskiyou, and Trinity Counties (Zeiner *et al*., 1990). California's breeding population is resident year-long in most areas as the climate is relatively mild (Jurek, 1988). Between mid-October and December,

migratory bald eagles arrive in California from areas north and northeast of the state. The wintering populations remain in California through March or early April.

Rangewide Trends and Current Threats: Though the construction of dams has limited the range of anadromous fish, an important historic bald eagle prey base, reservoir construction and the stocking of fish in reservoirs in the west have provided bald eagles with habitat for population expansion (Detrich, 1981; U.S. Fish and Wildlife Service, 1986). The Califomia bald eagle nesting population has increased in recent years from under 30 occupied territories in 1977 to 151 occupied territories in 1999 (Jurek, 2000). Based upon annual wintering and breeding bird survey data, it is estimated that between 100-300 bald eagles winter on National Forests in the Sierra Nevada, and at least 151-180 pairs remain year-round to breed (U.S. Forest Service, 2000). Most of the breeding population is found in the northern third of the state, primarily on public lands. Seventy percent of nests surveyed in 1979 were located near reservoirs (Lehman, 1979) and this trend has continued, with population increases occurring at several reservoirs since the time of that study.

The Bald Eagle Recovery Plan identifies reasons for the decline of the bald eagle, and states that habitat loss is the most important long-term threat to bald eagle populations. Other threats to the bald eagle include recreational development and human activities affecting the suitability of breeding, wintering, and foraging areas. Bald eagles are susceptible to disturbance by human activity during the breeding season, especially during egg laying and incubation, and such disturbances can lead to nest desertion or disruption of breeding attempts (U.S. Fish and Wildlife Service, 1986). Types of disturbance include recreational activities, fluctuating fish populations and availability of roost trees as a result of reservoir level fluctuations, wild fire, fragmentation of habitat, home sites, campgrounds, mines, timber harvest, and roads. Human activities are more likely to disturb bald eagles when located near roosting, foraging, and nesting areas (Stalmaster and Kaiser, 1998; Stalmaster *et al*., 1985; U.S. Fish and Wildlife Service, 1986).

Evaluation Results: For this effort, a weighted risk approach was taken to determine the appropriate eagle diet for calculation of wildlife values, based on the highest trophic level composition reasonably likely to occur, from the predominant habitat type characteristic of California's breeding bald eagles. In effect, this diet represented the greatest potential for dietary methylmercury exposure in bald eagles. Although alternate diets with higher trophic level compositions could be hypothesized, the diet for this effort was determined using a robust dataset for breeding California eagles.

Results of the analyses performed indicate that applying the human health TRC under the Average Concentration TL Approach is likely to result in dietary exposure that may place bald eagles at risk for adverse effects from methylmercury toxicity. The eagle's dietary concentration (DC) of methylmercury expected from the trophic level concentrations under this approach would be more than 230 percent of the eagle's calculated WV (DC - 0.431 mg/kg, WV - 0.184 mg/kg) (see Table 5). While the extent of any potential adverse effects from this DC cannot be quantified, the degree of WV exceedance suggests a high probability that dietary methylmercury

exposure from the TRC could reach a level at which adverse effects to bald eagles may be expected.

In contrast, the DC expected from the concentrations under the Highest TL Approach (DC - 0.196 mg/kg) would be less than 10 percent above the eagle's WV (see Table 7). Given the small differential between the two values, and a recognition of the various uncertainties and assumptions (*e.g.*, LOAEL-to-NOAEL extrapolation, allometric-derived FIR) inherent in the methodology, it is reasonable to conclude that dietary exposure resulting from applying the TRC under the Highest TL Approach should not place bald eagles at risk for adverse effects from methylmercury toxicity.

IX. EVALUATION RESULTS SUMMARY

IX.A. Average Concentration Trophic Level Approach

Based on the analyses conducted for this evaluation, applying the TRC with the estimated trophic level methylmercury concentrations under the Average Concentration TL Approach may be sufficiently protective for only two of the seven species considered: southern sea otter and Western snowy plover. The five other species examined (California least tern; California, light-footed, and Yuma clapper rails; bald eagle) would likely have dietary exposures under this approach that may place them at risk for adverse effects from methylmercury toxicity. The California clapper rail would not have been considered at risk under this approach if the WV generated with the UF_A of 1 was appropriate to represent the rail's sensitivity to methylmercury toxicity, relative to mallard ducks. However, the parallel evaluation discussed previously demonstrated that the WV generated with the UF_A of 3 was more appropriate for this subspecies, resulting in the conclusion that California clapper rails would also likely have dietary exposures that may place them at risk under this TL approach.

IX.B. Highest Trophic Level Approach

This approach, with its lower estimated trophic level methylmercury concentrations, would provide a greater degree of protection than the prior alternative. Applying the TRC under the Highest TL Approach should be sufficiently protective for four of the seven species considered: southern sea otter, California clapper rail, Western snowy plover, and bald eagle. At this time, no conclusion can be drawn regarding the light-footed clapper rail. If this subspecies' sensitivity to methylmercury is the same as the California clapper rail (*i.e.*, the alternative WV generated with the UF_A of 3 is appropriate), and the analysis of its dietary composition is correct, the light-footed rail would likely have dietary exposures under this approach that may place them at risk. However, if other biological characteristics (*e.g.*, a greater ability to detoxify ingested methylmercury, lower diet-to-egg transfer efficiency) indicate the WV generated with the UF_A of 1 is more appropriate for the light-footed rail, the evaluation results suggest this TL approach should be sufficiently protective for this subspecies. Further research is required to definitively answer these questions. The evaluation for the Yuma clapper rail, regardless of the WV used in

the analysis, indicates this subspecies would likely have a dietary exposure under this approach that may place it at risk for adverse effects from methylmercury toxicity. The same questions surrounding relative sensitivity apply to this subspecies, and research should be initiated to answer these questions and determine appropriate trophic level methylmercury concentrations to provide sufficient protection against toxicity. Finally, although methylmercury concentrations for all three trophic levels are expected to be substantially lower under this approach, the estimated trophic level 3 concentration of 0.075 mg/kg would still not be low enough to remove the potential risk of adverse effects from dietary methylmercury exposure for the California least tern. Because of the tern's small body size and its diet of exclusively trophic level 3 fish, this species may be at an elevated risk from methylmercury toxicity.

X. CONSIDERATION OF OTHER TAXONOMIC GROUPS

As explained previously in this document, the evaluation of the TRC's potential to adversely affect federally listed species in California was conducted with the assumption that upper trophic level wildlife species (*i.e.*, piscivorous or omnivorous birds and mammals) would have the greatest inherent risk from methylmercury exposure, due to methylmercury's propensity to bioaccumulate and biomagnify as it moves upward through aquatic food chains. However, there are numerous other listed species in California to consider (see Appendix) which may be adversely affected by the methylmercury TRC. Once the TRC's protectiveness was evaluated for the upper trophic level birds and mammals, the scientific literature was reviewed to assess whether the methylmercury concentrations expected under each TL approach may be protective for the remaining taxonomic groups.

X.A. Fish

The methodology employed for birds and mammals in this effort was based on an assessment of potential toxicity through ingestion of methylmercury-contaminated fish, shellfish, and other aquatic organisms. For fish, assessment of risk from the TRC was based solely on the potential for adverse effects associated with the tissue methylmercury concentrations expected under each of the TL approaches. It should be noted, however, that muscle tissue-bound concentrations represent the amount of methylmercury sequestered from dietary input over a fish's lifetime. It is possible that levels of circulatory methylmercury, reflective of current dietary exposure, may be responsible for any adverse effects. This possibility is due to the fact that re-mobilization of muscle-bound methylmercury may be negligible unless a reduction in available food necessitates catabolic utilization of muscle-bound proteins. However, until further work on circulatory methylmercury is conducted, muscle tissue concentrations remain the most appropriate indicator for evaluating the impact of the TRC on fish.

A great deal of research has been conducted over the years on the bioaccumulation of mercury by fish, providing data on fish tissue mercury concentrations associated with both overt and subtle toxicological effects (see reviews by: Wiener and Spry, 1996; Jarvinen and Ankley, 1999; Eisler,

2000; Wiener *et al*., 2002). Both Wiener *et al*. (2002) and Eisler (2000) examined the relationships between body burden and toxicological significance in several fish species. All of the overt effects concentrations presented were approximately an order of magnitude above even the highest concentration expected in trophic level 4 fish (0.66 mg/kg) when applying the TRC under the Average Concentration TL Approach.

Wiener *et al*. (2002) stated that, because of the high neurotoxicity of methylmercury, exposure levels causing more subtle adverse behavioral effects are likely much lower than those that would result in overt toxicity. These sublethal neurotoxic effects can impair the ability of fish to locate, capture, and ingest prey and to avoid predators. Unfortunately, studies that demonstrate these effects are generally based on waterborne concentrations of mercury, with few providing data on subsequent fish tissue levels.

Fjeld *et al*. (1998) demonstrated long-term impairment in feeding behavior of grayling (*Thymallus thymallus*) that had been exposed as eggs to waterborne methylmercuric chloride. The 3 year old grayling that exhibited impairment developed from yolk-fry with mercury concentrations as low as 0.27 mg/kg. The yolk-fry concentration of 0.27 mg/kg resulted from eggs in the treatment group exposed to 0.8 ug/L methylmercuric chloride, much higher than environmentally realistic waterborne levels. Compared to the control group, 3 year old fish from the 0.8 ug/L treatment group exhibited a 15 percent reduction in feeding efficiency and a 49 percent reduction in competitive feeding ability.

Based on limited data indicating that mercury concentrations in embryos of methylmercury-exposed brook trout are approximately 20 percent of that in the maternal axial muscle tissue, Fjeld *et al*. (1998) calculated that their lowest observed adverse effects concentration (LOAEC) for grayling yolk-fry (0.27 mg/kg) would translate to a maternal muscle tissue concentration of 1.35 mg/kg. This is double the concentration expected in trophic level 4 fish (0.66 mg/kg) under the Average Concentration TL Approach. Extrapolating a maternal muscle methylmercury concentration from a waterborne-induced embryolarval concentration is tenuous for two reasons: the outermost membrane of fish eggs may retard the uptake of both inorganic and methylmercury from the water column, and maternally-derived egg concentrations may be more associated with dietary intake during egg formation rather than existing muscle-bound concentrations (Latif *et al*, 2001; Hammerschmidt *et al*., 1999). However, Hammerschmidt *et al*. (1999) sampled wild yellow perch (*Perca flavescens*) from four seepage lakes in northern Wisconsin and found that the concentration of total mercury in eggs ranged from 20 to 5 percent of the concentration in the maternal carcass. Using this range of concentration ratios, the embryolarval LOAEC of 0.27 mg/kg could translate to maternal muscle tissue concentrations from 1.35 mg/kg (5:1 adult-egg ratio) to 5.4 mg/kg (20:1 adult-egg ratio).

These data suggest that the adult fish tissue concentrations expected under either trophic level approach would result in egg and embryolarval concentrations substantially below the LOAEC (0.27 mg/kg) reported for grayling. How far below the LOAEC depends on the trophic level approach used and assumptions regarding the adult-egg concentration ratio. By using

conservative assumptions (*i.e.*, 5:1 adult-egg ratio), the tissue concentration expected for trophic level 4 fish (0.66 mg/kg) under the Average Concentration Trophic Level Approach would result in an egg concentration of 0.132 mg/kg, approximately half the grayling LOAEC. Applying the same adult-egg concentration ratio to the tissue concentration expected for trophic level 4 fish (0.3 mg/kg) under the Highest Trophic Level Approach would result in an egg concentration of 0.06 mg/kg, approximately one-fifth the grayling LOAEC. While Fjeld *et al*. (1998) made no conclusions regarding a NOAEC (no observed adverse effects concentration) in their experiment, they did not observe any feeding behavior impairment in their lowest dose treatment group. This treatment group was exposed to a waterborne methylmercury concentration of 0.16 ug/L, and the resulting yolk-fry had a mercury concentration of 0.09 mg/kg wet weight. Although it can be determined with some certainty that the egg mercury concentration (0.06 mg/kg) estimated from the trophic level 4 fish concentration under the Highest Trophic Level Approach would not result in feeding behavior impairments in grayling, the same cannot be said for the egg mercury concentration (0.132 mg/kg) estimated with the Average Concentration Trophic Level Approach. The relative magnitude of effects seen at the 0.27 mg/kg LOAEC for grayling yolk-fry (*i.e.*, 49% reduction in competitive feeding ability) suggests the potential for adverse effects may not be completely removed even when eggs have mercury concentrations around 0.132 mg/kg.

In a more recent study, Webber and Haines (2003) examined the potential for behavioral alterations in fish with environmentally realistic tissue methylmercury concentrations. They concluded that alterations in predator-avoidance behaviors in golden shiners (*Notemigonus crysoleucas*) with environmentally realistic tissue methylmercury concentrations (0.536 mg/kg) may increase vulnerability to predation. Golden shiners should be considered trophic level 3 fish, due to their natural diet of zooplankton and aquatic insects (Moyle, 2002). The effects concentration of 0.536 mg/kg is well above the concentrations expected for trophic level 3 fish under either of the TL approaches evaluated here (0.165 mg/kg - Average Concentration Trophic Level Approach; 0.075 mg/kg - Highest Trophic Level Approach). These data suggest that alterations in predator-avoidance behaviors would not be expected in trophic level 3 fish if the TRC is applied under either approach. Although these data do not allow for any definitive conclusions regarding adult trophic level 4 fish, the possibility that a tissue concentration of 0.536 mg/kg could result in adverse behavioral effects suggests that the more conservative trophic level concentrations expected from the Highest Trophic Level Approach may be warranted in order to ensure adequate protection for federally listed fish species.

In addition to the potential for sublethal neurotoxic effects, Wiener and Spry (1996) concluded that reduced reproductive success in wild fish populations is the most plausible adverse effect expected from environmentally realistic concentrations. They noted that methylmercury can impair reproduction by affecting gonadal development or spawning success in adult fish, or by reducing egg hatching success and embryolarval health and survival. Mercury concentrations affecting both hatching success and embryolarval health are directly linked to the adult female body burden (circulatory and/or muscle-bound concentrations), as the majority of mercury in developing eggs is methylmercury derived through maternal transfer (Wiener *et al*., 2002). However, only a small fraction of the total muscle-bound methylmercury is transferred to the egg

mass and eliminated during spawning (Wiener *et al*., 2002; Hammerschmidt *et al*., 1999). Several key studies on mercury and reproductive endpoints are discussed below.

Birge *et al*. (1979) describe the results of two experiments involving embryolarval stage rainbow trout (*Salmo gairdneri*) exposed to waterborne inorganic mercury. In one study, trout eggs exposed to approximately 100 ng/L exhibited reduced survival after four days, with 100 percent mortality after eight days (at approximately 200 - 300 ng/L). After days four and seven of the experiment, mercury content of the eggs was approximately 0.068 and 0.097 mg/kg, respectively. In a second study, trout eggs were placed in aquaria with mercury-enriched sediment and clean water. There was a 28 percent reduction in hatching success and a 49 percent reduction in 10-day survival with a sediment mercury concentration of approximately 1.05 mg/kg. In this treatment group, mercury in the water column was approximately 150 ng/L, and tissues from the hatched larvae contained approximately 0.041 mg/kg.

Both of the above experiments demonstrated substantial adverse effects at low embryolarval inorganic mercury concentrations. If the adult-egg concentration ratios from the previous discussion on grayling (Fjeld *et al*., 1998) were applied to these inorganic mercury concentrations in embryolarval rainbow trout (*e.g.*, 0.04 mg/kg larval concentration and 5:1 adult-egg ratio), adult muscle tissue concentrations as low as 0.2 mg/kg could be associated with severe reproductive effects. However, the adult-egg ratios are based on maternal transfer of accumulated mercury, which is predominantly methylmercury in both the adult tissue and the developing eggs (Wiener *et al*., 2002). The mechanisms of mercury bioaccumulation and maternal transfer prevent a reliable extrapolation of adult fish tissue methylmercury concentrations from concentrations of inorganic mercury in eggs or larvae. In addition, the waterborne concentrations of inorganic mercury (100 - 150 ng/L) used to achieve the observed effects concentrations in embryolarval rainbow trout are substantially above all but the most highly polluted natural waters (Wiener and Spry, 1996). These high waterborne concentrations necessary to see adverse effects in eggs may be due to the apparent ability of the outermost membrane on fertilized fish eggs to retard the uptake of both inorganic and methylmercury from the surrounding water column into the developing embryo (Hammerschmidt *et al*., 1999). In order to accurately assess adult fish muscle tissue levels associated with embryolarval effects, the effects should be related to maternally-derived methylmercury concentrations.

Matta *et al*. (2001) examined the effects of dietary methylmercury on reproduction and survival in three generations of mummichogs (*Fundulus heteroclitus*). Treatment groups were fed methylmercuric chloride-contaminated fish food until four target tissue concentrations were reached (0.2, 0.5, 1.0, and 11.0 mg/kg). Although adverse reproductive effects were observed in this study, they were only manifested in F_1 generation offspring of the treatment group containing tissue methylmercury concentrations of 11 and 12 mg/kg in males and females, respectively. These values are substantially higher than any of the trophic level concentrations expected with the TRC. Of greater importance from this study are the data indicating a significant increase in male mortality in the 0.5 mg/kg tissue concentration treatment group. Survival was somewhat reduced in the 0.2 mg/kg treatment group, but not significantly. However, the almost 50 percent

reduction in the 0.5 mg/kg group indicates significant mortality may occur at concentrations between 0.2 and 0.5 mg/kg. The mummichog is a trophic level 3 fish from the eastern seaboard, similar to the California killifish (*Fundulus parvipinnis*). Although the tissue concentrations associated with increased male mortality from this study (0.2 - 0.5 mg/kg) are considerably higher than the TL3 concentration (0.075 mg/kg) expected by applying the TRC under the Highest Trophic Level Approach, they are close to the TL3 concentration (0.165 mg/kg) expected under the Average Concentration Trophic Level Approach.

The influence of mercury exposure on more subtle reproductive parameters in natural settings was examined by Friedmann *et al*. (1996a). Two indices of gonadal function, gonadosomatic index (GSI) and gonadal sex steroid levels, were measured in northern pike (*Esox lucius*) collected from Lake Champlain, New York and Vermont, in 1994. Northern pike were selected because they are trophic level 4 fish, with a greater degree of mercury bioaccumulation than lower trophic level fish. The GSI was determined by the ratio of gonadal weight to total body weight. The mean total mercury concentration in muscle from the 14 fish sampled was 0.325 mg/kg (range: 0.117 - 0.623 mg/kg). The means for males (n = 7) and females (n = 7) were 0.347 and 0.303 mg/kg, respectively. The researchers found no significant correlation between mercury content, GSI, and gonadal sex steroids, suggesting that mercury exposure in natural settings might not exert as dramatic an effect on teleost fish reproduction as indicated by earlier laboratory findings. However, the researchers raised the possibility that the mercury levels they observed might have a more subtle influence on reproductive physiology which could be detected given a larger sample size.

To evaluate this possibility, the same researchers (Friedmann *et al*., 1996b) conducted a dietary methylmercury feeding experiment with juvenile walleye (*Stizstedion vitreum*). After six months of dietary exposure, fish in the low- and high-mercury diet groups had mean total mercury tissue concentrations of 0.254 and 2.37 mg/kg, respectively. The results for the low-mercury diet group are most relevant to this TRC analysis, as the mercury concentration in the test fish (0.254 mg/kg) is of the same magnitude as the concentrations expected in trophic level 4 fish under either trophic level approach. No significant differences from controls were seen in this low-mercury group for growth and mortality rates. The mean GSIs of male and female fish from both dietary groups were lower than in fish from the control group, but the differences were not statistically significant in the analysis of variance (ANOVA). However, when combining data from the two dietary groups, the mean GSI of male fish fed either mercury-contaminated diet was significantly lower than in males fed the control diet. Also, male fish in both groups exhibited varying degrees of testicular atrophy, greater in the high-mercury group. Mean GSIs for female fish in either treatment group were not significantly different from controls. Levels of plasma cortisol, which is important for stress response and immune function in teleost fish, were significantly lower in low-mercury fish than in control group fish. The above findings suggested to the authors that methylmercury at environmentally realistic fish tissue levels (0.254 mg/kg) may adversely affect reproductive success by impairing testicular development in young teleost fish and may reduce juvenile survival by impairing immune function.

However, in another study examining growth and reproductive endpoints in wild populations of mercury-contaminated fish, Friedmann *et al*. (2002) presented conflicting conclusions. Fifty-two male largemouth bass (*Micropterus salmoides*) were collected from three New Jersey water bodies of varying mercury contamination. Mean total mercury concentrations in muscle tissue were 0.30 mg/kg (Assunpink Lake), 1.23 mg/kg (Manasquan Reservoir), and 5.42 mg/kg (Atlantic City Reservoir). No significant differences between the three lakes were found for body weight, length, condition factor, or GSI. Also, no significant relationship was found between muscle mercury content and adrenocortical function, indicated by interrenal nuclear diameter and serum cortisol levels following stress. Liver somatic index (LSI) was significantly lower in fish from the Atlantic City Reservoir compared to the other two lakes, but this reduction could not be definitively correlated with mercury concentrations. The elevated mercury levels in fish from the Atlantic City Reservoir may have altered androgen profiles, as evidenced by greater levels of serum 11-ketotestosterone, but no cause-effect relationship could be established. Based on the above findings, the authors concluded that elevated mercury levels in fish (*i.e.*, as high as 5.42 mg/kg) do not substantially decrease indicators of general and reproductive health (*i.e.*, GSI). This finding is in contrast to the previous dietary mercury study with juvenile walleye which indicated that an even lower muscle concentration (2.37 mg/kg) was associated with impaired gonadal development (Friedmann *et al*., 1996b). As an explanation for this apparent discrepancy, Friedmann *et al*. (2002) pointed to findings that wild fish populations exposed to toxicants in their environment can develop adaptations that allow them to live in more polluted sites than are predicted with laboratory models. In further support of this explanation, the authors cite the observation by Friedmann *et al*. (1996a) that a correlation between muscle mercury content and reduced GSI did not exist in Lake Champlain northern pike.

Latif *et al*. (2001) collected female walleye during two successive spawning seasons from one mercury-contaminated lake and two relatively pristine lakes in Canada. Mean total mercury concentrations in muscle tissue, in mg/kg, were 0.182 (Lake Winnipeg), 0.194 (Lake Manitoba), and 2.701 (Clay Lake). Mean methylmercury concentrations in eggs (mg/kg), converted from reported dry weight concentrations assuming an 85 percent moisture content, were approximately 0.001 (Lake Manitoba), 0.002 (Lake Winnipeg), and 0.148 (Clay Lake). In addition to any maternally transferred methylmercury, eggs and subsequent larvae were then exposed to varying concentrations of waterborne methylmercury. The experimental results demonstrated a significant decline in hatching success and embryonic heart rate with increasing exposures of waterborne methylmercury, for all three lake stocks. However, after statistically adjusting for waterborne methylmercury effects, the maternally transferred methylmercury in eggs was not significantly correlated with either hatching success or embryonic heart rate. The authors noted that hatching success in eggs from Clay Lake females declined with increasing egg methylmercury concentrations, although the trend was not significant, and suggested that a larger sample size may reveal statistically significant declines. For the purposes of this evaluation, the data from this study indicate that fish tissue methylmercury concentrations in trophic level 4 fish (0.182, 0.194 mg/kg) similar to those expected with the TRC should not result in maternally deposited egg concentrations associated with reduced hatching success.

The effects of dietary methylmercury on multiple reproductive endpoints was also examined by Hammerschmidt *et al*. (2002). Using fathead minnows (*Pimephales promelas*), the researchers measured gonadal development of males and females, spawning success, days to spawning, reproductive effort of females, developmental success of embryos, hatching success of embryos, survival of larvae, and growth of larvae. No reductions in growth or survival were seen in adult fish from any of the treatment groups, regardless of the tissue concentrations. Developmental and hatching success of embryos were not measurably affected by mercury concentrations in either the diets or bodies of parental fish. Similarly, larval survival and growth were not correlated with dietary or tissue methylmercury concentrations. However, in one of the treatment groups, female fish fed the same diet during Phases 1 and 2 (continuous exposure) exhibited reduced gonadal development (based on GSI) with increasing body burden mercury concentrations. No threshold for this effect was presented, but the whole body tissue concentration from the low dose group was approximately 0.68 mg/kg in females (converted from reported dry weights assuming 80% moisture in whole body). The reduced GSI in these fish led to lower egg production (average daily number of eggs laid per gram of female carcass) with increasing mercury concentrations in the adult tissues. Fish fed the same diet during Phases 1 and 2 also exhibited reduced spawning success compared to fish fed the control diet. Male and female fish fed the low dose diet showed an average tissue concentration of 0.625 mg/kg, and had a spawning success rate of only 46 percent. Fish fed the control diet had an average tissue concentration of 0.08 mg/kg, and had a spawning success rate of 75 percent. In fish fed the continuous exposure diets, the number of days to spawning increased with increasing tissue mercury concentrations. In females, days to spawning was also inversely related to gonadal development.

The tissue concentrations in fish fed the low dose diet (average 0.625 mg/kg) during Phases 1 and 2 were substantially above the levels expected for trophic level 3 fish when applying the TRC under either trophic level approach. However, the 0.625 mg/kg average value is similar to the concentration expected in trophic level 4 fish (0.66 mg/kg) under the Average Concentration Trophic Level Approach. Based on the fathead minnow findings described above, Hammerschmidt *et al*. (2002) concluded that methylmercury decreased reproduction in adult fathead minnows at dietary concentrations realistically encountered by predatory fishes in mercury contaminated waters, with the implication that exposed fish populations could be adversely affected by this reproductive impairment.

None of the data examined for this evaluation provided definitive answers regarding the level of protection for fish afforded by the TRC. The trophic level methylmercury concentrations expected from applying the TRC under both trophic level approaches appear to be well below observed adverse effects concentrations described in the scientific literature. However, the trophic level concentrations expected under the Average Concentration Trophic Level Approach, which are higher than those under the Highest Trophic Level Approach, are much closer to these adverse effects concentrations. Although the best currently available data suggest that the TRC would be sufficiently protective of listed fish, regardless of the trophic level approach used, the increasing emphasis on examining more subtle methylmercury-induced effects may reveal even

lower tissue-based threshold effects concentrations.

X.B. Reptiles and Amphibians

Evaluating the TRC with respect to reptile and amphibian species was more problematic than the evaluation for fish, birds, and mammals. The TRC was developed as a methylmercury limit in the edible tissues of fish and shellfish. The protectiveness of the TRC could then be evaluated for fish, based on toxicity associated with various fish tissue concentrations, or for piscivorous and omnivorous birds and mammals, based on the ingestion of methylmercury contaminated organisms. An evaluation for reptiles and amphibians can be based on ingestion if the species of concern feeds primarily on aquatic organisms and if there are sufficient data to establish reference doses, food ingestion rates, and dietary composition. If these species of concern do not feed on aquatic organisms, a risk assessment based solely on toxicity endpoints associated with known tissue mercury concentrations may be performed. However, this type of assessment cannot be used to evaluate the TRC, as there is currently no reliable way to compare tissue mercury concentrations in reptiles and amphibians with the various trophic level fish tissue concentrations expected from the two approaches. Too little is presently known about mercury bioaccumulation in reptiles and amphibians to allow for any comparative risk prediction capability based on bioaccumulation in fish. The majority of the information presented below on the ecotoxicology of metals in reptiles and amphibians is from a comprehensive review by Linder and Grillitsch (2000).

No reptile mortality due to metal intoxication has ever been reported (Linder and Grillitsch, 2000); however, relevant ecotoxicological data on the effects of mercury on reptiles is severely lacking. Of the available studies, most have focused on tissue metal concentrations in free-ranging animals without reference to the ambient conditions giving rise to those concentrations. However, studies showing the highest tissue levels of mercury and other metals were associated with areas apparently having a high degree of environmental contamination. Linder and Grillitsch (2000) reported that only a few studies examined laboratory exposure to a defined dose, and none of these involved mercury. In a later review, Campbell and Campbell (2001) reviewed 20 studies examining inorganic contaminants and snakes, and found one (Hopkins *et al*., 1999) that examined effects concentrations. Unfortunately, neither the Hopkins *et al*.(1999) study nor the follow-up study examining the effects of chronic dietary exposure to trace inorganic elements (Hopkins *et al*., 2002) involved mercury. The remaining 19 studies reviewed by Campbell and Campbell (2001) only examined mercury concentrations in snake tissues, with no connection to exposure or effects. Linder and Grillitsch (2000) found that the available data indicate reptiles in general do not biomagnify metals to an extent that would correspond to their trophic level. In one study comparing whole body mercury concentrations in biota from several trophic levels, Winger *et al*. (1984) reported mercury levels corresponding to trophic level, being consistently highest in water snakes (*Natrix* spp.) and little green herons (*Butorides virescens*). However, mercury levels in the garter snake (*Thamnophis sirtalis*) were among the lowest of several vertebrate species examined, with the highest levels in piscivorous birds (Dustman *et al*, 1972). Linder and Grillitsch (2000) also reported that the available literature appears to support

the hypothesis that reptiles exhibit a generally low sensitivity to metals. However, these authors caution against drawing definitive conclusions regarding reptiles and metal contaminants, due to the almost complete absence of toxicological research under fairly defined experimental conditions, and the absence of any information on embryotoxic potential.

The dietary habits of both snakes considered in this evaluation [San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) and giant garter snake (*Thamnophis gigas*)] indicate a strong dependence on aquatic ecosystems. The San Francisco garter snake is known to prey on red-legged frogs (*Rana aurora*), Pacific tree frogs (*Hyla regilla*), California newts (*Taricha torosa*), western toads (*Bufo boreas*), threespine stickleback (*Gasterosteus aculeatus*), and mosquitofish (*Gambusia affinis*) (U.S. Fish and Wildlife Service, 1985c). Known prey items of the giant garter snake include mosquitofish, common carp (*Cyprinus carpio*), Sacramento blackfish (*Orthodon microlepidouts*), and bullfrogs (*Rana catesbiana*) (U.S. Fish and Wildlife Service, 1999). It is reasonable to assume these snakes may also prey on other available fish and frog species.

These dietary habits clearly indicate that both snakes may be exposed to methylmercury through ingestion of fish and other aquatic-dependent prey. However, evaluating the effect of the TRC on these snakes based on ingestion of methylmercury contaminated prey is confounded by the lack of necessary data. Although it is possible to estimate a daily food ingestion rate for snakes from Nagy (2001) and to make assumptions regarding the trophic level composition of the diet, the existing toxicological data on snakes do not allow for determination of any reference dose. Without a scientifically determined effects concentration in snakes, no WVs can be generated. While the physiological similarities between birds and reptiles may suggest it is possible to take the avian test dose used in this effort, make certain assumptions regarding inter-taxonomic uncertainty, and then arrive at some reference dose and WVs for these snakes, any conclusions drawn from the subsequent evaluation of the TRC would be highly speculative. The combination of reptilian physiological and life history characteristics (*e.g.*, long life span, small home ranges, high trophic position, and ectothermic physiology) make such an extrapolation inappropriate (Hopkins *et al*., 2002). Nagy (2001) points out that the metabolic rate of reptiles results in daily food requirements drastically lower than both birds and mammals. A 1-kg reptile consumes only 9 percent of the amount eaten by a 1-kg bird and approximately 12 percent of the amount a 1-kg mammal requires. If snakes are no more sensitive to ingested methylmercury than are birds (*i.e.*, having the same reference dose), then the lower daily food ingestion rate resulting from the snake's metabolic needs might suggest that fish tissue methylmercury levels that are protective of birds should also be protective of snakes. Although the limited ecotoxicological data presented above may suggest that reptiles in general are less sensitive to methylmercury than other taxa, no definitive conclusions can be made regarding the protectiveness of the TRC for these species until dietary methylmercury effects concentrations can be established for snakes.

The toxicity of mercury has been studied to a much greater extent with amphibians than with reptiles. Most amphibian species have aquatic-dependent early life stages where exposure may be dominated by direct uptake of dissolved metals from water, while exposure through dietary

sources may become more predominant in the subsequent adult life stages (Linder and Grillitsch, 2000). The majority of available effects data for amphibians come from acute and chronic toxicity studies with early life stages of frogs, using waterborne concentrations of inorganic mercury (Linder and Grillitsch, 2000; U.S. Environmental Protection Agency, 1996; Birge *et al*., 1979). Lethality is the toxicological endpoint most commonly assessed in these studies, with the majority of embryo or larval LC50s (lethal concentration for 50% of test population) in the range of 10 - 100 ug/L (Linder and Grillitsch, 2000). It should be noted that several LC50s below 10 ug/L and above 100 ug/L have also been observed (Linder and Grillitsch, 2000; U.S. Environmental Protection Agency, 1996). Concentrations as low as 0.1 ug/L have resulted in up to 6 percent mortality of leopard frog (*Rana pipiens*) embryos (U.S. Environmental Protection Agency, 1996). Embryonic malformation is another commonly measured endpoint in mercury toxicity studies. Waterborne mercury concentrations associated with amphibian embryo malformations ranged from 2 - 75 ug mercuric chloride/L, with malformation rates ranging from 5 to greater than 10 percent (Birge *et al*., 1983).

Adverse effects have also been reported for amphibians exposed to methylmercuric chloride (U.S. Environmental Protection Agency, 1996). Concentrations of methylmercuric chloride between 0 - 4 ug/L resulted in an EC50 (effects concentration for 50% of test population) for embryo deformities in leopard frogs. No metamorphosis was seen in leopard frog tadpoles exposed to concentrations between 1 - 10 ug/L for 3 to 4 months. Greater than 10 percent deformity and mortality was observed in larvae of the African clawed frog (*Xenopus laevis*) exposed to 0.3 ug/L for more than 10 days.

Based on the limited data available, it appears that the early life stages of amphibians are the most sensitive to metal exposures (Linder and Grillitsch, 2000). All of the waterborne effects concentrations for mercury reported above are considerably higher than environmentally realistic levels. Although there will likely be a great deal of variation between water bodies within California, the waterborne concentrations of mercury associated with the TRC should be orders of magnitude below any of the effects concentrations described here. However, these water concentration toxicity data are insufficient to fully characterize risk from the TRC as they do not take into account dietary exposure in post-embryolarval stages or the potential for maternal transfer of bioaccumulated methylmercury into the eggs. Preliminary results from designed studies suggest that metals bioaccumulated into female amphibians may be depurated during egg development and laying (Linder and Grillitsch, 2000). This process, in combination with exposure through waterborne concentrations, could be toxicologically relevant for the embryolarval stages of amphibians.

Due to methylmercury's propensity to bioaccumulate throughout the lifetime of an animal that is dependent on the aquatic food chain, adverse effects in adult life stages may be possible from relatively low prey concentrations. Unfortunately, the effects of dietary exposure to methylmercury in later life stages of amphibians have not been adequately explored. The literature on the bioaccumulation of metals in amphibians is less developed than for reptiles, with only a few controlled experiments examining bioaccumulation from dietary sources (Linder and

Grillitsch, 2000). No data were found in the scientific literature specifically regarding mercury bioaccumulation in frogs, the only amphibian taxon considered in this evaluation of the TRC. However, the limited data on the uptake of metals by amphibians suggest that the bioaccumulation of methylmercury may be an important exposure pathway for frogs.

The single amphibian considered in this evaluation, the California red-legged frog (*Rana aurora draytonii*), feeds as an adult on both invertebrates and vertebrates. Vertebrate prey, such as the Pacific tree frog (*Hyla regilla*) and California mouse (*Peromyscus californicus*), can account for over half of the dietary biomass in large adults (U.S. Fish and Wildlife Service, 2002). It is not known how much of the frog's diet may be comprised of aquatic invertebrates, or whether small fish are ever consumed. The consumption of Pacific tree frogs may constitute an important methylmercury exposure pathway, if they are closely linked with a contaminated aquatic environment.

As discussed previously, the impact of the TRC can only be reliably evaluated for non-fish organisms if they feed on aquatic prey (*i.e.*, fish or aquatic invertebrates) and if there are sufficient data to determine an appropriate dietary test dose at which adverse effects in the organisms are observed. Although California red-legged frogs may consume substantial numbers of aquatic prey, the literature on amphibian ecotoxicology revealed no information indicating that any research has been done involving the effects of dietary exposure to mercury in amphibians (Linder and Grillitsch, 2000; U.S. Environmental Protection Agency, 1996; Birge *et al*., 1979). This lack of data eliminates the possibility of evaluating the TRC for red-legged frogs using a methylmercury ingestion approach.

The methodology used in this evaluation of the TRC is based on the assumption that upper trophic level wildlife species (*i.e.*, piscivorous and omnivorous birds and mammals) have the greatest inherent risk from exposure to methylmercury. No currently available information was found to contradict this assumption, although an increasing emphasis on ecotoxicological research with reptiles and amphibians may provide new data with which to compare these inter-taxonomic sensitivities. Consumption of aquatic organisms by the California red-legged frog and the two species of garter snakes may expose them to toxicologically relevant concentrations of methylmercury, although possibly less so than in those species (*e.g.*, piscivorous birds and mammals) with a greater daily dietary reliance on aquatic prey. The available scientific literature strongly suggests that both reptiles and amphibians can bioaccumulate methylmercury, although the degree to which this occurs has not been fully characterized. However, until the appropriate toxicological data are generated, no definitive conclusions can be drawn about the protectiveness of either TRC trophic level approach for the California red-legged frog, San Francisco garter snake, or giant garter snake.

XI. DISCUSSION

As explained previously, the objective of this effort was to evaluate whether promulgation of the EPA's human health criterion for methylmercury may affect any federally listed threatened or endangered species in California. To do this, a risk assessment methodology was developed and used to analyze the potential effect of the TRC on several of these listed species. The species selected for analysis were presumed to be at the greatest risk of dietary exposure, due to their high trophic position and/or dietary dependence on the aquatic ecosystem. The results of these analyses indicate that some of these species should be sufficiently protected against adverse effects from methylmercury toxicity, depending on the trophic level approach evaluated. For other species, the evaluation results suggest that the TRC may not be adequate to protect against adverse effects.

Risk assessments such as the one used in this effort are designed to gauge the *potential* for adverse effects. The WVs calculated in this document are assumed to represent protective dietary concentrations of methylmercury, at which no adverse effects are expected. Then, if the predicted DC value for any given species is at or below the corresponding WV, it may be concluded with reasonable confidence that adverse effects to that species are not likely to occur. In contrast, a DC value higher than the corresponding WV only results in a presumption of risk for adverse effects. This is due to the fact that WVs are derived from toxicity data for surrogate species, with various assumptions about interspecific sensitivities, dietary composition of the species of concern, and the use of uncertainty factors to estimate a dose at which no adverse effects should occur. Therefore, any presumption of risk for a species can only be definitively confirmed or dismissed by available scientific evidence that serves to remove these layers of uncertainty.

The Service's Environmental Contaminants Division believes the analyses presented in this document represent the most current state of knowledge regarding the risk to California's listed species from dietary methylmercury. The mammalian and avian test doses used in this effort, which serve as the toxicological foundation for this methodology, remain the best available benchmarks of effects concentrations for these taxonomic groups. Uncertainty factors have previously been applied to these test doses, initially for the GLI and then updated for the MSRC (U.S. Environmental Protection Agency, 1995d; 1997a, respectively), to establish reference doses for key piscivorous wildlife species at which no adverse effects would be expected. To date, no new evidence has been presented suggesting that the uncertainty factors used for this evaluation should be altered to establish higher reference doses for any of the species considered. In several cases, the dietary compositions used in species evaluations were based on limited empirical data; however, until new data are generated, these compositions remain the most reliable estimates. Finally, future controlled methylmercury dosing experiments with individuals of the species evaluated could potentially yield more accurate reference doses (*i.e.*, NOAELs); however, any such experiments are highly unlikely due to the regulatory status of these species as threatened or endangered.

For the reasons cited above, we believe the presumption of risk for certain species indicated by the results of our evaluation cannot presently be dismissed by the available scientific evidence. Those species for which the predicted DCs are significantly above the corresponding WVs (*i.e.*, >10% higher) would be considered at risk for adverse effects from methylmercury toxicity. Conclusions about the protectiveness of the TRC for each species, under both trophic level approaches evaluated, are summarized below in Table 8. These conclusions reflect the interpretation of the evaluation results by the Service's Environmental Contaminants Division only, and are not intended to represent the views of those EPA or Service scientists who helped develop the risk assessment methodology. In addition, these conclusions do not constitute the results of consultation under Section 7 of the ESA.

Table 8. Protectiveness of Tissue Residue Criterion for Seven California Species

Is the TRC Protective for...	Southern Sea Otter	Ca. Least Tern	Ca. Clapper Rail	Light-footed Clapper Rail	Yuma Clapper Rail	Western Snowy Plover	Bald Eagle
Under Average Concentration TL Approach?	Yes	**No**	Yes	**No**	**No**	Yes	**No**
- with Alternate WV Generated from UF_A of 3?	na	na	**No**	**No**	**No**	Yes	na
Under Highest TL Approach?	Yes	**No**	Yes	Yes	**No**	Yes	Yes
- with Alternate WV Generated from UF_A of 3?	na	na	Yes	**No**	**No**	Yes	na

Applying the TRC under the Average Concentration Trophic Level Approach would place five of the seven listed species at risk for adverse effects: California least tern; California, light-footed, and Yuma clapper rails; bald eagle. Only the southern sea otter and western snowy plover would be sufficiently protected under this approach. Applying the TRC under the Highest Trophic Level Approach would place two of the seven species, California least tern and Yuma clapper rail, at risk for adverse effects. The southern sea otter, California clapper rail, western snowy plover, and bald eagle should be sufficiently protected under this approach. No conclusions can be drawn at this time regarding the light-footed clapper rail, due to remaining uncertainty about this subspecies' sensitivity to methylmercury.

The two species determined to still be at risk under the Highest Trophic Level Approach are the California least tern and the Yuma clapper rail. As explained previously in this document, the methodology outlined in the Average Concentration Trophic Level Approach can be used to calculate the trophic level-specific methylmercury concentrations necessary to maintain any species' DC at or below its calculated WV. Using Equation 3 from this methodology and substituting any WV for the DC term, we can solve for the methylmercury concentration in trophic level 2 prey:

FDTL2 = WV / [(%TL2) + (%TL3 × MTL3) + (%TL4 × MTL3 × MTL4)]

Once the trophic level 2 concentration is calculated, the remaining trophic levels can be determined using our established food chain multiplier relationships:

FDTL3 = FDTL2 × MTL3
FDTL4 = FDTL3 × MTL4

Using the WVs determined for the least tern and Yuma clapper rail, along with the trophic level composition of their diets, the trophic level methylmercury concentrations required to maintain these WVs can be calculated (Table 9).

Table 9. Trophic Level Methylmercury Concentrations Calculated for California Least Tern and Yuma Clapper Rail

	California Least Tern (WV = 0.030 mg/kg)	Yuma Clapper Rail (WV generated with UF_A of 1 = 0.040 mg/kg)	Yuma Clapper Rail (WV generated with UF_A of 3 = 0.013 mg/kg)
FDTL2	0.005 mg/kg	0.009 mg/kg	0.003 mg/kg
FDTL3	0.030 mg/kg	0.053 mg/kg	0.017 mg/kg
FDTL4	0.120 mg/kg	0.210 mg/kg	0.068 mg/kg

Of the two approaches evaluated, the Highest Trophic Level Approach affords a greater degree of protection for California's listed bird and mammal species than the Average Concentration Trophic Level Approach. As stated previously, the best currently available data on mercury toxicity in fish suggest that the TRC under either approach should be sufficiently protective of all listed fish in California; however, the trophic level concentrations expected under the Average Concentration Trophic Level Approach would be much closer to observed adverse effects concentrations described in the scientific literature. Finally, although a lack of relevant data precludes any conclusions regarding the potential impact of the TRC on the reptile and amphibian species considered, the lower trophic level concentrations expected under the Highest Trophic Level Approach would afford a greater measure of protection than those expected under

the Average Concentration Trophic Level Approach. Based on the above conclusions, we believe that the TRC would not adequately protect all listed species in California; however, applying the TRC under the Highest Trophic Level Approach would reduce the number of species at risk.

Finally, it must be noted that the risk assessment methodology presented in this document was not applied to any wildlife species other than the federally listed species from the Appendix. However, other non-listed wildlife may be potentially at risk under the TRC, due to their dietary dependence on aquatic ecosystems. Using the same approach followed in this effort, regulatory agencies should be able to determine whether concentrations of methylmercury in fish tissue under the TRC may also pose a risk to these non-listed wildlife species.

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XII.B. PERSONAL COMMUNICATIONS

Heinz, G.H. 2002, 2003. Wildlife Biologist. U.S. Department of the Interior, U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

Schwarzbach, S.E. 2003. Fish and Wildlife Administrator. U.S. Department of the Interior, U.S. Geological Survey, Western Ecological Research Center Headquarters, Sacramento, California.

APPENDIX Federally Listed Threatened (T) and Endangered (E) Species in California Potentially At Risk From Methylmercury in Aquatic Ecosystems

Birds:
(T) Bald Eagle
(E) California Least Tern
(E) California Clapper Rail
(E) Yuma Clapper Rail
(E) Light-Footed Clapper Rail
(T) Western Snowy Plover

Amphibians and Reptiles:
(T) California Red-Legged Frogs
(T) Giant Garter Snake
(E) San Francisco Garter Snake

Fish:
(T) Coho Salmon (and Critical Habitat)
- (T) Central CA (and Critical Habitat)
- (T) So. OR/Northern CA (and Critical Habitat)

(T&E) Chinook Salmon (and Critical Habitat)
- (T) Central Valley Spring ESU (and Critical Habitat)
- (T) CA Coast ESU (and Critical Habitat)
- (E) Winter Run (and Critical Habitat)

(T&E) Steelhead Trout (and Proposed Critical Habitat and Critical Habitat)
- (PT) Northern CA ESU
- (T) Central CA Coast ESU (and Critical Habitat)
- (T) Central Valley ESU (and Critical Habitat)
- (T) South Central CA Coast ESU (and Critical Habitat)
- (E) Southern CA ESU (and Critical Habitat)

(T) Little Kern Golden Trout (and Critical Habitat)
(T) Paiute Cutthroat Trout
(T) Lahonton Cutthroat Trout
(E) Bonytail Chub (and Critical Habitat)
(E) Unarmored Threespine Stickleback (and Proposed Critical Habitat)
(E) Shortnose Sucker (and Proposed Critical Habitat)
(E) Lost River Sucker (and Proposed Critical Habitat)
(T) Sacramento Splittail

Mammals:
(T) Southern Sea Otter

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Critical Perspectives

CRITICAL PERSPECTIVES ON MERCURY TOXICITY REFERENCE VALUES FOR PROTECTION OF FISH

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Abstract: Environmental management decisions at mercury-contaminated sediment sites are predicated on the understanding of risks to various receptors, including fish. Toxicity reference values (TRVs) for interpreting risks to fish have been developed to assess mercury concentrations in fish or fish prey. These TRVs were systematically evaluated based on several lines of evidence. First, their conceptual basis and specific derivation were evaluated, including a close review of underlying toxicity studies. Second, case studies were reviewed to investigate whether TRVs are predictive of effects on fish populations in the field. Third, TRVs were compared with available information regarding preindustrial and present-day background concentrations of mercury in fish. The findings show that existing TRVs are highly uncertain, because they were developed using limited data from studies not designed for TRV derivation. Although field studies also entail uncertainty, several case studies indicate no evidence of adverse effects despite mercury exposures that exceed the available TRVs. Some TRVs also fall within the range of background mercury concentrations in predatory or prey fish. Lack of information on the selenium status of mercury-exposed fish is a critical confounding factor, and the form of methylmercury used in toxicity testing may also contribute to differences between TRV-based predictions and field observations of mercury effects on fish. On balance, the available information indicates that several of the TRVs reviewed are lower than necessary to protect fish populations. The 20% effect concentration from a previously published dose–response analysis appears closer to an effect threshold, based on available laboratory data. Additional research is needed to provide a stronger basis to establish dose–response relationships for mercury effects on fish. *Environ Toxicol Chem* 2016;35:529–549. © 2016 SETAC

Keywords: Methylmercury Reproductive toxicity Population-level effects Ecological risk assessment Dose–response modeling Tissue residue-effect relationships

INTRODUCTION

Numerous studies have investigated mercury bioaccumulation in fish [1–3], often focusing on fish as a vector for mercury exposure of humans and wildlife. Studies of mercury effects on fish themselves historically lagged behind assessments of fish consumers [4] but have been implemented more frequently in recent years [5]. Many of these studies have focused on biochemical and histological responses of fish to mercury [5,6], although a few studies have directly evaluated reproductive success or effects on fish populations. In recognition of the need to consider protection of fish populations in environmental decision-making, scientists have proposed toxicity reference values (TRVs) for mercury effects on fish based on previously published studies (Table 1).

Environmental management decisions at mercury-contaminated sediment sites entail many considerations, typically including the assessment of risks to fish, as well as risks to humans, aquatic-feeding wildlife, and benthic invertebrates. Depending on site characteristics, perceived risks to fish—based on comparisons with TRVs—can be among the controlling factors to determine sediment cleanup goals. Mercury TRVs for fish also may influence risk-based source control efforts for air and water emissions.

Likely reflecting the application of the precautionary principle to compensate for uncertainty, ecotoxicity data and results very often are interpreted conservatively during the derivation of TRVs. On the other hand, as articulated by US Environmental Protection Agency (USEPA) [7], cleanup actions to address ecological risks should not do more ecological harm than good, recognizing that cleanup actions can cause habitat disruption along with other unintended consequences (e.g., carbon emissions, contaminant suspension and release, or community quality of life impacts during construction). Toward that goal, risk assessors and managers should strive to base decisions on TRVs that are sufficiently protective without being overly protective. Given the implications of mercury TRVs for fish on broader environmental management goals, a critical review is warranted.

The present TRV review considers several lines of evidence. First, we evaluate the conceptual basis and specific derivation of prominent TRVs, including a close review of underlying laboratory toxicity studies. We also consider additional laboratory studies, most of which were published after the TRVs were developed. Second, we investigate whether the laboratory-based TRVs are predictive of effects on fish populations in the field, through a review of 8 case studies. Third, we compare the TRVs with available information regarding preindustrial and present-day background concentrations of mercury in fish. This approach offers utility beyond a simple critique of TRV developers' data

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Table 1. Mercury toxicity reference values for protection of fish

TRV source	TRV (mg/kg, wet wt)	Description/basis
Adult whole-body concentration		
Beckvar et al. [8]	0.2	Tissue TEL: Geometric mean of LOAELs (15th percentile) and NOAELs (50th percentile); includes effects on reproduction, growth, development, and behavior
Dillon et al. [9]	0.77	EC20 calculated from multispecies dose–response curve; effects on reproduction and survival
Sandheinrich and Wiener [5]	0.3–0.5	Onset of effects on biochemistry, cells/tissues, and reproduction
Prey tissue concentration		
Depew et al. [16]	0.04	Reproductive effect threshold, highest NOAEL below lowest LOAEL
Depew et al. [16]	0.06	Biochemical effect threshold, highest NOAEL below lowest LOAEL
Depew et al. [16]	0.50	Behavioral effect threshold, highest NOAEL below lowest LOAEL
Depew et al. [16]	1.44	Growth effect threshold, highest NOAEL below lowest LOAEL
Depew et al. [16]	2.80	Mortality threshold, TEL

TRV = toxicity reference value; TEL = threshold-effect level; LOAEL = lowest-observed-adverse-effect level; NOAEL = no-observed-adverse-effect level; EC20 = 20% effect concentration.

interpretation, by identifying independent datasets that can be used to test TRV-based predictions. Furthermore, our review of field case studies provides a unique compilation that may be useful to researchers and risk assessors. Based on our review, we also offer recommendations for research to support future development of improved TRVs for mercury effects on fish. In the interest of maintaining the focus in this analysis on direct effects on fish, this review does not attempt to put the TRVs that are protective of fish into a broader context of TRVs or guidelines that are protective of people or wildlife that consume fish; as noted above, fish consumers historically have been the focus of work to characterize concentrations of mercury in fish tissue.

TRV DERIVATION

In this section, we present the available mercury TRVs that have been derived for protection of fish and the derivation of those TRVs, followed by a critical review of fish tissue TRVs, fish tissue dose–response relationships, and fish prey TRVs. To our knowledge, the TRV sources reviewed here represent the only originally derived mercury TRVs for protection of fish published in the last 15 yr on the basis of adult or juvenile fish tissue or prey concentrations. Although TRVs are also available on the basis of early life stage tissue concentrations [8,9], such TRVs are not considered in this review for 2 reasons. First, mercury monitoring and exposure assessment is generally conducted using adult fish tissue analyses, and mercury concentrations in fish early life stages are not comparable to those in adult fish. Second, comparability of mercury concentrations is limited even among early life stage tissue analyses, because chemical concentrations in fish larvae and fry change rapidly as a result of growth dilution [10]. Thus, applicability of early life stage tissue-based TRVs is expected to be limited. However, effects on early life stages as a result of maternal transfer were included in the derivation of TRVs based on adult tissue concentrations. Aqueous mercury exposures and effects on fish and other aquatic life have been reviewed elsewhere [11] and are less relevant than tissue-based TRVs because of mercury's high capacity for bioaccumulation and the very low mercury concentrations normally occurring in water.

Fish tissue mercury concentrations are presented in the present review on a consistent basis to the extent possible. All tissue concentrations are reported on a wet weight basis unless stated otherwise. Mercury concentrations in fish tissue are generally assumed to consist primarily of methylmercury [12], such that total mercury and methylmercury concentrations in fish are used interchangeably. This assumption has the potential to introduce uncertainty, however, because the fish tissue TRV derivations include total mercury data for fish exposed in the laboratory to inorganic mercury [8,9], and because in rare instances environmentally exposed fish have been found to contain substantial amounts of inorganic mercury [13]. Some studies and case studies cited below provide mercury concentrations in fish muscle but not whole fish. In those cases, we estimated whole-body mercury concentrations using the following equation from Peterson et al. [14]:

$$\log\left(\mathrm{Hg}_{\text{whole-body}}\right) = 0.9005\log(\mathrm{Hg}_{\text{muscle}}) - 0.2712 \qquad (1)$$

This fillet–whole body conversion method is robust because it was derived from a large dataset, representing 13 freshwater fish species from 65 sites ($n = 210$), and showed high explanatory power ($r^2 = 0.96$) [14]. Normalization of fish tissue mercury concentrations based on fish length is also commonly employed for some purposes. This practice is not necessarily applicable to laboratory studies but is discussed further below with respect to field studies (see *Case Study Review* section). Lastly, unlike hydrophobic organic compounds, mercury tends to partition to skeletal muscle rather than lipids [15], so lipid normalization of mercury concentrations would not be meaningful.

Overview of TRVs

Table 1 presents prominent mercury TRVs for protection of fish [5,8,9,16]. These TRVs are based on compilations of laboratory studies reporting paired exposure and effects data (although Sandheinrich and Wiener [5] also considered some field studies) and are expressed as mercury concentrations in biota tissue. The listed TRVs reflect adult fish or prey tissue concentrations that are not expected to cause adverse effects, including adverse effects in the offspring exposed to mercury via maternal transfer. Most of the TRV sources express exposure on the basis of whole-body mercury concentrations in potentially affected fish [5,8,9]. Depew et al. [16], however, focused on methylmercury concentrations in fish diet, which apply to prey organisms (i.e., smaller fish, invertebrates, or plants, depending on the diet of the fish species being assessed). Laboratory studies used to derive the TRVs are identified in Table 2.

Beckvar et al. [8] developed a mercury TRV of 0.2 mg/kg for the protection of fish (including early life stages exposed through maternal transfer), based on whole-body tissue residues in juvenile and adult fish. To generate the TRV, Beckvar et al. [8] evaluated hypothesis testing results from published

Table 2. Summary of laboratory studies included in TRV derivation

Species	Ref.	Beckvar et al. [8]	Dillon et al. [9]	Depew et al. [16]	Sandheinrich and Wiener [5][a]	Comments
Atlantic croaker (*Micropogonias undulatus*)	[49]			X		Different diets among treatment groups (not a controlled comparison); larval swimming speed differed in response to vibration but not visual stimulus; ecological significance uncertain
Brook trout (*Salvelinus fontinalis*)	[28]	X	X			Statistically significant effect corresponds to spawning failure, but lesser effects not statistically significant (Was statistical power adequate?)
Fathead minnow (*Pimephales promelas*)	[45]	X	X			Fish exposed to inorganic mercury, while all other studies used methylmercury exposures; high variability at low doses
Fathead minnow (*P. promelas*)	[21]	X	X	X	X	Important comparison of exposure-timing effects; results show high variability; authors' statistical analysis does not identify NOAEL or LOAEL treatments
Fathead minnow (*P. promelas*)	[43]	X	X	X	X	Low control spawning rate (32%)
Fathead minnow (*P. promelas*)	[44]		X	X	X	Low control spawning rate (40%)
Golden shiner (*Notemigonus crysoleucas*)	[122]	X			X	Good study of shoaling-related behavior; applying laboratory behavioral results to population-level effects is uncertain
Mummichog (*Fundulus heterocilitus*)	[25]	X	X	X		Male mortality significant but potentially related to aggressive behavior (other studies indicate mortality endpoint is less sensitive); no effect on productivity over three generations, but only parental generation adults were dosed with methylmercury
Rainbow trout (*Oncorhynchus mykiss*)	[123]		X			Measured mortality but not reproduction; whole fish analyzed only for 1 treatment
Striped mullet (*Mugil cephalus*)	[24]	X				Ecological significance of fin regeneration endpoint uncertain; small magnitude of effect (low-dose group 10% lower than control)
Walleye (*Stizostedion vitreum*)	[23]	X	X	X	X	Control mortality (species hard to maintain in captivity); dose groups combined to achieve statistical significance (interpretation ambiguous); indirect relationship between gonadosomatic index and reproductive success
Medaka (*Oryzias latipes*)	[124]		X			Measured mortality but not reproduction

[a]Additional laboratory studies focusing on suborganismal endpoints were also considered by Sandheinrich and Wiener [5] but are not listed here for brevity.
TRV = toxicity reference value; LOAEL = lowest-observed-adverse-effect level; NOAEL = no-observed-adverse-effect level.

laboratory toxicity studies that were deemed to meet the following requirements: no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL) provided for the same endpoint (although identified NOAELs frequently represented control treatments); control performance acceptable; whole-body concentrations measured; exposure duration not acute; and effects on survival, growth, reproduction, development, or behavior reported. Beckvar et al. [8] compared multiple derivation methods and recommended the tissue threshold-effect level method as the most appropriate approach for interpreting adult fish tissue mercury toxicity data. As described by Beckvar et al. [8], the tissue threshold-effect level is defined as the geometric mean of the 15th percentile in the effects dataset and the 50th percentile in the no-effects dataset. Beckvar et al. [8] indicated that the tissue threshold-effect level method was considered superior to the other methods evaluated because it is the only percentile-based method that represents all the available data (i.e., from both the effects and the no-effects datasets) and because, unlike some other methods, it yielded a TRV that exceeded control tissue mercury concentrations. Although Beckvar et al. [8] acknowledge that this TRV is most suitable as a screening level, it is susceptible to misinterpretation as an effects threshold in regulatory and management settings.

Whereas Beckvar et al. [8] focused on hypothesis testing (NOAELs and LOAELs), Dillon et al. [9] used more detailed information from the available toxicity studies to evaluate dose–response relationships. The Dillon et al. [9] analysis was limited to test endpoints directly related to fish survival and reproduction (including early life stage survival), which are the organism-level endpoints most directly relevant to effects on fish populations. For each exposure group and endpoint, Dillon et al. [9] calculated the percent difference from the control group. The net effect of multiple endpoints (e.g., survival, spawning success, hatching success, early life stage survival) was calculated by summing the percent effect identified for each endpoint. The results for each exposure group from each study were then assembled and interpreted collectively using nonlinear regression. Based on the fitted regression, the authors estimated a relatively low magnitude of effect (5.5%) at 0.2 mg/kg, the tissue TRV identified for adult and juvenile fish by Beckvar et al. [8]. The magnitudes of effect associated with tissue concentrations of 0.5 mg/kg, 1 mg/kg, and 3 mg/kg were estimated as 13%, 24%, and 50%, respectively. Although the objective of Dillon et al. [9] was to determine a dose–response function rather than a specific TRV, their analysis supports identification of specific mercury concentrations predicted to cause a given level of effect. Because a 20% effect level is often considered for ecological risk assessment purposes [17,18], we used the Dillon et al. [9] dose–response equation to identify a 20% effect concentration (EC20) of 0.77 mg/kg. The 95% confidence interval for the EC20 (estimated from Figure 1 in Dillon et al. [9]) is 0.4 mg/kg to 1.3 mg/kg.

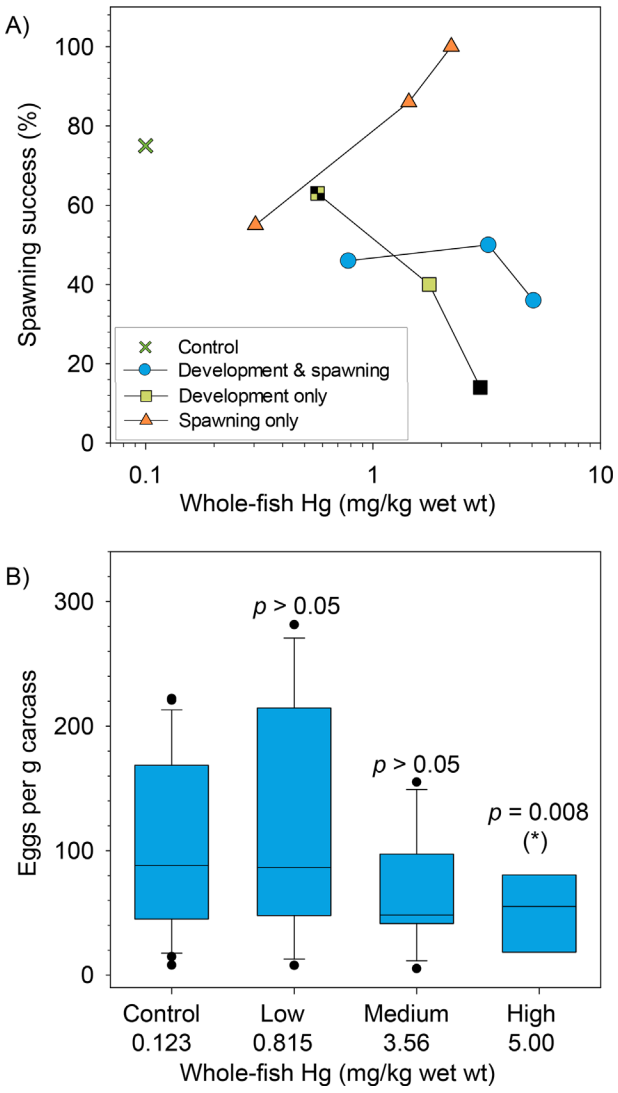

Figure 1. Statistical reanalysis of fathead minnow reproductive data from Hammerschmidt et al. [21]. (**A**) Effect of Hg on fathead minnow spawning. Black shading indicates a statistically significant difference from control. The result used as *toxic* for toxicity reference value (TRV) derivation is checkered. Symbols indicate the life stage during which fish received a mercury-spiked diet. (**B**) Effect of Hg on fathead minnow fecundity. Boxes, horizontal bars, error bars (whiskers), and points indicate interquartile ranges, medians, 10th and 90th percentiles, and extreme values, respectively. An asterisk (*) indicates statistically significant difference from the control.

Sandheinrich and Wiener [5] focused on the incidence of effects at fish tissue mercury concentrations exceeding the Beckvar et al. [8] TRV, including effects on biochemistry, cells, and tissues as well as reproductive and growth effects. Rather than applying a quantitative method to reduce the available data to a single TRV, Sandheinrich and Wiener [5] identified a concentration range (0.3–0.5 mg/kg in whole fish) associated with the onset of these effects in laboratory and field studies. The authors used these findings to justify application of the Beckvar et al. [8] TRV as a protective no-effect level in subsequent risk assessments [19,20].

Depew et al. [16] developed mercury TRVs for fish based on methylmercury concentrations in fish diet. This approach is consistent with evidence that dietary mercury intake during gonad development may be more closely linked than adult tissue mercury concentrations to reproductive effects [21,22]. The threshold concentrations proposed by Depew et al. [16] were based on 20 freshwater and marine/brackish studies presenting the results of laboratory experiments in which methylmercury was administered via diet, feeding strategy and experimental controls were deemed acceptable, and adult and/or juvenile toxicity endpoints were reported. Depew et al. [16] classified endpoints as severe (mortality), high (effects on growth and development or reproduction), or moderate (effects without defined ecological consequences). A NOAEL and/or a LOAEL were identified from each study for a given fish species and endpoint category, and species evaluated in multiple studies were represented by the geometric mean of results for each endpoint category. Depew et al. [16] calculated candidate threshold concentrations using 2 methods: first, as the highest NOAEL below the lowest LOAEL; and second, using the TEL approach, analogous to Beckvar et al. [8]. The TRV identified by Depew et al. [16] for reproductive effects is 0.04 mg/kg methylmercury in fish diet. Depew et al. [16] did not correlate the fish-diet TRV to whole-body mercury concentrations in potentially affected fish.

Review of fish tissue TRVs

Conceptually, the approach to TRV derivation used by Beckvar et al. [8], described in *Overview of TRVs*, is reasonable for development of screening-level TRVs; and, to be clear, Beckvar et al. [8] recommend using their resulting TRV solely for screening purposes. However, the implementation of this approach is limited by the availability of appropriate data. Sandheinrich and Wiener [5] incorporated additional data in their review by broadening the types of data they considered relevant to assessing adverse effects on fish to include suborganismal endpoints as well as field studies. Although this approach is more comprehensive, it increases uncertainty regarding linkages between the underlying data and the potential for effects on fish populations. Below, we discuss the merits and uncertainties of data underlying the Beckvar et al. [8] TRV, followed by a discussion of the conceptual approach employed by Sandheinrich and Wiener [5].

Beckvar et al. [8] included 8 studies in their TRV derivation for mercury in adult fish. The most sensitive studies tested mercury effects on walleye (*Sander vitreus*) [23], striped mullet (*Mugil cephalus*) [24], fathead minnow (*Pimephales promelas*) [21], and mummichog (*Fundulus heteroclitus*) [25]. Friedmann et al. [23] fed methylmercury-injected fish to juvenile walleye for 6 mo, after which low-dose walleye contained 0.25 mg/kg mercury and high-dose walleye contained 2.4 mg/kg mercury, on a whole-body wet-weight basis. Beckvar et al. [8] identified the lower exposure as a LOAEL for TRV derivation. However, gonadosomatic indices (i.e., gonad weight as a percentage of total body weight) did not differ from control results for either dose group, although the authors observed a significant difference when both dose groups were combined. Combining dose groups does not align with the assignment of treatment-specific NOAEL or LOAEL values for TRV derivation purposes. Testicular tissue showed significant cell atrophy in the high-dose group and "a lesser degree" of atrophy in the low-dose group. The significance of "a lesser degree" of testicular cell atrophy on reproductive function is unknown. In addition, walleye are difficult to maintain in captivity [23], and relatively high (28%) mortality in the control group suggests the possibility of interactions between captivity stress and contaminant stress in the test. By comparison, the same authors did not find significant relationships between gonadosomatic index and tissue mercury concentrations in field-collected northern pike or largemouth bass, despite concentrations similar

to and higher than those reported in the laboratory-exposed walleye [26,27]. In theory, this lack of agreement between field observations and laboratory predictions may reflect, at least in part, the ameliorating effects of selenium on mercury toxicity (see the *Discussion* section). However, neither study [26,27] analyzed field-collected fish tissue for selenium, and selenium concentrations in fish can be highly variable in the wild. Lastly, gonadosomatic index is not a direct measurement of reproductive success (i.e., organ weight is an indicator of only potential effects on offspring production). In light of the control mortality in the walleye study, the ambiguous statistical results, and the indirect relationship between the measured endpoints and reproductive success, the results of Friedmann et al. [23] are highly uncertain and provide a weak basis for TRV derivation.

Weis and Weis [24] tested the effect of aqueous methylmercury exposure on regrowth of amputated fins in striped mullet. After 13 d of regrowth, fin length was 10% lower than in the control group, a small but statistically significant difference. The corresponding tissue mercury concentration was 0.3 mg/kg, identified by Beckvar et al. [8] as a LOAEL. The relevance of fin regeneration rate to fish populations is uncertain.

Hammerschmidt et al. [21] studied the effects of dietary exposures of methylmercuric chloride on fathead minnow reproduction (Figure 1). Fish were exposed to methylmercuric chloride during sexual development, during spawning, or both. While no effects of methylmercury on hatching success or offspring survival were detected, spawning success was lower than in the control group for all groups exposed to mercury during sexual development. On this basis, Beckvar et al. [8] determined a LOAEL of 0.39 mg/kg wet weight (converted from a male tissue concentration of 1.97 mg/kg dry wt [21]). Although Hammerschmidt et al. [21] did report a significant reduction in reproductive potential with increasing exposure using the Cox regression model, they did not include an analysis of differences in spawning rates among the treatment groups, and therefore the analysis does not support development of a conventional NOAEL or LOAEL. When we evaluated all of the available spawning success data using a chi-squared test, only the treatment with the lowest spawning success (14%; tissue residue = 3.0 mg/kg, converted from dry wt; development-only exposure) yielded a statistically significant difference from the control ($p = 0.02$; Figure 1) due to low statistical power. In contrast to the development-only exposure groups, fish exposed only during spawning exhibited no dose-dependent change in spawning success, and Hammerschmidt et al. [21] considered them unaffected by mercury exposure. Spawning success in the spawning-only exposure groups ranged from 55% (lowest dose group) to 100% (highest dose group), indicating a high degree of variability in spawning success that runs counter to expectations if the observed variation had been the result of mercury exposure. Given the high variability, the sample sizes were not sufficient to support statistically robust determination of pairwise differences from control responses for spawning success. Interestingly, Beckvar et al. [8] gave a different interpretation to similar results for brook trout (*Salvelinus fontinalis*) [28], for which intermediate mercury exposures yielded substantial reductions in productivity that were not statistically significant. In that case, consistent with the researchers' [28] interpretation, Beckvar et al. [8] selected the statistically different treatment group as the basis for the brook trout LOAEL. The contrasting interpretation of these 2 studies by the researchers and subsequently by Beckvar et al. [8] illustrates the differences in interpretation that can arise for variable test endpoints such as fish reproduction when the statistical power of the toxicity tests does not meet the data quality needs of TRV developers.

Hammerschmidt et al. [21] also evaluated other reproductive endpoints, including male and female gonadosomatic indices, days to spawning, and daily fecundity (as eggs laid per gram carcass per day). Although most of these endpoints were significantly correlated to tissue mercury concentrations, Hammerschmidt et al. [21] did not perform statistical tests to discriminate which specific dose groups differed from controls. Using the underlying fecundity data (as eggs per gram carcass) for fish exposed during both development and spawning (C. Hammerschmidt, Wright State University, Dayton, OH, USA, personal communication), we conducted pairwise comparisons of each dose group with the control using *t* tests (Figure 1). Similar to spawning success, the difference in fecundity was significant only for the highest dose group ($p = 0.008$; whole-fish mercury = 5.0 mg/kg), although the data also suggest reduced fecundity in the middle dose group (whole-fish mercury = 3.5 mg/kg). The results of Hammerschmidt et al. [21] are important in identifying the possibility of effects on fish reproduction at environmentally relevant exposure levels, but variability in the underlying data leads to difficulties in identifying a specific LOAEL from the study.

Matta et al. [25] studied the effects of 4 concentrations of dietary methylmercuric chloride on 3 generations of mummichogs. Only adult F0 fish received the mercury-spiked diet, such that exposure to subsequent generations was limited to maternal transfer. None of the test organisms was dosed with methylmercury during gonad development. Based on the subsequent findings of Hammerschmidt et al. [21], no reproductive effects would be expected under such a dosing regime, and, indeed, no effects on mummichog reproductive success were observed over multiple generations. In the first generation, adult male mortality was elevated in all but the lowest dose group, although the magnitude of mortality did not show a concentration–response relationship. As noted by Depew et al. [16], the observed mortality may have been related to the increased aggressive behavior reported by Matta et al. [25] in first-generation adult males. Based on adult male mortality, Beckvar et al. [8] identified the NOAEL and LOAEL from Matta et al. [25] as 0.21 mg/kg and 0.44 mg/kg, respectively. However, Depew et al. [16] judged the LOAEL from Matta et al. [25] to be unsuitable as the basis for their mercury TRV for mortality effects, because the mercury exposure level was considerably lower than exposures associated with mortality or growth effects in several other fish species, and the observed mortality may have been behaviorally mediated rather than an expression of overt lethality. While the mortality was clearly an adverse effect on the affected individuals regardless of whether it was behaviorally mediated, there is greater uncertainty in extrapolating a behavioral effect from laboratory to field settings compared with overt lethality. To the extent that the male mummichog mortality results from Matta et al. [25] are used in ecological risk assessments or risk management decision-making, their interpretation should be qualified by the understanding that female survival was unaffected, and male abundance is less important to fish productivity than female abundance.

In summary, there is a high degree of uncertainty in all of the studies considered by Beckvar et al. [8] for evaluating effects of mercury in adult fish at whole-body concentrations between 0.2 mg/kg and 0.5 mg/kg. This concentration range is particularly relevant to environmental concentrations of mercury in larger fish within eastern North America [29]. The remaining

studies reviewed by Beckvar et al. [8] also are not without uncertainty, but we do not present a detailed review here because the LOAELs are all higher (0.52–5 mg/kg) and have less impact on the final TRV. However, these studies are incorporated as appropriate in the dose–response analyses discussed in the *Fish tissue dose–response analysis* section.

Sandheinrich and Wiener [5] made a case for adverse effects of mercury on fish at whole-body concentrations in the range of 0.3 mg/kg to 0.5 mg/kg. Aside from the studies reviewed in the present study, their evaluation primarily included studies of biochemical and physiological endpoints, as well as certain field studies. Biochemical and physiological endpoints are not necessarily directly linked to effects on fish populations, and the magnitude of response that would correspond to an ecologically relevant effect is generally unknown. For this reason, such endpoints often are excluded from TRV derivation [18]. As an example, Sandheinrich and Wiener [5] identified increased prevalence of macrophage aggregates in fish organs as an adverse effect, because macrophage aggregates collect components of cells damaged by oxidative stress. In contrast, Soulen et al. [30] recently identified macrophage aggregates as the site of mercury demethylation in fish, and Barst et al. [31] identified preferential accumulation of both mercury and selenium in fish macrophage aggregates, possibly indicating sequestration of mercury as an inert HgSe compound. Whether macrophage aggregates are indicators of cell damage, mercury detoxification, or both, none of these hypotheses sheds light on the magnitude of change in macrophage aggregate prevalence that would be associated with adverse effects at the organismal or population levels. As this example illustrates, inclusion of suborganismal endpoints does not provide clarity at the level of biological organization that is the focus of most environmental cleanup decisions.

Sandheinrich and Wiener [5] also evaluated field studies of fish condition (i.e., weight relative to length) at sites remote from local mercury point sources. Effects of mercury on fish condition are difficult to discern from such studies, because differences in fish mercury concentrations among water bodies are caused by factors that are also likely to affect fish condition, as well as fish populations and communities. These factors include watershed forest cover and extent of wetlands, sulfate and pH levels, and biological productivity [3,32,33]. In particular, higher primary productivity tends to reduce mercury concentrations in the food web because the bioavailable mercury mass is diluted by increased algal mass [3,34,35]. Similarly, fish growth efficiency also inversely affects mercury bioaccumulation through biodilution [3,36–38]. Therefore, lower fish condition could potentially be a cause—rather than an effect—of higher mercury concentrations in individual fish, particularly in the absence of elevated local mercury inputs. Consistent with this interpretation, fish growth in controlled experiments shows only limited sensitivity to mercury exposure, as reviewed by Depew et al. [16] and Wiener and Spry [4]. Based on these concerns, we excluded field studies focusing on fish condition from our review of field case studies. In summary, although it is more comprehensive, Sandheinrich and Wiener's [5] review does not resolve the data limitations and associated uncertainties that affect the Beckvar et al. [8] TRV, at least from the perspective of environmental management decision-making.

Fish tissue dose–response analysis

Dillon et al. [9] built on the screening-level TRV derivation of Beckvar et al. [8] to develop a dose–response relationship for mercury effects on fish. Conceptually, the dose–response analysis of Dillon et al. [9] should benefit environmental assessors and managers, in that it allows for consideration of severity of effect, proportion of population affected, and degree of protection sought through risk management decisions. Dillon et al. [9] focused on the most population-relevant toxicity endpoints (reproduction and survival, including early life stage survival), thus taking a less precautionary approach to uncertainties related to endpoints such as gonadosomatic indices and fin regeneration. The dose–response approach also eliminates hypothesis testing, although low test replication for reproductive endpoints remains a source of variability and uncertainty in the dataset.

Although the conceptual approach of Dillon et al. [9] has the potential to generate results that are reasonably well aligned with real-world effects on fish populations, we identified several specific decisions in the authors' implementation of this approach where alternative judgments reasonably could be supported. To evaluate whether these judgments, described below, affect the outcome of the dose–response analysis, we conducted a sensitivity analysis. We varied assumptions that we believe are open to reasonable scientific interpretation or debate, and we incorporated data from additional relevant studies. The dataset used in our sensitivity analysis is presented as Supplemental Data.

Modifications of Dillon et al. [9] dataset. First, we integrated the results for multiple endpoints by multiplication, rather than the additive approach of Dillon et al. [9]. The integration of endpoints by addition can produce effects that exceed 100%. Consider a hypothetical exposure in which one-half of F0 fish survive, one-half of the surviving fish spawn, and one-half of the spawned eggs hatch (all effects normalized to control). Adding the results of these endpoints would indicate 150% effect, whereas one can deduce intuitively that the number of hatched fish will actually be one-eighth of the control (i.e., an 87.5% reduction in number of offspring); that is, the endpoints are multiplicative rather than additive

$$\text{Net effect} = 100\% - \Pi(100\% - \text{endpoint}\,\%\,\text{effect}) \qquad (2)$$

Making this correction allows a larger number of endpoints to be integrated, as well as calculation of the overall effect of exposure on offspring production. We applied the multiplicative integration of endpoints without regard to whether control or mercury-exposed fish performed better for any given endpoint. This approach allowed random variations to cancel each other and also allowed for hormetic effects (if any). The approach can result in $<0\%$ effect ($>100\%$ performance), which could be illogical if applied outside the context of a comparison with controls; however, the alternative (excluding endpoints with performance better than control) would inherently result in overestimation of effects because of biased treatment of potentially random variation. Consistent with the application of Dillon et al. [9], aggregation of endpoints by multiplication should only be applied to endpoints that contribute directly to offspring production. For instance, in the hypothetical example above, growth data would not be incorporated. The outcome of this calculation is thus an estimate of the net effect of mercury exposure on reproduction (e.g., net production of viable offspring, if all relevant endpoints are reported) relative to control performance in each laboratory test.

Second, we expanded the number of endpoints integrated for each study, such that the resulting percent effect represented the net effect on production and survival of offspring. Dillon

et al. [9] did not evaluate all relevant endpoints for each study, likely because of the additivity issue noted above. For example, in evaluating Hammerschmidt et al.'s [21] fathead minnow study, Dillon et al. [9] considered only spawning success. However, Hammerschmidt et al. [21] also reported fecundity, development success, hatching success, and larval survival. We included all of these endpoints in our analysis.

Third, we narrowed the scope of the dose–response analysis to focus on reproduction, eliminating studies that only provided adult mortality data. However, we did incorporate parental and offspring mortality results in the calculation of net effect on production of viable offspring. The literature review of Dillon et al. [9] for the survival endpoint omitted several studies reporting low mortality associated with high mercury tissue residues. Among studies not included by Dillon et al. [9], Olson et al. [39] observed no mortality in fathead minnows at whole-body tissue mercury concentrations of 10.9 mg/kg during 48 wk of aqueous exposure. Similarly, mortality was not observed in rainbow trout fingerlings containing up to 30 mg/kg during 84 d of dietary exposure [40] or 12 mg/kg in a separate 15-wk dietary exposure [41] (converted from muscle concentration per Equation 1). In a 70-d experiment with sheepshead minnow (*Cyprinodon variegatus*) and inland silverside (*Menidia beryllina*), increased mortality occurred at whole-fish mercury concentrations exceeding 10 mg/kg (converted from dry weight) [42]. Although some of these studies predate current analytical and toxicity testing methods, they are contemporaneous with other studies included in Dillon et al.'s analysis [9], such that any analytical uncertainties are equally applicable to studies included and excluded by Dillon et al. [9]. These studies suggest that a dose–response analysis based on adult fish survival might not be protective of fish reproduction and early life stage survival.

Fourth, we omitted fathead minnow reproductive studies by Drevnick and Sandheinrich [43] and Sandheinrich and Miller [44], because control spawning rates in these studies (32–40%) were much lower than those achieved in other studies on fathead minnows (75–100% [21,45]). It is unclear why the control spawning rates were so low, and they raise the possibility of uncontrolled laboratory artifacts, specimen handling and stress, and/or study design flaws. In any case, the results reported by Drevnick and Sandheinrich [43] and Sandheinrich and Miller [44] were similar to those reported by Hammerschmidt et al. [21] except that the tissue mercury concentrations were higher, such that removing Drevnick and Sandheinrich [43] and Sandheinrich and Miller [44] from the dataset actually yields a more protective outcome than would otherwise result.

Fifth, for comparability with other studies, we included results from Hammerschmidt et al. [21] only for fathead minnows exposed to mercury during both development and spawning. Fish that were exposed only during development had depurated part of their tissue burden before being tested for toxicity. Conversely, fish that were exposed only during spawning were insensitive to reproductive effects despite substantial whole-body mercury concentrations. For the same reason, we excluded the mummichog data from Matta et al. [25], because only the F0 adults were dosed with mercury, which may have caused or contributed to the lack of reproductive effects despite the high tissue concentrations found in that study. We recognize that in the field, some fish are exposed to mercury during only part of their life cycle, and fish tissue-based dose–response data for continuously exposed fish may be either over- or underprotective in such cases, depending on which part of the life cycle experienced the mercury exposure. Nevertheless, if one is to pursue fish tissue-based TRVs for protection of fish at all, then consistency in the underlying dataset is needed to provide interpretable results.

Sixth, we omitted certain treatment groups from Snarski and Olson's [45] fathead minnow study in which the fish received a suboptimal diet. Snarski and Olson [45] evaluated survival and development of juvenile fathead minnows exposed to aqueous inorganic mercury. Two types of food were evaluated: dry trout starter and live brine shrimp. The control fish fed brine shrimp exhibited better and more uniform growth, and this diet was used exclusively in subsequent reproductive tests. These results suggest that the data for brine shrimp-fed fish should be preferred and, indeed, Beckvar et al. [8] did not consider results from the dry trout starter-fed treatment groups. Snarski and Olson [45] reported spinal development impairment only for fish fed dry trout starter; these results were considered by Dillon et al. [9] but eliminated from consideration for our sensitivity analysis.

Finally, 2 inaccuracies from the dataset of Dillon et al. [9] were corrected. For the brook trout study of McKim et al. [28], Dillon et al. [9] list as tissue concentrations for the F1 generation data that actually are for depurated F0 fish (and therefore are not applicable); we eliminated these data. Also, we could not reproduce the average wet weight tissue concentrations estimated by Dillon et al. [9] from dry weight male and female concentrations reported in Hammerschmidt et al. [21]. We recalculated the respective wet weight concentrations assuming the fish contained 75% moisture.

Additional toxicity studies. We identified 3 additional studies investigating effects of mercury exposure on fish reproductive parameters, which were not available to or considered by Dillon et al. [9]. Tatara et al. [46] reported results of a 4-yr, multigenerational mesocosm experiment studying effects of mercury-contaminated sediments on mosquitofish (*Gambusia holbrooki*). A limitation of the study conducted by Tatara et al. [46] (similar to other studies included in the dose–response dataset) is that none of the mercury treatment levels was low enough to be without adverse effects. Penglase et al. [47] evaluated the effects of dietary methylmercury and selenium exposure on female growth, survival, and behavior, as well as reproductive parameters in zebrafish (*Danio rerio*). For purposes of this sensitivity analysis, we only considered dose groups with low selenium, sufficient to meet selenium nutritional requirements. A limitation of the Penglase et al. [47] study is that the dose groups included only the control and 1 high-dose group. Stefansson et al. [48] evaluated effects of adult dietary methylmercury exposure on egg production in sheepshead minnow (*C. variegatus*). Their study was designed to evaluate maternal transfer exposure sources and not to derive TRVs; thus, there are limitations to its use in TRV development that relate to its consideration for a purpose other than was originally intended. For example, the sample size in the high-dose group was too small to test for statistical significance. Also, consistent with the study's intended purpose, Stefansson et al. [48] evaluated egg production and not spawning, hatching, or offspring viability. We included these additional studies in our analysis because they provide information comparable to the studies analyzed by Dillon et al. [9]. However, each of the additional studies has limitations for purposes of TRV development, so their inclusion does not fundamentally address the need for additional investigation of mercury effects on fish reproduction.

Statistical analysis of dose–response model fit. To evaluate the uncertainty associated with a multispecies dose–response relationship, statistical model fit was evaluated based on the approximate r^2, which is the proportion of variance explained by the model. A nonlinear regression was fit according to the same equation used by Dillon et al. [9]

$$Y = \frac{100}{1 + 10^{(log\ \mathrm{EC50} - log\ X)(Hill\ Slope)}} \quad (3)$$

where Y is the percent injury, X is the tissue residue in mg/kg wet weight, and EC50 is the effective concentration halfway between 0% and 100% injury. The results yield an approximate r^2 of 0.343. This low r^2 shows that the variability in response among species and across studies is too high to allow a reliable estimate of broadly applicable (i.e., multispecies) effect concentrations using this approach.

Sensitivity analysis conclusions. Figure 2 compares the modified dataset with the dataset developed by Dillon et al. [9]. The data for fathead minnow and brook trout suggest possible effects at mercury residues similar to the 0.77 mg/kg EC20 derived from the original dose–response analysis [9], although, as discussed, none of the effects at these lower tissue residues was statistically significant (see *Review of fish tissue TRVs*). Tests with other species were much less sensitive with respect to net production of offspring. Compared with the findings of Dillon et al. [9], the modified dataset still shows that the frequency of effects increases at tissue concentrations above the 0.77 mg/kg EC20. Because of the variability across studies, which may reflect differences among species as well as different study designs and test conditions, the combination of multiple species in the residue-effect curve is inherently problematic. In the modified dataset, it is possible to discern which species and which experiments contributed to those effects; in the Dillon et al. study [9], however, all data are plotted alike. The additional studies included in the modified dataset accentuate the observed variability, where essentially any outcome is possible at higher exposures. This result is consistent with confounding by unmeasured mercury–selenium interactions (see the *Discussion* section).

In summary, our sensitivity analysis indicates that the Dillon et al. [9] EC20 of 0.77 mg/kg is closer to a threshold for reproductive effects than is the Beckvar et al. [8] TRV, based on currently available laboratory toxicity data. Our analysis does not support 0.77 mg/kg as a true EC20 that is broadly applicable across a variety of fish populations and communities. However, this finding does not negate the benefits of using a dose–response approach to characterize mercury effects on fish. Instead, it underscores the need for high-quality investigations of mercury dose–response relationships for reproductive endpoints in multiple representative fish species.

Review of fish prey TRVs

Depew et al. [16] developed separate TRVs for different types of effects, including effects on survival, growth, and reproduction, as well as effects with unknown or poorly characterized ecological consequences (i.e., suborganismal and behavioral effects). Conceptually, this approach is useful in discriminating the nature of effects potentially associated with fish prey mercury concentrations in excess of each TRV. In their development of TRVs for reproductive effects of methylmercury in fish diet, Depew et al. [16] reviewed many of the same studies discussed above [21,23,25], and the same uncertainties that affected the use of the study results by Beckvar et al. [8] also affect the Depew et al. [16] evaluation. Appropriately, Depew et al. [16] state that their TRVs should be considered preliminary because of data limitations.

In addition to the previously discussed studies, the review by Depew et al. [16] of mercury effects on fish reproduction included a dietary LOAEL of 0.05 mg/kg based on Atlantic croaker (*Micropogonias undulatus*) larval behavior following parental dietary exposure to mercury and maternal transfer to offspring [49]. Diets in the latter study consisted of shrimp (control), blue marlin tissue (low-mercury group), and blue marlin supplemented with contaminated shrimp (high-mercury group). Differences in the compositions of diets for the different dose groups introduce uncertainty to the assessment, because in addition to varying methylmercury exposures, the control and treatment groups may have received different nutrition and selenium exposures, and they likely experienced different exposure to unmeasured co-contaminants. No significant differences among groups were observed for larval growth or responses to visual startle stimulus. Significant regressions were reported between egg mercury concentrations and certain behavioral variables (i.e., percentage of time active during routine behavior and duration and speed of response to vibratory startle stimulus); however, there was considerable overlap among individual responses in the 3 exposure groups. In addition, it is uncertain whether the observed behavioral trends would affect predator avoidance and larval survival. Although

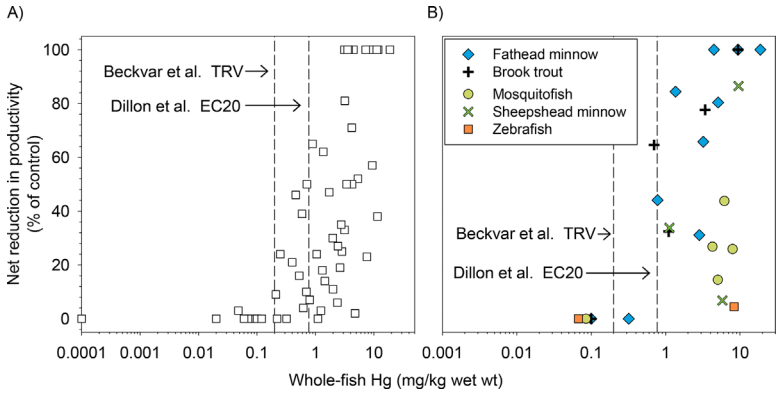

Figure 2. Comparison of (**A**) Dillon et al. [9] dose–response data set and (**B**) modified dose–response dataset. The modified dataset provides a sensitivity analysis of the impact of specific judgments incorporated in the dose–response analysis as well as the addition of new data. Dashed lines represent Beckvar et al. [8] toxicity reference value (TRV) and Dillon et al. [9] 20% effect concentration (EC20).

Murphy et al. [50] conducted a population modeling exploration using the Alvarez et al. [49] study results, Murphy et al. [50] did not suggest that their model accurately represented field conditions. The Alvarez et al. [49] study is of interest to generate further hypotheses about mercury effects on fish behavior, but it is not an appropriate basis for TRV development, because of its uncontrolled study design and the uncertain and indirect ecological consequences of the endpoints measured.

Furthermore, Depew et al. [16] identified the TRV for mercury effects on fish reproduction based on the highest NOAEL below the lowest LOAEL for reproduction. The only so-called NOAELs lower than the Alvarez et al. [49] LOAEL were actually control treatments from other studies. As a result, the reproductive TRV is equal to the mercury content of the control diet in the Friedmann et al. [23] walleye study. The same outcome would have resulted even if the Alvarez et al. [49] study had been excluded, because nearly all of the so-called NOAELs identified by Depew et al. [16] for reproductive endpoints were control treatments. Laboratory controls are nontoxic by definition. If a TRV derivation method produces a result within the range of control tissue concentrations, it probably does not indicate that control conditions are toxic, but rather that the derivation method or underlying data are at fault. The data available to develop a dietary TRV for mercury effects on fish reproduction are limited and highly uncertain. Because the resulting TRV is based on a control concentration, it is not an effect threshold and should not be used as such.

CASE STUDY REVIEW

Our review of mercury effects on fish populations and communities considered case studies at mercury-contaminated sites. The objective of this evaluation was to determine whether adverse effects were observed at fish or prey tissue concentrations consistent with the published TRVs discussed above. Using Google Scholar and other online searches, reference lists of pertinent papers, and direct inquiry to researchers, we searched broadly in the peer-reviewed and gray literature for studies targeting measures of fish reproductive success and recruitment, population age or size structure, population abundance, or fish community characteristics paired with mercury concentrations in fish tissue or fish diet. We focused on these effect endpoints because many, although not all, environmental management decisions are intended to protect environmental resources at the population or community level [7,51,52]. In other words, fish population attributes such as abundance, age composition, population growth, and population viability are typically considered more relevant from a management perspective than the health or persistence of individual organisms. Because the fish evaluated in these case studies are wild and living in their native habitats, their exposure to mercury is primarily via diet (for adults) and maternal transfer (for offspring).

Initially, we also considered inclusion of fish community monitoring studies conducted on a regional or national basis, as well as field studies evaluating fish growth or condition (weight relative to length) at sites remote from local mercury sources. However, we were able to obtain regional datasets of paired fish community and fish tissue mercury data only for regions where few fish contained mercury in excess of TRV concentrations. More importantly, interpretation of such studies is likely to be affected by confounding factors such as biodilution, as described previously (see section *Review of fish tissue TRVs*). We also did not include studies that evaluated relationships between mercury concentrations in field-collected fish and various effects on biochemistry, cells, and tissues. In the absence of quantitative linkages to relate the magnitude of biomarker or histopathological responses to effects on reproductive success or survival, the significance to fish populations of such suborganismal effects is difficult to interpret. However, if observed population effects associated with mercury were explained by effects on biochemistry, cells, and tissues, those relationships are noted.

We retained case studies that did not report statistical power, because omitting them would have eliminated the case study review. Few field studies conducted on fish or wildlife address statistical power, despite its importance in understanding the degree to which study design can detect significant differences between populations, if such differences in fact exist. Thus, where we report that no effects were observed in a field study, it is because no effects were detected but not necessarily because a lack of effects was statistically demonstrated.

Eight sites were identified where the requisite biological and mercury data were colocated spatially and temporally, as follows: South River, Virginia, USA; North Fork Holston River, Virginia, USA; Onondaga Lake, New York, USA; La Grande Hydroelectric Complex reservoirs, Quebec, Canada; Savannah River and associated streams, South Carolina, USA; Clear Lake, California, USA; East Fork Poplar Creek, Tennessee, USA; and the Hudson–Raritan Estuary, New Jersey, USA. These were the only sites identified that met the criteria for inclusion defined a priori and listed above (i.e., mercury-contaminated sites with tissue data and relevant reproductive, population, or community effects assessed). Most of the case studies address sites where mercury is the sole or primary contaminant. However, we also present information for 2 sites characterized by complex contaminant mixtures (East Fork Poplar Creek and the Hudson–Raritan Estuary). These sites are included because some have viewed them as mercury sites, although site investigators acknowledged the role of chemical mixtures, and because they provide useful examples of investigation tools that may be applicable at other sites. Results of the case study review are summarized in Table 3.

Normalization of mercury concentrations to a standard fish length is commonly performed for purposes of clarifying spatial and temporal trends in mercury monitoring programs [19,53,54]. Length normalization is performed because fish tissue mercury concentrations typically increase with increasing fish size, and variability in the size of sampled fish can thus add variability to such trend analyses. For purposes of relating tissue concentrations to potential effects, length normalization is not necessarily applicable, because toxic effects are presumably related to the concentration in each organism regardless of length. In contrast, length normalization is useful in cases where mercury exposure and effects are not measured in the same individuals (e.g., for population or community parameters) and the relationship between spatial trends in mercury exposure and effects is of interest. Regardless, length-normalized concentrations were available or calculable for only a minority of the case studies (i.e., South River, North Fork Holston River, La Grande Hydroelectric Complex). Each of the case studies is described below.

South River

Because of historical industrial operations in Waynesboro, Virginia (USA), mercury concentrations in fish tissue are elevated in much of the South River and downstream in the

Table 3. Summary of case studies evaluating effects on fish at mercury-contaminated sites

Site	Exposure (whole-body mercury; mg/kg wet wt)[a]	Effect	Ref.
South River, VA, USA	Smallmouth bass, sample location means: 0.48–1.36 Prey fish, sample location means: 0.10–1.29	No effect on population density or biomass, growth, condition, predation efficiency (based on stomach contents), community richness, or community structure (based on feeding guilds)	[55,56,64]
Onondaga Lake, NY, USA	Largemouth bass, mean: 0.81	No effect on population density, reproduction, or recruitment	[68,71; Tyszko, 2010[b]]
North Fork Holston River, VA, USA	Smallmouth bass, mean (range): 0.60 (0.27–1.13)	Above-average catch rates, high adult survival, high relative stock density	[60,72,74]
La Grande Reservoirs, QC, Canada	70-cm northern pike: 1.1–1.6; 40-cm walleye: 1.0; 60-cm lake trout: 1.0	No effect on population abundance, growth, or condition	[76]
Savannah River, SC, USA	Redbreast sunfish and 8 other species, sample location means: 0.08–0.47	Good fish community quality (based on Index of Biotic Integrity), no effect on fish condition or pathology	[77]
Clear Lake, CA, USA	Largemouth bass, mean (range): 0.18 (0.02–0.97)	Inconclusive (see text)	[83]
East Fork Poplar Creek, TN, USA	Redbreast sunfish: multiple chemicals	Decreased fecundity, altered population size structure, decreased biomass of sensitive species	[84,87,89]
Hudson-Raritan Estuary, NJ, USA	Mummichog, bluefish: multiple chemicals	Mummichog: decreased abundance mediated by effects on predation efficiency and predator avoidance Bluefish: reduced predation efficiency and growth	[65,96,97]

[a]Whole-body mercury concentrations measured for Savannah River and estimated from muscle concentrations per Peterson et al. [14] for remaining sites.
[b]S.M. Tyszko, 2010, Master's thesis, State University of New York, Syracuse, NY, USA.

South Fork Shenandoah River, compared with reference locations upstream and in the North River. Several aspects of fish population and community status have been evaluated in relation to mercury exposures in this system. As a top predator with high site fidelity, smallmouth bass (*Micropterus dolomieu*) contain relatively high mercury concentrations [55]. Average whole-body concentrations in smallmouth bass from South River sample locations downstream from mercury source areas ranged from 0.48 mg/kg to 1.36 mg/kg, as estimated from fillet data [56]. Mercury concentrations in South Fork Shenandoah River smallmouth bass showed much less spatial variation and averaged 0.61 mg/kg on a whole-body basis [56]. Mercury concentrations in whole smallmouth bass from reference locations in the North River and upstream South River are approximately 0.1 mg/kg [56]. Concentrations in prey fish were also measured at smallmouth bass population survey locations, with average length-normalized concentrations ranging from 0.11 mg/kg to 0.90 mg/kg in common shiner (*Luxilus cornutus*) and from 0.10 mg/kg to 1.29 mg/kg in longnose dace (*Rhinichthys cataractae*) [55]. Fish tissue mercury concentrations measured in conjunction with smallmouth bass population survey locations are given only on a length-normalized basis [55]; the specific length selected for standardization purposes is not stated.

Despite elevated mercury concentrations in smallmouth bass and their prey, population density and biomass of smallmouth bass downstream of Waynesboro are comparable to reference conditions and show no relationship to length-normalized mercury tissue concentrations [55] (Figure 3). Smallmouth bass growth (length vs age) and condition (weight relative to length) also show no differences from reference conditions [57]. Smallmouth bass recruitment has been evaluated in the South Fork Shenandoah River only. Recruitment is strongly influenced by flow conditions [58] and is qualitatively similar between the South Fork Shenandoah River and other nearby rivers [58–61]. Smallmouth bass in the South Fork Shenandoah River and several other rivers in the region (not including the South River) have suffered from mortality events apparently related to 1 or more pathogens [61,62]. The cause of these

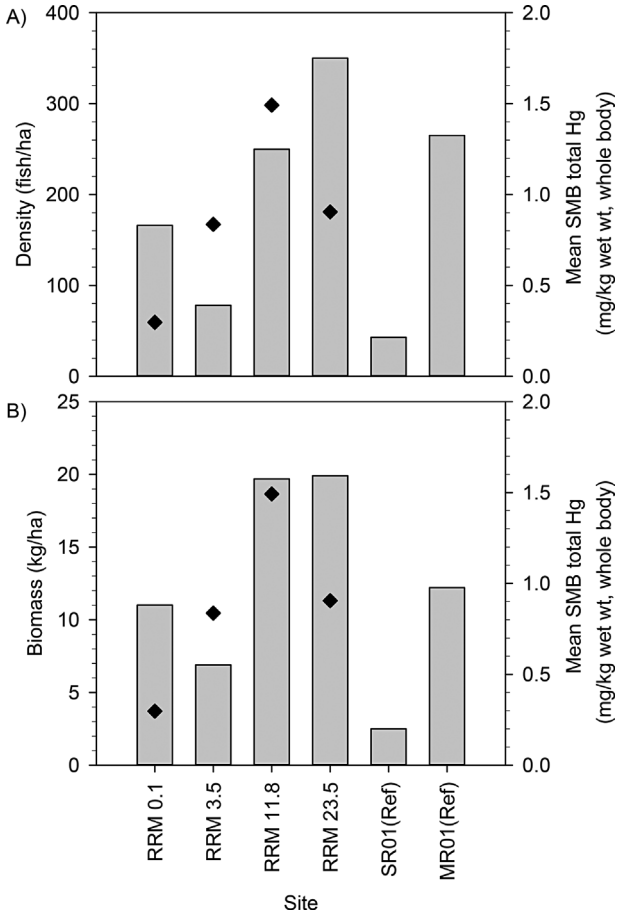

Figure 3. Comparison of smallmouth bass (SMB) (**A**) density and (**B**) biomass (bars) with whole-body mercury concentrations (diamonds) at South River stations (relative river miles [RRM] shown) and reference locations (upstream South River [SR] and Middle River [MR]) [55]. Paired smallmouth bass mercury concentrations were not analyzed from the reference stations, but other data [56] indicate whole-body mercury concentrations of approximately 0.1 mg/kg in smallmouth bass from uncontaminated reference locations in the vicinity.

outbreaks is not fully understood, but mercury has been evaluated and is not considered an important contributing factor given the geographic distribution of the outbreaks [62], whereas agricultural inputs such as arsenic and herbicides are suspected contributors to immunosuppression in the affected fish [63]. These mortality events have resulted in a lower proportion of older, larger smallmouth bass in the South Fork Shenandoah River population [59,60]. In addition to the population attributes described above, an investigation of fish diet provides an opportunity to examine predation efficiency in South River and South Fork Shenandoah River smallmouth bass. Specifically, an analysis of stomach contents found very similar diet composition and incidences of empty stomachs in fish from the 2 mercury-affected rivers compared with a North River reference area [64]. This result contrasts with findings in areas of the Hudson–Raritan Estuary, where dietary shifts and a high incidence of empty stomachs were observed in concert with impaired prey capture behavior in fish exposed to mixtures of contaminants [65] (see *Hudson-Raritan estuary*). Thus, multiple lines of evidence from the South River and South Fork Shenandoah River show no evidence of mercury-related impairment of smallmouth bass populations despite elevated mercury exposures.

Fish community data for the South River also indicate general similarity across mercury gradients and in comparison with reference conditions (Figure 4). Taxa richness at South River stations was equal to or higher than at reference stations, and the relative abundance of various feeding guilds was similar across stations [55]. Lower taxa richness and increased relative abundance of omnivorous fish have sometimes been considered indicators of anthropogenic impacts in rivers [66]; no such effects were observed in the South River. The only notable change in trophic composition is an increase in piscivore prevalence from upstream to downstream within the South River (Figure 4), which is consistent with increasing drainage area and river size. The absence of detectable adverse effects on the South River fish community is consistent with a study of physiological effects in rock bass (*Ambloplites rupestris*) collected from the South River upstream and downstream of Waynesboro, which found only limited physiological differences and concluded that "mercury is not having a significant impact on the rock bass" [67]. In summary, multiple measures of fish population and community condition have been evaluated in the South River and the South Fork Shenandoah River, and adverse effects as a result of mercury are not detectable despite fish mercury concentrations exceeding most of the TRVs shown in Table 1.

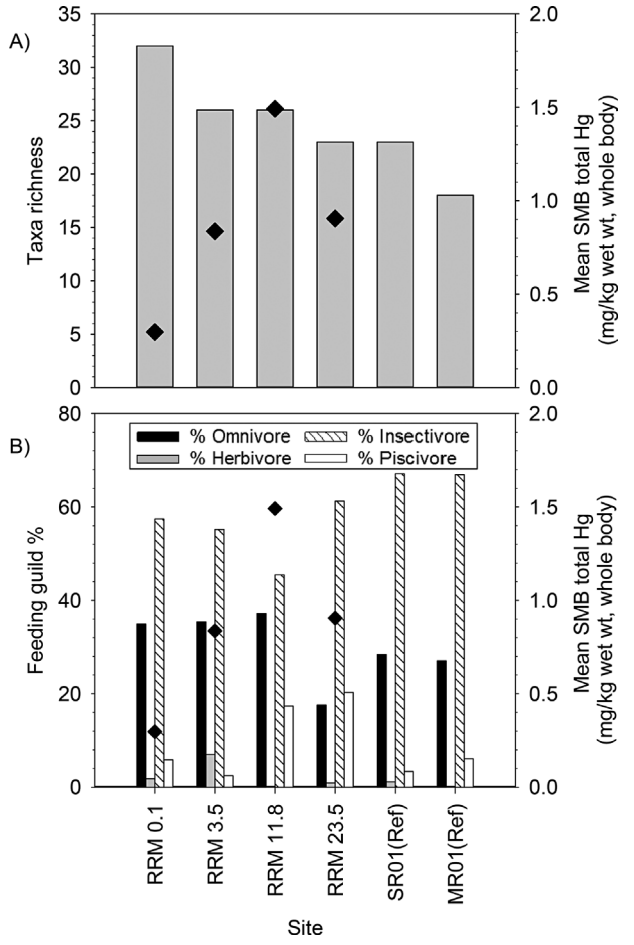

Figure 4. Comparison of fish (**A**) taxa richness and (**B**) feeding guild composition of fish community (bars) with whole-body mercury concentrations in smallmouth bass (SMB) (diamonds) at South River stations (relative river miles [RRM] shown) and reference locations (upstream South River [SR] and Middle River [MR]) [55]. Paired smallmouth bass mercury concentrations were not analyzed from the reference stations, but other data [56] indicate whole-body mercury concentrations of approximately 0.1 mg/kg in smallmouth bass from uncontaminated reference locations in the vicinity.

Onondaga Lake

Onondaga Lake, New York, is recovering from more than 125 yr of historical municipal and industrial discharges, including inputs of mercury. Dredging and capping of Onondaga Lake sediments began in summer 2012, and dredging was completed in 2014 to address historically impacted sediments. Major reductions in ammonia and phosphorous input into the lake have been achieved with the use of improved wastewater technology in 2004 to 2005 and more recent efforts to reduce combined sewer overflows into the lake [68].

Mercury concentrations in whole sport fish for all samples collected in 2009 to 2010 ranged from 0.0085 mg/kg to 2.2 mg/kg (estimated from fillet) [69,70]. The average mercury concentration in largemouth bass collected in 2008 was 0.81 mg/kg (estimated from fillet) [71]. A baseline assessment of largemouth bass in the littoral zone conducted in 2008 and 2009 showed that largemouth bass density and size structure was better than the New York State average for lakes (S.M. Tyszko, 2010, Master's thesis, State University of New York, Syracuse, NY, USA). Conversely, studies indicate a below-average smallmouth bass population [68]; however, this has been attributed to an increase in the macrophyte coverage that is preferred by largemouth bass [68]. Successful reproduction and recruitment of largemouth bass within the lake has been confirmed through surveys of fish nests and young-of-year fish [68]. Also, largemouth bass growth rates, condition, and survival rates are similar to statewide averages [68]. These findings demonstrate an apparent lack of reproductive or population-level effects on largemouth bass despite tissue mercury levels that exceed most of the TRVs shown in Table 1.

North Fork Holston River

Mactec Engineering and Consulting [72] assessed the North Fork Holston River system to evaluate historical mercury releases from the Saltville Waste Disposal Ponds Site. In 2005, mercury was analyzed in smallmouth bass, rock bass, hog suckers (*Hypentelium nigricans*), and sunfish (*Lepomis* spp.) sampled over a 70-mile area. Mean (range)

whole-body mercury concentrations were estimated from fillet analyses as 0.60 mg/kg (0.27–1.13 mg/kg), 0.51 mg/kg (0.31–0.72 mg/kg), 0.47 mg/kg (0.25–0.68 mg/kg), and 0.42 mg/kg (0.22–0.68 mg/kg), respectively. Thus, 100% of the samples contained mercury concentrations exceeding the Beckvar et al. [8] TRV of 0.2 mg/kg, and concentrations exceeding the Dillon et al. [9] EC20 of 0.77 mg/kg were observed in some smallmouth bass. Although mercury was not measured in fish from an upstream reference area, for comparison, the mean whole-body mercury concentration (estimated from fillet) for smallmouth bass collected across southwestern Virginia in 2004 to 2006, excluding North Fork Holston River, was 0.14 mg/kg ($n = 52$) [73].

The Virginia Department of Game and Inland Fisheries monitors smallmouth bass populations in 16 rivers statewide, including the North Fork Holston River [60]. Relative to other Virginia rivers, smallmouth bass in the North Fork Holston River have above-average catch rates (number of fish per hour), moderate growth rates, the highest adult survival rate (79% annually), and the highest relative stock density of "quality" fish (i.e., among smallmouth bass of catchable size, 57% are >28 cm) [60,74]. Although bass mortality in the North Fork Holston River may be somewhat decreased relative to other rivers because of a fish consumption advisory, Virginia Department of Game and Inland Fisheries [60] considers angling to be a minor contributor to bass mortality compared with other causes. Thus, the smallmouth bass population in the North Fork Holston River does not appear to be adversely affected despite tissue mercury concentrations consistently in excess of the Beckvar et al. [8] TRV.

La Grande Hydroelectric Complex

Increases in mercury bioaccumulation are characteristic of newly flooded reservoirs, as a result of conditions that favor mercury methylation [75]. A study of boreal reservoirs at the La Grande Hydroelectric Complex (Quebec, Canada) showed no adverse effects on fish despite 3- to 6-fold increases in fish mercury concentrations [76]. The researchers conducted the study from 1978 to 2003 at 16 stations in 3 reservoirs created from natural rivers and 3 natural reference lakes. Before flooding, mercury concentrations in whole piscivorous fish averaged 0.3 mg/kg to 0.4 mg/kg (estimated from muscle concentrations), based on 70-cm northern pike (*Esox lucius*), 40-cm walleye (*Stizostedion vitreum*), and 60-cm lake trout (*Salvelinus namaycush*). Although these mercury concentrations exceed the Beckvar et al. [8] TRV, they represent present-day background concentrations in the project area, where factors such as forested land cover may promote mercury bioaccumulation (see *Background Concentrations* section). Following reservoir creation, mercury bioaccumulation in these piscivorous fish species peaked approximately 10 yr after flooding, with average whole-body concentrations of 1.0 mg/kg to 1.6 mg/kg.

Schetagne and Therrien [76] measured fish population abundance in the La Grande reservoirs using a catch per unit effort approach, estimated as number of fish per net per day, and averaged by month and year. They evaluated fish health using a condition factor based on weight and length of fish. Fish growth was evaluated based on the relationship between age and length. Statistical and graphical evaluations demonstrated that fish abundance, growth, and condition improved even when mercury concentrations in fish increased. Increased primary and secondary productivity (i.e., food availability) in the newly filled reservoirs was apparently the most important factor affecting resident fish populations. Uncertainties in the Schetagne and Therrien [76] study include a lack of information on recruitment and a lack of temporally paired data from natural lakes (although the authors state that natural lakes were sampled for use as reference conditions, these data are not presented). Nevertheless, it is evident that effects of mercury on fish reproduction (if any) were not a limiting factor for these fish populations.

Savannah River, Savannah Creek, and stream basins

Former weapons manufacturing operations at the Savannah River Site (South Carolina, USA) resulted in mercury contamination of stream and river habitat. Site investigation activities in 1996 to 1998 included mercury analyses of fish samples and evaluation of fish communities in Savannah River, Savannah River Swamp, and several stream drainage basins of the Savannah River Site [77]. Elevated fish mercury concentrations were found in the Lower Three Runs stream (maximum = 0.86 mg/kg) and the Savannah River (maximum = 1.25 mg/kg). In 8 instances, representing both site and reference locations, colocated fish tissue mercury and Index of Biotic Integrity (IBI) scores were available for a given year. The tissue concentrations were reported as the average of 3 species for each location [77]. Nine species were represented, with only redbreast sunfish (*Lepomis auritus*) common to all locations; the variation in species sampled introduces variability in spatial comparisons. Whole-body fish tissue mercury concentrations also were not length-normalized, and fish length data were not available for us to perform normalizations. For the 8 sites evaluated here, whole-body mercury tissue concentrations ranged from 0.08 mg/kg to 0.47 mg/kg.

Fish communities were evaluated using an IBI calibrated for regional conditions by Paller et al. [78] (Table 4). The IBI approach integrates multiple fish community metrics that reflect categories of species richness and composition, trophic structure, fish abundance, and fish condition [79,80]. As formulated by Paller et al. [78], the scores of 12 metrics are added for each station to give an IBI with possible scores ranging from 12 (very poor) to 60 (excellent). The IBI approach has been criticized for combining disparate types of information, such that more specific responses to stressors could potentially be obscured [81]. Nevertheless, fish IBI studies have demonstrated the ability to detect adverse effects of a variety of stressors on fish communities [82]. Figure 5 compares the

Table 4. Index of Biological Integrity metrics used in Savannah River (SC, USA) evaluation

Category	Metrics[a]
Species richness and composition metrics	Percentage of expected number of total species (+), percentage of expected number of native minnow species (+), percentage of expected number of piscivorous species (+), percentage of expected number of madtom and darter species (+), percent native minnows (+), percent sunfish (–/+/–)
Indicator species metrics	Percent tolerant fish (–)
Trophic function metrics	Percent generalized insectivores (–)
Abundance and condition metrics	Fish abundance by stream order (+), percent with disease or anomalies (–)

[a]Indices of Biotic Integrity formulated for regional conditions applicable to Savannah River, South Carolina, USA [78].
(+) = metric score increases with higher metric value; (–) = metric score decreases with higher metric value; (–/+/–) = metric score is higher at moderate values compared with higher and lower metric values.

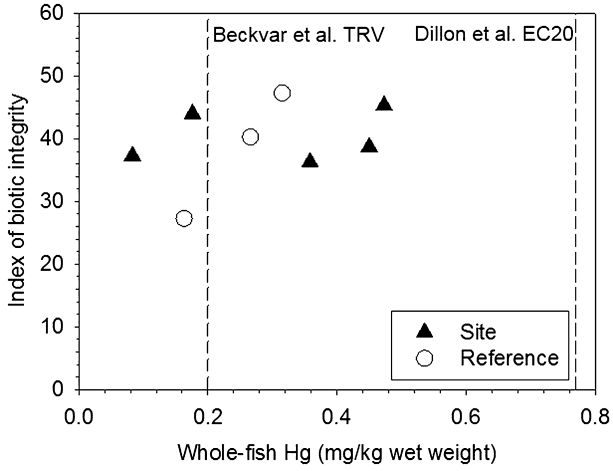

Figure 5. Whole-fish Hg concentrations versus Index of Biotic Integrity scores for Savannah River, Savannah Creek, and stream basins, South Carolina [77]. Dashed lines represent Beckvar et al. [8] toxicity reference value (TRV) and Dillon et al. [9] 20% effect concentration (EC20).

average IBI and average whole-body fish tissue mercury results; no relationship between mercury and IBI is apparent. In general, the authors reported good IBI, fish condition comparable to reference locations, and low fish pathology in the presence of contaminants and concluded that the contaminants that were present did not cause significant ecological degradation [77].

Clear Lake

Clear Lake, California, contains high concentrations of mercury in sediment and water as a result of historical mining operations. Mercury concentrations in whole largemouth bass throughout the lake ranged from 0.02 mg/kg to 0.97 mg/kg, with an average of 0.18 mg/kg (estimated from muscle concentrations) [83]. Suchanek et al. [83] reported a strong inverse relationship between fish abundance and distance from the mine, caused by either mercury exposures or habitat differences, including the extent of submerged aquatic vegetation cover. However, the authors' spatial trend analysis for mercury did not use length-normalized fish tissue concentrations, and linear regression analyses showed that relationships between fish length and mercury concentrations were similar for most areas of the lake [83]. Thus, it is unclear whether any size-independent trend in mercury tissue concentrations existed or was associated with the spatial trend in fish abundance. Overall, the Clear Lake case is inconclusive with regard to possible effects of mercury on fish populations.

East Fork Poplar Creek

As noted in the introduction to the case study review, East Fork Poplar Creek is 1 of 2 sites (along with the Hudson–Raritan Estuary) that are included in this review, even though site investigators acknowledge that mercury is 1 of multiple chemical stressors present. These 2 sites are reviewed here because they have sometimes been presented as mercury-dominated sites [84] and because they provide useful examples of investigation tools that may be applicable at other sites. The chemical mixture present in aquatic systems at the Oak Ridge Reservation (Oak Ridge, TN, USA) resulted from historical weapons development and manufacturing operations. The East Fork Poplar Creek was a primary receiving water for site discharges. Fish health and fish community quality have been studied extensively at the site [84–90]. Although adverse effects on fish have been observed, they are not solely attributed to mercury; other stressors identified by the authors include physical habitat quality and exposures to polychlorinated biphenyls (PCBs), other metals, and chlorine [84,88–90]. Whereas mercury concentrations in whole redbreast sunfish ranged up to 1 mg/kg, PCB concentrations in the same fish also ranged up to approximately 1 mg/kg [84,89]. Acute fish kills and chronic fish mortality were observed between 1990 and 1993 and were attributed to chlorine discharges and to episodic spills or releases of a variety of chemicals [90]. Thus, the East Fork Poplar Creek case study provides information on effects of a mixture of stressors, including mercury.

Adverse effects on redbreast sunfish associated with the highest contaminant exposures included lower fecundity compared with reference fish and population size structure weighted toward smaller fish [87]. Fish community analyses indicated no evidence of adverse effect on species richness and abundance, but the biomass of sensitive species was lower than in the reference fish community [84,89]. The researchers also investigated a range of biochemical and physiological characteristics. By themselves, these biomarkers would not have provided information on fish population or community status; but when considered together with attributes at higher levels of biological organization, they provide insight into potential causes and mechanisms of the observed adverse effects [87]. For example, responses of detoxification enzymes were taken to indicate toxicant exposure, and decreased fecundity was potentially linked to impaired manufacture of yolk proteins in the liver [87]. Consistent with the authors' conclusion that observed effects reflected multiple stressors, mercury concentrations in fish showed few correlations with a range of fish health biomarkers [88].

Hudson–Raritan Estuary

The Hudson–Raritan Estuary lies in one of the most urbanized and industrialized areas of North America and has a long history of contamination by many different chemicals [91]. Weis et al. [65,92–97] reported extensively on impacts of contaminated sediment exposures on fish, focusing on sites within the Hudson–Raritan Estuary. Their studies employed fish and contaminated sediment collected from a heavily industrialized salt marsh in Piles Creek (Linden, NJ, USA), which is a tributary of the Arthur Kill, and from heavily industrialized portions of the Hackensack River. Sediments from these waterways were impacted by metals (including mercury), pesticides, polycyclic aromatic hydrocarbons, and PCBs. Adverse effects on fish were observed but were not necessarily attributable to mercury.

Through field and laboratory investigations, Weis et al. evaluated effects on fish populations and aquatic community structure in contaminated and clean estuaries, as mediated by predator–prey relations (see Weis et al. [65] and Weis and Candelmo [97] for reviews). Methods included taxonomic and chemical analyses of fish stomach contents and available uneaten prey, laboratory tests of prey capture effort and effectiveness, and transplanting fish between contaminated and reference sites. Mummichogs exposed to contaminated sediment ate more detritus (based on stomach contents), were less effective predators, exhibited reduced predator avoidance, and were smaller and less abundant than their reference counterparts. Although similar effects could be induced by aqueous mercury exposure [95], and Piles Creek mummichogs contained elevated mercury concentrations (estimated from muscle as

approximately 0.5 mg/kg in whole fish [98]), Weis et al. [93] demonstrated that the observed effects were not specific to mercury and could be induced in mummichogs by various contaminants that likely were also stressors in Piles Creek.

Young-of-the-year bluefish (*Pomatomus saltatrix*) were similarly affected by chemical exposure. Bluefish fed prey from the Hackensack River had significantly elevated whole-body concentrations of PCBs (2.2 mg/kg), pesticides (0.26 mg/kg DDTs), and total mercury (1.52 mg/kg) compared with reference fish [96]. In the laboratory, bluefish displayed reduced feeding, spontaneous activity, and growth compared with the bluefish fed reference prey [96], whereas bluefish collected from the Hackensack River had a higher incidence of empty stomachs than those from the reference area [65]. Invertebrate prey also exhibited altered behaviors; but with less predation pressure, they grew larger and more numerous [65]. In these investigations, predators were more affected by contaminants than were their prey. In other settings, however, the net impact on benthic and fish population diversity and abundance would depend on whether and how the particular predator or prey is affected and the relative impacts on both [65].

Weis et al. [65] acknowledged that because the Hackensack River and Piles Creek sites are impacted by multiple chemicals, they "have not attempted to attribute the effects seen to any particular contaminant, [although they] have observed correlations of behavior with levels of mercury and PCBs." Their studies relied on a binary approach in which predator and prey were exposed to industrial or reference sediment—chemical isolation and chemical gradient experiments were not performed. Their work supports a compelling conceptual model of the ecological consequences of contaminant exposure at the study sites. However, given the presence of chemical mixtures, their method and results are not useful as tests of TRV-based predictions of mercury toxicity. Even if their underlying study design could support derivation of a mercury TRV, it would reflect a threshold that is only applicable to the combined effects of mercury in the presence of the particular mixture of chemical stressors in this system. Application of similar techniques to sites contaminated primarily with mercury would be needed to provide information more directly relevant to mercury TRV development and evaluation.

Case study summary

Through an extensive search of peer-reviewed and gray literature, we identified 8 mercury-contaminated sites with datasets that supported comparisons of mercury concentrations in fish or their prey and effects on fish populations or communities. Of these 8 sites, 5 found no detectable adverse effects despite mercury concentrations that exceeded multiple TRVs (South River, North Fork Holston River, Onondaga Lake, Savannah River, and La Grande Hydroelectric Complex). A mercury mine site (Clear Lake) yielded average fish tissue concentrations similar to the Beckvar et al. [8] TRV, and it was unclear whether any adverse effect occurred or whether fish distribution was simply a function of habitat characteristics. At the remaining 2 sites (East Fork Poplar Creek, the Hudson–Raritan Estuary), clear adverse effects on fish populations were associated with exposure to multiple contaminants including mercury. We identified no cases where adverse effects were detected in fish populations or communities that were clearly attributable to mercury, whereas multiple case studies did not detect adverse effects despite mercury exposures in excess of applicable TRVs. There are many possible explanations for the lack of agreement between field observations and laboratory predictions—such as compensatory mechanisms and development of tolerance, differences in levels of ecological organization considered in laboratory and field studies, ameliorating effects of selenium on mercury toxicity, and conservative approaches to TRV development. The *Discussion* section weighs these possible explanations and offers recommendations for further research.

BACKGROUND CONCENTRATIONS

Natural background concentrations of mercury in fish—those that were present prior to the industrial revolution and attributable to natural sources of mercury such as geothermal activity and volcanic emissions [99]—are relevant to assessing the reasonableness of mercury TRVs, because mercury is a naturally occurring element and fish have presumably evolved to tolerate mercury exposure at levels that typically occur naturally. We acknowledge that, in principal, some naturally occurring elements can pose a degree of risk to individual organisms even in the absence of anthropogenic sources, either because of mechanisms of toxicity characterized by a continuous risk function (i.e., lacking an effect threshold) or because of outlying extremes of naturally occurring concentrations or sensitivity in individual organisms. Nevertheless, it is apparent that fish populations have persisted for tens to hundreds of millions of years despite normal exposures to naturally occurring mercury. Therefore, reasonable TRVs should not predict adverse effects on fish populations at exposures consistent with typical preindustrial natural background conditions.

Recognizing that background concentrations have increased since the industrial revolution as a result of anthropogenic sources of mercury (e.g., power generation, artisanal gold mining [99]), present-day background data are somewhat less effective as a reality check on the reasonableness of TRVs. Characterization of naturally occurring mercury concentrations in fish, however, is challenging because of a paucity of preindustrial fish tissue data and the difficulty in differentiating natural and anthropogenic sources in present-day tissue data. Even for fish collected from remote locations, present-day background concentrations of mercury in fish do not reflect preindustrial natural background conditions as a result of global atmospheric deposition of mercury from anthropogenic sources, as well as anthropogenic increases in sulfate deposition [32,100,101]. Present-day background mercury concentrations in fish tissue are linked to atmospheric mercury deposition [101], as well as sulfate deposition and a variety of land cover and water quality characteristics [32].

Theoretically, museum specimens of fish collected before the industrial revolution could be a valuable source of data on natural background concentrations of mercury in fish. However, an extensive literature search identified virtually no pre-1850 fish tissue data from museum specimens. Inclusion of data from more recent museum specimens would risk overestimating natural background concentrations. Therefore, 3 other lines of evidence are considered in an effort to understand whether available TRVs are lower than background conditions: modeled natural background concentrations [102]; measured mercury concentrations in fish used as controls in toxicity tests [8]; and measured mercury concentrations in fish collected from remote areas [103,104], considered together with regional estimates of mercury deposition increases. Given the broad

array of fish monitoring studies available on present-day mercury concentrations, the studies supporting the second and third lines of evidence are intended to be representative, rather than exhaustive.

Hope and Louch [102] modeled fish tissue concentrations of methylmercury under a variety of scenarios reflective of pre-Anthropocene conditions, defined as *natural background* or the period prior to significant anthropogenic effects on the environment. This exercise used the USEPA's Spreadsheet-Based Ecological Risk Assessment for the Fate of Mercury (SERAFM) model. Hope and Louch [102] reported that mean natural background mercury concentrations in whole prey fish were estimated to range from 0.03 mg/kg to 0.1 mg/kg, with the lowest concentrations estimated for rivers and the highest estimated for stratified dystrophic lakes. Median concentrations in whole prey fish were somewhat lower than the means, ranging from 0.005 mg/kg to 0.03 mg/kg. For whole predatory fish, mean natural background concentrations of mercury were estimated to range from 0.1 mg/kg to 0.3 mg/kg. In the absence of empirical data (i.e., pre-Anthropocene fish samples), Hope and Louch's [102] model estimates cannot be validated directly, although the SERAFM model was validated under present-day conditions.

A second line of evidence relevant to present-day background conditions is provided by concentrations of mercury in control fish tissue from toxicity tests, as reported by Beckvar et al. [8]. Beckvar et al. [8] reported that concentrations of mercury in control fish mercury ranged from 0.04 mg/kg to 0.22 mg/kg. A range of 0.04 mg/kg to 0.1 mg/kg in control fish results when pre-1985 results are excluded [8] because of the analytical uncertainty associated with older analytical methods [105].

A third line of evidence also relevant to present-day background conditions is provided by several studies reporting mercury concentrations in fish collected from Canadian ecozones with relatively limited impacts from sulfate deposition [106] and mercury deposition [103]. For example, Depew et al. [104] reported median yellow perch mercury concentrations of 0.02 mg/kg and 0.06 mg/kg for the Boreal Plains and Prairies ecozones in central Canada. Selin et al. [103] estimate that mercury deposition in this region has increased approximately 2- to 3-fold relative to preindustrial mercury deposition, and it appears that the present-day prey fish mercury concentrations exceed estimated pre-Anthropocene concentrations by roughly the same margin. The La Grande Hydroelectric Complex case study (see section *La Grande Hydroelectric Complex*) provides a similar example for predatory fish. The site is located in northwestern Quebec, where anthropogenic increases in mercury and sulfate deposition are limited [103,106]. Whole-body mercury concentrations in piscivorous fish prior to dam construction in the area were estimated as 0.3 mg/kg to 0.4 mg/kg [76].

Taken together, the available information supports the suggestion by Hope and Louch [102] that the estimated pre-Anthropocene fish tissue mercury concentrations may serve as a reasonable, although approximate, floor level at or below which predictions of adverse effects attributable to mercury in fish are unrealistic. The prey tissue TRV of 0.04 mg/kg developed by Depew et al. [16] is consistent with background concentrations of mercury in lower trophic level fish, which is expected, given that the TRV was set equal to a mercury concentration in prey from a control treatment.

The Beckvar et al. [8] TRV of 0.2 mg/kg falls at the high end of present-day background concentrations of mercury in larger fish (Table 5), but fish tissue mercury concentrations

Table 5. Mercury concentration in freshwater whole fish from North American regional and national monitoring programs

Area	Water body	Species or species type	Years	Concentration (mg/kg wet wt)				Ref.
				Average	Median	Minimum	Maximum	
Large fish								
USA, Northeastern	Rivers	Bass, catfish[a,b]	2008–2009	0.00, 0.07	0.10, 0.06	0.01, 0.02	0.23, 0.16	[125]
USA, Southern	Rivers	Bass, catfish[a,b]	2008–2009	0.10, 0.04	0.08, 0.03	0.02, 0.01	0.30, 0.12	[125]
USA, Midwestern	Rivers	Bass, catfish[a,b]	2008–2009	0.07, 0.04	0.06, 0.03	0.03, 0.01	0.15, 0.07	[125]
USA, Western	Rivers	Bass, catfish[a,b]	2008–2009	0.11, 0.05	0.11, 0.06	0.03, 0.02	0.24, 0.09	[125]
USA, Northeastern	Lakes	Predatory fish, bottom dwellers[a,c,d]	2000–2003	0.14, 0.14	0.13, 0.13	0.03, 0.01	0.29, 0.38	[126]
USA, Southern	Lakes	Predatory fish, bottom dwellers[a,c,d]	2000–2003	0.09, 0.08	0.08, 0.07	0.02, 0.005	0.29, 0.25	[126]
USA, Midwestern	Lakes	Predatory fish, bottom dwellers[a,c,d]	2000–2003	0.09, 0.07	0.08, 0.06	0.01, 0.01	0.27, 0.20	[126]
USA, Western	Lakes	Predatory fish, bottom dwellers[a,c,d]	2000–2003	0.14, 0.13	0.10, 0.11	0.02, 0.01	1.5, 0.60	[126]
Canada, National	Lakes, rivers	Large fish (median > 20 cm)[a,e]	1990–2010	NA	0.03–0.32[f]	<DL	4.6	[29]
USA, Southeastern	Large rivers	Largemouth bass	2004	0.37–0.53	NA	0.22	0.78	[127]
USA, Southeastern	Large rivers	Common carp	2004	0.10–0.34	NA	0.05	0.31	[127]
USA, Western	Rivers	Large piscivores, large nonpiscivores (>12 cm)	2004–2005	0.26, 0.090	NA	NA	NA	[128]
USA, Oregon, Western	Rivers	Large fish (>12 cm)	1997–1998	0.042–0.23	NA	NA	NA	[129]
USA, Oregon, Eastern	Rivers	Large fish (>12 cm)	1997–1998	0.035–0.15	NA	NA	NA	[129]
USA, Great Lakes	Lakes	Sport fish	2000–2009	0.17	0.14	0.059	0.70	[130]
USA, Great Lakes	Lakes	Largemouth bass and walleye	1970–2009	0.19–0.28	0.14–0.23	NA	NA	[131]
Prey Fish								
Canada, National	Lakes, rivers	Yellow perch, 12 cm[g]	1990–2010	0.09	0.04–0.1[h]	0.01	0.96	[104]
Canada, National	Lakes, rivers	Small fish (median < 20 cm)[a,e]	1990–2010	NA	0.02–0.18[f]	<DL	0.84	[29]
USA, Northeastern	Lakes	Yellow perch, brook trout	1980–2003	0.15, 0.37	NA	NA	NA	[132]
USA, Northeastern	Rivers	Yellow perch, brook trout	1980–2003	0.25, 0.27	NA	NA	NA	[132]
USA, Oregon, Western	Rivers	Small fish (<12 cm)	1997–1998	0.025	NA	NA	NA	[129]
USA, Oregon, Eastern	Rivers	Small fish (<12 cm)	1997–1998	0.015	NA	NA	NA	[129]

[a]Whole-body Hg estimated from fillet per Peterson et al. [9]: log (whole-body Hg) = –0.2712 + 0.9005 log (fillet Hg).
[b]Bass include largemouth and smallmouth bass; catfish include channel, flathead, and blue catfish.
[c]Predatory fish include largemouth bass, smallmouth bass, walleye, and northern pike.
[d]Bottom dwellers include channel catfish, common carp, white sucker, and brown bullhead.
[e]Range of species-specific concentrations.
[f]Range in species-specific median concentrations.
[g]Multispecies data normalized to standard species, size, and sample type.
[h]Range of ecozone-specific median concentrations.
<DL = less than the detection limit; NA = not available.

comparable to this TRV apparently can occur naturally under conditions that favor mercury methylation, such as in dystrophic lakes or in watersheds with abundant forest and wetland cover [32,35,102]. Taken together with the uncertainties in the data underlying this TRV (see section *Review of fish tissue TRVs*), it would appear that the Beckvar et al. [8] TRV is lower than necessary for protection of adult and early life stages of fish. The Dillon et al. [9] EC20 of 0.77 mg/kg is greater than both preindustrial or present-day background mercury concentrations in fish and may provide a more relevant TRV for protection of both adult fish and offspring exposed via maternal transfer, although field case studies reviewed in the present report suggest that even the Dillon et al. [9] value can overpredict adverse effects on fish.

DISCUSSION

The present review of TRV derivation and underlying data identified significant limitations in the available chronic toxicity data and high uncertainty in the resulting TRVs. The lowest of the available TRVs fall within the range of naturally occurring background mercury concentrations in fish, with the Depew et al. [16] prey tissue TRV falling well within background concentrations and the Beckvar et al. [8] fish tissue TRV falling toward the higher end of background concentrations in larger fish. The case study review provides no indication that these lower TRVs should be interpreted as threshold concentrations above which adverse effects on fish reproduction or fish populations may be expected. The Beckvar et al. [8] TRV was developed as a screening level (i.e., a TRV below which toxicity is not expected), and it can be argued that a screening-level TRV is not intended to be a predictive effect threshold. However, the case studies also do not validate Sandheinrich and Wiener's [5] estimate of 0.3 mg/kg to 0.5 mg/kg as a threshold for the onset of adverse effects, at least for the endpoints targeted in our review. The Dillon et al. [9] EC20 of 0.77 mg/kg appears closer to an effect threshold for reproductive effects in some species, based on laboratory toxicity data, but field studies did not detect adverse effects on fish at multiple sites where tissue concentrations equaled or substantially exceeded this level (i.e., South River, Onondaga Lake, La Grande Hydroelectric Complex). Although adverse effects on fish were detected in 2 case studies, severe contamination by other chemicals precluded attribution of effects to mercury in those cases.

There are many reasons why laboratory and field studies may differ with respect to observed and predicted effects of mercury on fish. Differences between laboratory and field conditions undoubtedly play a role; some differences are inevitable, while others could be remedied with improved study design and data collection. Discrepancies can also arise through the conservative interpretation of uncertain laboratory data in the absence of field verification. In addition to the uncertainties identified above in the TRV derivation review, several other important sources of uncertainty are identified below.

Differences in the levels of ecological organization considered in field studies and in laboratory bioassays that underpin TRVs often contribute to inconsistencies between observations from field studies and hazards predicted by exceedances of TRVs. This challenge is not unique to mercury exposures. As discussed by Barnthouse et al. [107] with regard to PCB effects on fish populations, field studies generally evaluate endpoints relevant to population- and community-level effects (e.g., population size, community diversity, biomass, condition, sex ratios, age structure), whereas TRVs are most often derived from laboratory toxicity bioassays on survival, growth, and reproduction of individual specimens. Survival, growth, and reproduction are certainly *linked* to population-level effects, but findings on individual organisms in the laboratory do not necessarily translate to population-level effects in the field because of factors such as adaptation and tolerance, competition, predator–prey interactions, migration, emigration, environmental variability, and density-dependence [65,108–112]. Maltby et al. [113] note that "the fact that some populations persist in stressed environments, even though adverse effects on individuals and the potential to cause population-level effects can be demonstrated, raises the possibility of compensatory mechanisms that ameliorate predicted adverse effects." Conversely, laboratory tests could also underestimate effects; for instance, Ankley [114] notes that "one factor that limits the predictive power of current laboratory tests is that they are relatively short-term assessments of conditions in which chronic toxicity may be a dominant process." Although mesocosm studies and field manipulations offer possible solutions to some of the challenges inherent in extrapolating from laboratory-derived TRVs to field outcomes, neither approach is yet in common use for assessing site-specific effects of mercury on fish. While the matter of assessment at different levels of ecological organization is not unique to mercury, other factors that also contribute to this disconnect are specific to mercury in fish, as discussed below.

Although still at a relatively early stage of research and in need of further study, the disconnect between field and laboratory studies may be partially related to differences in the form of mercury tested in the laboratory relative to that present in fish in the field. Whereas methylmercury effects on fish reproduction have been tested primarily using methylmercury chloride, methylmercury exists in fish in the form of methylmercury cysteine [115]. Methylmercury chloride is not an ion pair; the chloride component is covalently bound [115]. Thus, methylmercury chloride and methylmercury cysteine are not the same chemical and might not produce the same exposure–response relationships [115]. Only 1 comparison of the relative toxicity of these chemical forms is available. Harris et al. [115] reported that methylmercury cysteine is much less toxic to zebrafish on an acute basis than methylmercury chloride, but differences in toxicity on a chronic basis have not been tested. A difference in toxicokinetics is suggested by a rat bioaccumulation study, in which rats fed contaminated fish exhibited higher fecal excretion and lower mercury accumulation than rats fed uncontaminated fish spiked with methylmercury chloride [116]. Additional research is needed to clarify whether laboratory studies conducted with methylmercury chloride are directly applicable to interpreting fish tissue concentrations of methylmercury cysteine.

Furthermore, the antagonistic interaction between selenium and mercury toxicity has long been recognized [117–120] and can be expected to confound comparisons among mercury toxicity studies when selenium is not measured. In contrast to mercury, selenium is a biologically essential element for nervous system function that only becomes toxic at high concentrations. Exposure to mercury that might otherwise be expected to cause toxic effects can be mitigated in the presence of selenium. This reduction in mercury toxicity has been shown to be widespread among virtually all aquatic and terrestrial species. The onset of mercury toxicity roughly corresponds to when the molar concentration of mercury exceeds that of selenium in tissue or diet [117,118]. In addition to reducing toxicity, there is also strong evidence that the presence of

selenium can reduce mercury bioaccumulation [117,119]. Although the observed reduction in mercury toxicity by selenium is well known, the mechanism remained uncertain until recently. Historically, the mode of action was thought to be the protective binding of mercury by selenium, preventing the activation of direct effects of mercury on cellular processes and enzyme inhibition [117,119]. Other evidence suggests that other modes of actions, such as the formation of selenium–mercury complexes [119], enhanced demethylation of methylmercury, or an effect on the partitioning of mercury in organs and tissues or within individual cells [117–119], may also be important. However, more recent evidence suggests that mercury toxicity is in fact the result of selenium deficiency as a result of the sequestration of selenium by mercury [118,120], and thus the presence of an excess of selenium guards against the selenium deficiency caused by this sequestration. Penglase et al. [47] reported a synergistic toxicological effect of mercury and selenium on fish reproduction, under conditions of high exposure to both metals with tissue concentrations of mercury in excess of selenium. Additional research is needed to support the interpretation of mercury–selenium interactions for chronic effects on fish, especially in cases where selenium concentrations approach toxic levels. However, enough information is already available to consider mercury–selenium molar ratios as an important line of evidence for assessing the likelihood of adverse effects on fish as a result of mercury. Considering that very few of the mercury toxicity studies or case studies reviewed for the present study reported the selenium status of mercury-exposed fish, unmeasured mercury–selenium interactions are a significant source of uncertainty in applying the resulting toxicity data.

Another possible source of discrepancies between TRV-based predictions and case study results is differential sensitivity among fish species. Fish vary in their responses to mercury exposure, and differences in sensitivity are presumably subject to natural selection. It is logical that fish at higher trophic levels should be more mercury-tolerant than other fish, because mercury is naturally present at higher concentrations in piscivorous fish than in smaller fish. This consideration is especially applicable to marine species such as sharks and marlin, which contain notably high mercury concentrations [121]. Because piscivorous fish tend to be more difficult to maintain in the laboratory [23], most laboratory toxicity tests are necessarily conducted with smaller fish.

An additional consideration for any tissue-based dose–response relationship for mercury is that exposure before and during egg formation, rather than total maternal tissue burden at the time of spawning, is critical to effects of mercury on fish reproduction [21,22,48]. Thus, a tissue-based TRV derived from studies in which fish were exposed during both development and spawning is potentially problematic when applied to fish that move between areas of differing mercury exposure. Such TRVs could be either overprotective (i.e., in cases where fish accumulate mercury primarily after egg formation) or underprotective (i.e., when compared with tissue data for adult fish that experienced higher mercury exposures during egg formation and lower exposures subsequently). This issue lends conceptual support to the development of fish-protective TRVs based on mercury concentrations in fish diet rather than tissue, as attempted by Depew et al. [16]. However, the effort of Depew et al. [16] was hampered by limitations in the available data, as discussed (see section *Review of fish prey TRVs*).

CONCLUSIONS

At present, insufficient high-quality exposure–response data for critical endpoints presents the greatest challenge to identification of predictive effect thresholds and dose–response relationships for mercury effects on fish populations. Although data for fathead minnows and brook trout suggest the possibility of adverse reproductive effects (e.g., spawning, early life stage development and survival) corresponding to tissue residues below 1 mg/kg, none of the critical results are statistically significant. While definitive laboratory studies are lacking, the available laboratory and field studies suggest that the Beckvar et al. [8] TRV of 0.2 mg/kg is not a threshold above which adverse impacts on fish populations should be expected. Although limited, the available laboratory data suggest that the Dillon et al. [9] EC20 is closer than the Beckvar et al. [8] TRV to a fish tissue threshold for reproduction; but risk managers should use this and any other fish tissue TRV with caution, given the limited data and many uncertainties discussed in the present study. The Depew et al. [16] fish prey TRV is equal to a control concentration; it is not an effect threshold and should not be used as such. The available field studies demonstrate that, at least in some cases, fish populations can remain apparently unaffected despite mercury exposures well in excess of any of these TRVs.

Ultimately, the development of more effective mercury TRVs and dose–response relationships for protection of fish will require additional research. Statistically rigorous, controlled exposure–response studies for multiple species are needed to better characterize effects of dietary methylmercury exposure on fish reproduction. Although numerous studies have evaluated mercury effects on fish gonads [6], high-quality dose–response relationships relating mercury diet and tissue concentrations to reproductive outcomes remain a critical data gap. Further studies are needed to support interpretation of mercury–selenium interactions for chronic effects on fish, especially in cases where selenium concentrations approach toxic levels. Comparative studies with methylmercury cysteine are also needed to understand whether testing with methylmercury chloride introduces a significant bias in chronic laboratory studies. Additional fish population and community studies across mercury gradients are also warranted to evaluate whether effects on fish resulting from elevated mercury exposures actually occur. In the meantime, risk assessors are advised to consider the available data from field studies in addition to TRV comparisons, to measure the site-specific selenium status of fish, and to conduct site-specific investigations of fish populations if needed to support appropriate environmental management decisions.

Supplemental Data—The Supplemental Data are available on the Wiley Online Library at DOI: 10.1002/etc.3267.

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Data availability—See Supplemental Data. Other data are available from the primary references cited in the present study.

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